LAND MANAGEMENT HANDBOOK

79

Silvicultural Systems Handbook for British Columbia

Developing Silvicultural Pathways for Diverse Forest Stand and Landscape Goals

2025

BRITISH COLUMBIA

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Developing Silvicultural Pathways for Diverse Forest Stand and Landscape Goals

Mike Jull, Ken Zielke, Ken Day, Bryce Bancroft,
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Cover photo: Mosaic of subalpine fir, spruce, pine, trembling aspen, and black cottonwood in a previously harvested area in the lower Bowron River watershed, SBSwk subzone northeast of Prince George. Image source: Aleza Lake Research Forest Society.

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PREFACE

The purpose of this updated *Silvicultural Systems Handbook for British Columbia* (the Handbook) is to provide a central reference, conceptual framework, and recommended best practices for prescribing, naming, and applying different silvicultural systems and **stand** development pathways in British Columbia's forests. It replaces the 2003 *Silvicultural Systems Handbook for British Columbia*.

The updated Handbook provides recommended approaches to the design, planning, and application of silvicultural treatments, objectives, and stand development pathways, so that silvicultural systems may be customized in a manner suited to British Columbia's different ecosystems and forests, and the diverse cultural, social, and economic contexts within which they will be applied.

In support of these goals, the Handbook includes guidance for:

- Considering First Nations perspectives and values in the development of silvicultural plans and practices.
- Consistent silvicultural systems terminology and definitions with provincial application.
- Processes for the consistent naming of different silvicultural systems.
- Building silvicultural plans, including best practices for **site** and stand level planning and field implementation of diverse silvicultural systems.

This Handbook addresses the design and application of appropriate silvicultural systems that are consistent with various plans and strategies and their supporting policies and standards. It provides a structured approach to help forest practitioners design silvicultural plans and make well-crafted decisions at different spatial scales, and especially at the stand/site level. It is based on a foundation of the ecological principles and objectives underlying each **silvicultural system** and it outlines decision-making processes for developing a **silvicultural plan** consistent with both shorter- and longer-term stand management objectives.

Throughout this document, words in bold font are defined in the glossary at the end of the Handbook.

Exceptionally large Douglas-fir protected in a no-harvest reserve. Image source: Aleza Lake Research Forest Society.

ACKNOWLEDGEMENTS

Many have contributed their cumulative knowledge, experience, and wisdom to this Handbook.

The origins of this Handbook date back to silvicultural systems extension and educational materials for British Columbia originally developed and compiled by Bryce Bancroft, John Przeczek, Ken Zielke, and colleagues in the late 1990s. These and related extension materials were the foundation for the 2003 *Silvicultural Systems Handbook for British Columbia* published by the B.C. Ministry of Forests.

This current (2025) Handbook was commissioned by the Office of the Chief Forester, B.C. Ministry of Forests. The core mandate was to update and build upon the original 2003 work, incorporate First Nations perspectives and values in the development of silvicultural practices, and provide insights from the past two decades of operational experience with diverse British Columbia silvicultural systems, partial-cutting, and **retention** practices.

We gratefully acknowledge the many individuals and professionals who contributed, both individually and collectively, to a wide range of initial discussions, brainstorming, conceptualization, and building the overall vision for this Handbook, including Bryce Bancroft, Ken Byrne, Colin Chisholm, Ken Day, Deb DeLong, Theresa Denton, Che Elkin, Mike Jull, Dennis MacDonald, Jim McGrath, Garry Merkel, Rainer Muenter, Dave Walkem, and Ken Zielke.

As we built out the Handbook, the core team drew in authors and subject matter experts who had different areas of expertise and on-the-ground experience in different geographic areas of British Columbia. The Handbook was developed collaboratively, with intermingling and sharing of ideas, and many sections of the Handbook incorporate ideas and guidance from several different authors.

Many people responded to questions and discussion throughout the development of this document and we appreciate their thoughtful conversation and input. We particularly want to acknowledge the many practitioners who engaged in a formal peer review of the document. Their diverse and frank comments have made this document a much more useful resource. Thank you to Jodi Axelson, Paul Barolet, Bill Beese, Jannelle Dale, Kari Doyle, Chris Elden, Cosmin Filipescu, Neil Hughes, John Karakatsoulis, Erik Leslie, Deb Mackillop, Chelsea McLean, Eleanor McWilliams, Garnet Miereau, Rainer Muenter, Gretchen Prystawik, Kori Vernier, and Michaela Waterhouse.

Bowron River Floodplain and riparian forests.
Image source: Aleza Lake Research Forest Society.

Northern wetbelt silvicultural system trial, Minnow Creek site, ICHwk subzone, Robson Valley, B.C. EP 1119.03.
Image source: Aleza Lake Research Forest Society.

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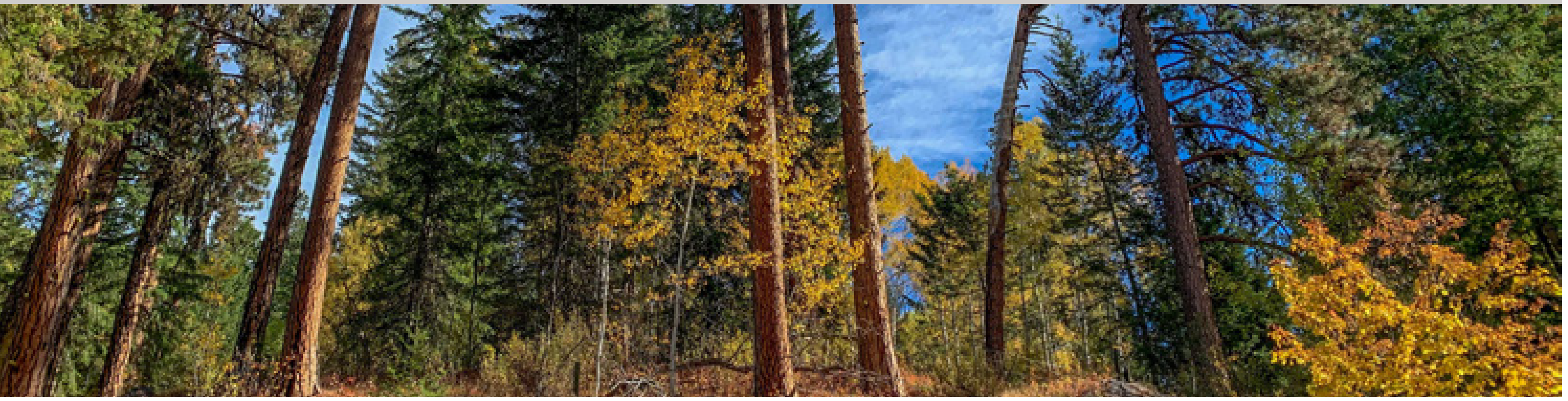
PART 1 – INTRODUCTION TO THE HANDBOOK



Uneven-aged Ponderosa pine–Douglas-fir stand in southern interior British Columbia. Image source: Ken Zielke (used with permission).

1.1 OVERVIEW AND PURPOSE OF THE HANDBOOK

FIGURE 1 *The Yos totem pole, located along the Malahat Connector section of the Trans Canada Trail, running through the forests of the Malahat First Nation between Cowichan and Greater Victoria. A thunderbird is the central figure in the totem pole, with a salmon under each wing. The pole was created by master carvers Moy Sutherland Jr. from Tla-o-qui-aht First Nation (Tofino) and John Marston from Stz'uminus First Nation (Chemainus) and various Malahat Nation youth. Image source: Theresa Denton (used with permission).*

"If 20th century forestry was about simplifying systems, producing wood, and managing at the stand level, 21st century forestry will be defined by understanding complexity, providing for a wide range of ecological goods and services, and managing across broad landscapes."

Kathryn Kohm and Jerry Franklin (1997)

Forest management and silvicultural practices in British Columbia are in an era of profound change. These changes have been spurred by diverse and intertwined influences including evolving forest management goals, values, and perspectives within society, and improved ecological understandings of forests.

First Nations are applying their rights, roles, values, and deep knowledge of the land in British Columbia forest and ecosystem stewardship (Figure 1) and are working in partnerships with the Province of British Columbia (the Province), the forest sector, and communities in re-envisioning the present and future of forest management in this region.

Our collective scientific and cultural understandings of forests, their functional complexity, and the organisms that depend upon forested ecosystems are evolving, as is our understanding of human influences and interdependencies on forests and our environment.

The changing climate, natural disturbances, cumulative impacts of past forest management practices, and a desire for **landscape**-level forest ecosystem management, are all driving forces for changing and continually adapting British Columbia forest management and silvicultural practices.

The purpose of this updated *Silvicultural Systems Handbook for British Columbia* (the Handbook) is to provide a central reference, conceptual framework, and recommended best practices for prescribing, naming, and applying different silvicultural systems and stand development pathways in British Columbia's forests.

Supporting this central purpose, this Handbook provides the following guidance:

- Considerations for incorporation of First Nations perspectives and principles into silvicultural prescriptions and practices.
- Guidance for identifying and developing stand-level silvicultural objectives and practices that are consistent with higher-level plans.
- Recommended approaches to the design, planning, and application of the silvicultural treatments, objectives, and stand development pathways that are the building blocks of different silvicultural systems.
- Consistent silvicultural systems terminology and definitions that have provincial application, to allow clear communication on the use of different silvicultural systems.
- Principles and tools to guide the stand-level planning, prescription, and implementation of different silvicultural systems and stand management approaches in British Columbia.

The Handbook is intended to provide a guiding framework and "toolbox" of silvicultural approaches to help forest practitioners design silvicultural plans (including harvesting, **regeneration**, stand tending and other approaches singly and in combination), and make well-crafted decisions at several spatial scales (see terminology sidebar), but especially at the stand or site level.

TERMINOLOGY: SPATIAL SCALES

Landscape: A planning area delineated based on a number of biophysical features. Typically, they cover a watershed or series of watersheds incorporating multiple individual stands.[1]

Forest: A complex ecological system and natural resource in which trees are the dominant life-form. In an administrative sense, this definition may be taken one step further to also mean a tenure unit, comprising part of one or more landscapes.

Stand: The basic management unit for the application of silvicultural decisions, defined by differences in forest age, composition, or productivity. (Ashton and Kelty 2018).

Site: An area described or defined by its biotic, climatic, and soil conditions in relation to its capacity to produce vegetation. It tends to describe the smallest scale for forest management planning, below a stand.[2]

[1] www.bcfpb.ca/news-resources/glossary/#L (accessed Sept. 2, 2024).

[2] www.for.gov.bc.ca/hfd/library/documents/glossary/Glossary.pdf (accessed Sept. 2, 2024).

The needs and interests of First Nations have been a central consideration in the development of this Handbook. As expressed in the opening words of the 2019 *BC First Nations Forest Strategy*, *"First Nations have relied on forest resources for generations. As stewards of their traditional territories, First Nations have a deep and inherent understanding of the waters, plants, animals, and soils. The forest is, and has been, culturally, economically, and environmentally important as a source of food, shelter, tools and medicine, as well as providing materials for art and cultural and spiritual activities. First Nations are key players in addressing the economic, social, and environmental challenges of managing forest lands and resources."*

In preparing this Handbook, we recognized the need for the evolution of silvicultural systems and practices beyond conventional or "textbook" approaches to this topic area. This includes the need for broadened silvicultural concepts and a common language to help forest practitioners, planners, and communities envision and communicate all the different silvicultural and stand management approaches that may be designed to meet ecological, cultural, social, and economic goals in different areas and sites across diverse lands, tenures, and territories within British Columbia.

A core concept of the Handbook is the recognition of the ecological importance of the forest elements that prescribed silvicultural practices deliberately leave behind as biological legacies (e.g., **retention** of individual trees, groups of trees, downed logs, and areas of uncut forest). Older classic or "traditional" silvicultural texts commonly organized and classified silvicultural systems according to the method of tree regeneration (or reforestation). However, current perspectives of many ecologists and biologists, First Nations knowledge-holders, forest managers, and others, increasingly emphasize the importance of not just what is taken out of the stand, but what is left behind. The range of objectives in future will include restoring grasslands and shrublands and restoring old-growth objectives that do not necessarily include regeneration in the typical sense of silviculture in British Columbia.

Feller buncher in selection cutting in subalpine stand EP 1119.02, Pinkerton Mountain, B.C. Image source: Mike Jull (used with permission).

The Handbook also incorporates a related core concept that stand-level management goals for ecosystem management and biodiversity, and those of timber management and commodity production, are not necessarily mutually exclusive nor polar opposites within the defined area. They can—and in many cases to be sustainable need to—co-exist, with the appropriate silvicultural approaches. Rigorous silvicultural system planning examines all the values and priorities within a given stand and considers the vital larger role of **higher-level planning** (i.e., forest-level strategic landscape planning) in directing the balance between different forest values (and appropriate silvicultural activities and outcomes within specified areas) on different landscapes.

Silvicultural planning takes place within a governance and practice environment that evolves and changes over time. However, the ecological principles underlying each silvicultural system, and the need for a thoughtful decision-making process for developing a silvicultural prescription for a given set of objectives, are important foundations for forest practices now and in the future.

This Handbook has been developed to guide and inform a range of user groups. These include forest professionals who may be planning or implementing forest- or stand-level plans that include or focus on silvicultural systems; forest landscape planning teams and technical working groups; individuals providing technical guidance to provincial and First Nations governments, land and resource managers, forest licence holders, and related organizations; allied professional and technical organizations; and assessors of policy and practice (such as the Forest Practices Board).

The authors also recognize others for whom this Handbook is a useful resource and guide to British Columbia forest management and silvicultural practices. Such users include community and stakeholder groups, interested members of the public, the scientific and research community, and higher-learning institutions (such as colleges and universities) and their students.

For all audiences, this Handbook strives for a plain-language approach to its subject matter, and minimizes technical jargon or acronyms where feasible, without sacrificing necessary detail or technical precision. Wherever possible, terms are defined for readers. Words in bold font are defined in the glossary at the end of the Handbook. As the Handbook moves into deeper technical detail, a consistent language is used.

PART 2 – SILVICULTURAL INNOVATION

2.1 FIRST THINGS FIRST – WHAT IS A SILVICULTURAL SYSTEM?

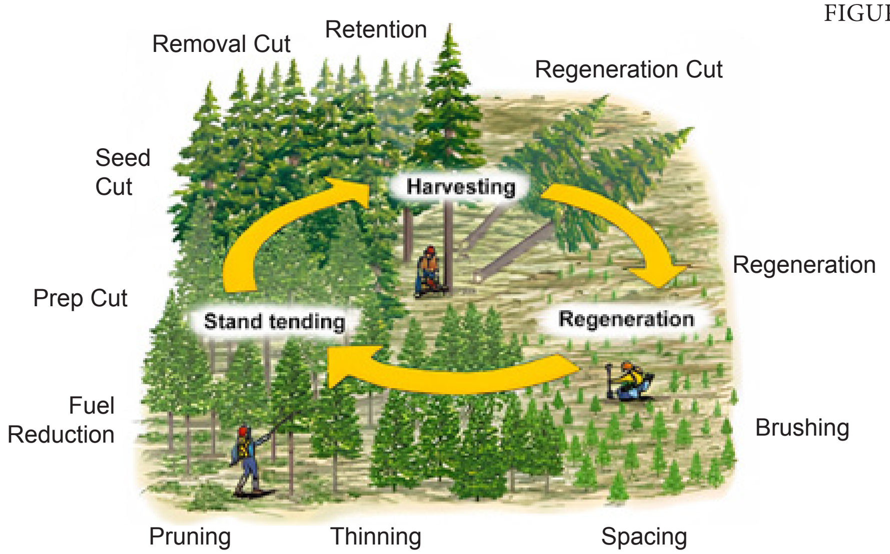


FIGURE 2 *A silvicultural system describes a series of interventions to develop, maintain, and replace a stand through time. The nature and intensity of the intervention varies with the stand development pathway. This figure illustrates that a wide variety of interventions are available to modify the stand development along any chosen pathway.*

Forestry literature and textbooks from North America and around the world define the concept of "**silvicultural system**" (Figure 2) in various ways. In general, these definitions have common elements and, increasingly over recent decades, reference the many different values of forests including ecosystem functions and **resilience**, cultural values, and the commodity uses of forests.

In this Handbook, we define the term and concept of a silvicultural system as follows:

*A silvicultural system is a plan for the care, development, maintenance, and/or replacement of a forest stand over time, via stand **interventions** to promote specific stand structural characteristics, ecological conditions, and features consistent with desired objectives and values for the site. Time periods for silvicultural systems are longer, typically ranging from multiple decades to one or more centuries. These time spans are sometimes expressed as "over the life of the stand."*

Clear descriptions of the target stand conditions and the **stand development pathway**(s) needed to achieve those conditions are essential elements in the design of a site-specific silvicultural system. Within each system, silvicultural interventions include a prescribed sequence of treatments over time to promote the continued growth and development of a desired forest and vegetation community on a given site. These may include specific harvesting, regeneration, **thinning** (Figures 3 and 4), **intermediate cuttings**, or other stand density reductions, and stand tending methods at time intervals consistent with desired conditions.

Naming conventions for silvicultural systems are based on the regeneration method, focussing particularly on the distribution and pattern of stand structure retained

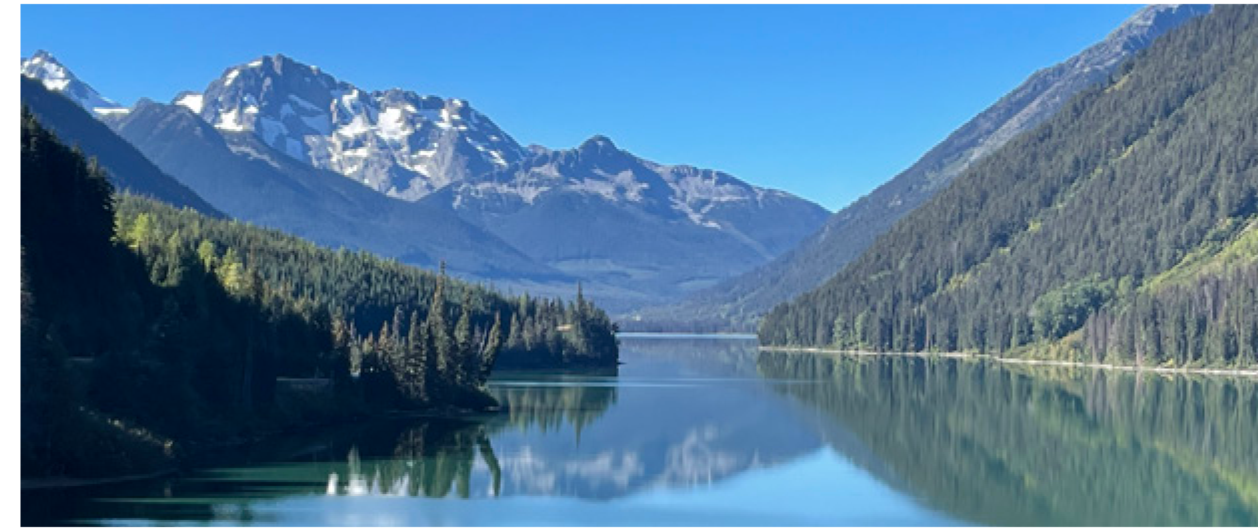
or removed over time and the degree of mature **forest influence** on the site and on the regenerating stand. Table 1 introduces the standard terminology used in British Columbia. Refer to Appendix 1 for more details on this terminology from the 2003 *Silviculture Systems Handbook*. Section 4.4 describes a naming convention intended to place a stand development pathway into the silvicultural systems context. It shows how complex stand development prescriptions may borrow from several general categories of silvicultural systems with additional modifiers to those shown in Table 1 on the following page.

FIGURES 3 AND 4

Two thinning interventions in two different forest ecosystems: Figure 3 (RIGHT) A thinning intervention in single-tree selection in the Dry Interior Douglas-fir ecosystem IDFxm EP 903. Image source: UBC Alex Fraser Research Forest; and Figure 4 (BELOW) A commercial thinning intervention in an even-aged spruce stand. Image source: Aleza Lake Research Forest Society.

TABLE 1 *Overview of general categories of silvicultural systems and their associated regeneration methods, based on Ashton and Kelty (2018) and modified with British Columbia experience. These systems and associated terms are further explained in Section 4.4.*

General Silvicultural System	Potential Modifiers
Clearcut • Single age class regenerated either with planting or non-coppice natural regeneration with site preparation (natural seeding). • More than 50% of the harvested area in a regeneration cut is more than two tree-lengths from edge or individual tree.	• With reserves.
Patch Cut • A single age class regenerated by planting or natural regeneration. • Less than 50% of the harvested area in a regeneration cut is more than two tree-lengths from edge or individual tree, yet this is not an explicit design criterion.	• With reserves or retention.
Seed Tree • Single age class where intent is natural regeneration with seed from retained overstory trees. Planting may be used to supplement stocking. • In traditional systems, seed trees are removed after regeneration is established.	• With reserves or retention.
Coppice • Single age class regenerated vegetatively (e.g., by root or stump sprouts).	• With reserves. • With standards.
Shelterwood • Single age class where intent is natural regeneration in the shelter of retained overstory trees. Planting may be used to supplement stocking. • Overstory is traditionally removed at some point after regeneration is established.	• With reserves or retention. • Uniform or group cutting.
Irregular Shelterwood • Two age-classes regenerated by natural regeneration in the shelter of a retained overstory. • Mid-rotation harvest to remove overstory, thin mid-story and establish new regeneration cohort. • Final overstory removal is optional. It may be left as legacy leave trees.	• With reserves or retention. • Uniform or group cutting.
Selection • At least three age classes and a wide range of tree height classes regenerated by natural regeneration in the shelter of a retained overstory. • Repeated thinning to provide growing space for developing cohorts.	• With reserves or retention. • Uniform or group cutting.
Retention • As an explicit design criterion, less than 50% of the harvested area in the regeneration cut is more than two tree-lengths from standing live trees throughout the rotation. • At least two age classes because a targeted proportion of the overstory is retained throughout the rotation. • Regeneration can be by any method.	• Dispersed or group retention. • Retention is for long-term.



Duffey Lake viewscape, in the Coast–Interior transition zone between Pemberton and Lillooet, B.C. Image source: Mike Jull (used with permission).

2.2 TAKING UP THE CHALLENGE OF SILVICULTURAL INNOVATION WITH SILVICULTURAL SYSTEMS

British Columbia is in an era of significant change in our forest management. We are faced with multiple challenges and opportunities:

- Planning for forest landscapes with First Nations in lead roles, signalling a move towards a much wider array of goals and objectives applied to the land base.
- Climate change, challenging what practitioners thought of as foundational knowledge and principles.
- Increasingly destructive fires and floods, demanding a response in the way we manage stands, forests, and landscapes.
- Wood being increasingly chosen for climate-friendly products with which to build and fuel our society.

Society's expectations for improving the management of our forests are high. Forest professionals and the forest sector are increasingly expected to balance traditional timber supply and economic concerns with expectations for the many environmental, social, and cultural forest values and outcomes influenced by forest management.

Gorley and Merkel (2020) recommended that British Columbia create a silviculture innovation program aimed at developing harvest alternatives to clearcutting that maintain old-forest and ecosystem values. The core intent of this innovation is to move from harvest and regeneration practices focussed on economic efficiency to multiple silvicultural systems focussed on managing for multiple values. They advised the government to collaborate broadly to test and refine a wide range of silvicultural systems to achieve different goals and objectives.

Forest practitioners in British Columbia have a pivotal role in defining, developing, and piloting new silvicultural approaches, studying their outcomes, and sharing those learnings. This presents the opportunity to broaden our forestry expertise and creativity toward more diverse silvicultural systems. This will be a new challenge that will span decades and careers. This Handbook provides a structured approach to silvicultural systems applications to help professionals begin this journey toward achieving the broad range of objectives that the forests of British Columbia can provide.

The challenges and opportunities await!

PART 3 – EVOLVING SILVICULTURAL PRACTICES

This Handbook describes the broad forest and stand management concerns, concepts, and needs that influence and inform the design and application of silvicultural practices and systems across the province, in different places and situations. This section addresses the broader perspective of First Nations principles, values, and goals and how they influence silviculture in British Columbia.

3.1 BRITISH COLUMBIA'S CHANGING FORESTS

In British Columbia we are managing forests and landscapes that are substantially changed from the forests that existed under First Nations stewardship in centuries past. For millennia, First Nations stewarded the land and resources by accumulating knowledge and applying and adapting techniques and methods that protected their village sites and sustained or enhanced the availability of plant and animal populations in resource areas over years or generations (Turner 2014). The arrival of European settlers in the 1800s, and the subsequent impacts to First Nations populations due to disease, colonization, and industrial development of natural resources, have led to significant changes in British Columbia's forests.

In the 21st century, cumulative effects of forest practices over more than 150 years, a growing population, and development of infrastructure and communities have changed the nature of many British Columbia forest landscapes. These complex and often interlocking changes include roads, railroads, pipelines, and transmission lines that create linear features across the landscape. Historical forest practices have reduced the **resistance** or resilience of forests to a range of natural disturbances such as drought, insects and disease, and wildfire. It is widely recognized that fire suppression in the 20th century led to aging forests that became ingrown and dense and accumulated more fuel. The warming climate is also influencing natural disturbance rates and patterns. However, while the environment and conditions in British Columbia's forests have changed, the knowledge and experience of First Nations remain as important today as ever.

3.2 GROWING ROLE OF FIRST NATIONS IN FOREST MANAGEMENT

First Nations have never ceded their rights to land in British Columbia and today many Nations are exerting those rights and becoming more involved in management decisions affecting their lands.

Many First Nations communities in British Columbia include forestry as a mainstay of their economic portfolio. Starting in the 1980s, First Nations began to exert their interest in forestry through political action. By the late 1990s, many First Nations businesses or corporate/First Nation partnerships had been established to create relationships and respond to economic development interests of First Nations.

Forest tenure opportunities now provide some First Nations communities with tenures such as community forests and First Nations woodland licences, in addition to tenures they have acquired through purchase or direct award.

The 2007 United Nations Declaration on the Rights of Indigenous People (UNDRIP) recognizes the human rights of Indigenous Peoples around the world. British Columbia followed in 2019 with the Declaration Act[3] (DRIPA), which commits to implementing the principles of UNDRIP, including First Nations and the Province working government-to-government. The 2022–2027 Action Plan for implementing DRIPA includes several actions relevant to forest management, including:

- Co-develop strategic-level policies, programs, and initiatives to advance collaborative stewardship of the environment, land, and resources, which address cumulative effects and respect First Nations knowledge.
- Integrate traditional practices and cultural uses of fire into wildfire prevention and land management practices and support the reintroduction of strategized burning.

Several forest management initiatives around the province are working to combine science and traditional ecological knowledge. The partnership between 'Namgis First Nation and Western Forest Products (Svanvik et al. 2024) is one example of people embracing the opportunity for change and working together to define a new path. Another example is the ecosystem **restoration** and fuel reduction that Williams Lake First Nation is implementing around the City of Williams Lake.

In developing silvicultural practices for a given place and situation, forest professionals need to consider and incorporate First Nations principles, values, and goals as part of the planning process. While there are cultural differences between communities and Nations,

View from floatplane of Kitasoo Xai'xais Nation Big House near Klemtu, in the Great Bear Rainforest. Image source: Theresa Denton (used with permission).

there are also common values, such as those expressed in various ways as "how to live right with the land." First Nations principles, values and goals help inform forest professionals' thinking on their stewardship approaches in the context of forest management and silviculture. For professionals, this means thinking beyond just the legal and statutory realms of British Columbia forest management, to the socio-cultural environment and expectations that influence how we do forestry in an area. It also means talking to local Nations to understand their values and expectations.

3.3 FIRST NATIONS VALUE STATEMENTS

In the longer-term historical perspective (before the mid-1800s), First Nations land stewardship ensured that groups could survive on the resources within their territories, and for some Nations, within family parts of their territories.

Traditionally, the main purpose of active land management was to support sustenance, focussing on providing resources to support high-producing fishing camps, ungulate hunting activity, and medicinal plant and berry gathering. First Nations also had highly complex trading systems, where peoples traded with other peoples for items that did not exist in their territories. Communities have

[3] Declaration on the Rights of Indigenous Peoples Act.

Totem poles, Haida Gwaii. Image source: Forest Practices Board.

spent millennia learning traditional cultural practices and strategies applicable to areas of their lands. As a result, First Nations have a profoundly intimate and respectful knowledge of everything on the land.

Most Indigenous cultures are earth-based; that is, they try to maintain a way of being that keeps people in balance with nature's cycles and in their place as one of many things that are all equal in the eyes of nature. This belief system includes an inherent stewardship responsibility to take care of the land properly. This core value drives most First Nations earth-based cultures' actions, decisions, and relationships with respect to land, including their approaches to modern land stewardship.

These approaches are broadly expressed in the following value statements:

3.3.1 Water and Connectivity

Water connects all parts of the land. From major bodies of water to small creeks and tributaries, from low elevation to high. Waterbodies and flows are a vital life-giving resource for fish and wildlife species, ecosystem-functioning and local human communities. First Nations communities often refer to water as the life blood of the land that supports all living things. Any break in this complex connection can have significant negative effects.

Protecting water quality and quantity by protecting riparian ecosystems ensures strong water and habitat connections across our diverse terrain. During planning phases, it is important to understand the variety of life that depends on healthy water systems to recognize values and riparian ecosystem attributes that need to be protected and managed.

Maintaining healthy riparian ecosystems, quality drinking water, and stream health are key priorities when considering or choosing management approaches.

3.3.2 Ecosystem Health and Habitat

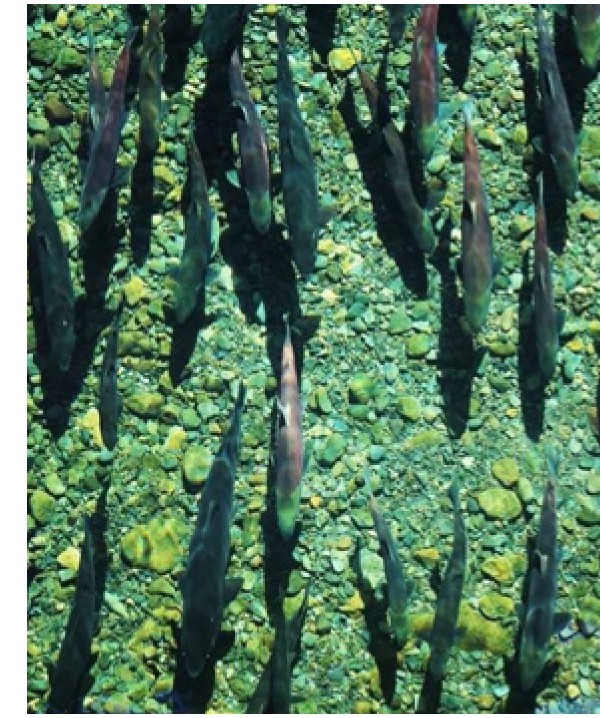
A core belief in First Nations earth-based cultures is that if you take care of the land, it will take care of you and all other living things, and that all other living things have the same right to be here as you do.

Healthy ecosystems are a fundamental attribute of biodiversity and habitats for all living things. Trees are the product of ecosystems and the interconnectedness of a stand of trees is part of a biologically complex community of plants, animals, and aquatic life. The elements and structures created by the trees are integral to the health of the ecosystem and the habitats they provide, sustaining their interconnectedness.

Trees are not just timber associated with dollar value alone; their value is reflected also in all the animals, water, and people that rely upon them for sustenance, security, and livelihoods. The same is true for all the non-timber components of the forest, as trees depend on them in many complex ways to grow and thrive.

Healthy ecosystems provide a diverse set of conditions necessary to maintain biodiversity. Managing to restore healthy ecosystems will yield timber as a byproduct of management.

Consider tailoring management approaches to maintain these larger connections, especially where they apply to sensitive areas.



Salmon over spawning beds, coastal British Columbia. Image source: Theresa Denton (used with permission).

Arrow-leaf balsamroot - Dry Interior Douglas-fir ecosystem (IDFxm). Image source: UBC Alex Fraser Research Forest.

Prescribed underburn in drybelt Douglas-fir / ponderosa pine stand. Image source: B.C. Ministry of Forests.

3.3.3 Sacred Places

Sacred places must be respected. They are identified by a First Nations community through millennia of use and oral tradition and communications. Most of the time the cultural value of these sites is incompatible with significant human disturbance, including timber harvesting and land alteration. They are usually located within a First Nation's traditional territory but may also be located quite a distance away. Sacred places hold great traditional, cultural, and spiritual significance. Access may be remote and the terrain difficult to traverse. Respect the trust given by the Nation when they refer to a sacred area. These locations are not usually disclosed in detail to developers or others.

3.3.4 Cultural and Prescribed Burning

Many First Nations practiced the widespread use of cultural and prescribed fire throughout the interior of British Columbia, where Nations used seasonal cultural burning to refresh the land and soils, promote new growth, keep invasive plants and problem insects such as ticks in check, and to create safer places to live. Suppressing this practice for well over a century has led to the accumulation of forest litter and dead trees, which contribute to high-severity wildfires.

Nations are working collaboratively with the Province and communities to improve fire prevention and suppression. Leaning on First Nations knowledge and western science to manage this critical problem of forest management is proving to be successful.

3.3.5 Meaningful Collaboration in Planning and Monitoring

From a First Nations perspective, forest and land management needs to acknowledge the connectivity of all aspects of land and consider cumulative effects. Therefore, it is very important to collaborate with First Nations, keeping communications open, transparent, and trustworthy. By sharing knowledge for a specific area early during the planning phase, proponents and Nations have a better chance at working together to address any concerns or opportunities. An open communication style benefits everyone and fosters collaboration. It is especially beneficial when communities are actively participating in monitoring during all phases of forest development, including post-harvesting operations.

Bark stripping on a coastal western redcedar tree. Indigenous cultural use. Image source: Theresa Denton (used with permission).

3.3.6 Expectations for Managing to What the Land can Sustain

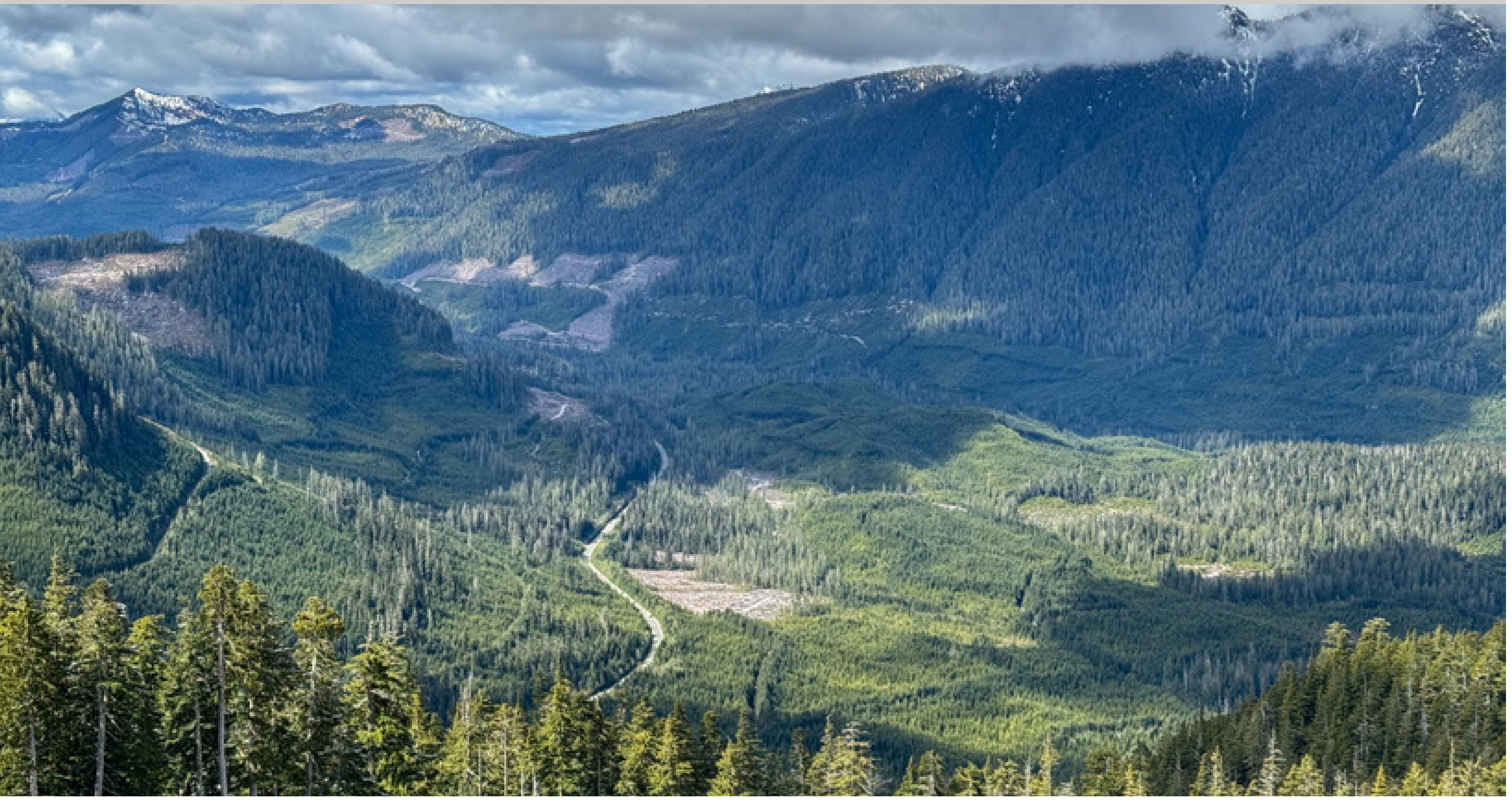
Most First Nations believe that the land is meant to be used—it is how you use it that is important. First Nations have many responsibilities to their citizens (Figure 5) that in today's world also require an economic generator. This often includes various forest-based businesses, including industrial forestry in their territories. Each of these activities is done in a way that cannot compromise the land, community forest-based businesses, or the community's ability to continue to sustain themselves from their territories.

FIGURE 5 *(RIGHT) Cultural thinning intervention for medicinal plants in a Wet Warm Interior Douglas-fir (IDFww) site on Líl'wat Nation Mt. Currie IR# 6 lands near Pemberton, B.C. Image source: Ken Zielke (used with permission).*

"Our ever-expanding understanding of forest behaviour and management, as well as the effects of climate change, have made it clear that we can no longer continue to harvest timber and manage forests using the approaches we have in the past while also conserving the forest values we cherish. We therefore have to be honest with ourselves and collectively and transparently make the choices necessary to ensure future generations of British Columbians can enjoy and benefit from our magnificent forests, as we have done."

Al Gorley RPF and Garry Merkel RPF 2020

PART 4 – FROM CURRENT CONDITION TO A DESIRED FUTURE: PLANNING AND DEFINING A SILVICULTURAL SYSTEM



A forested landscape altered by decades of harvesting and forest management, West of Sayward, B.C. on Vancouver Island. Image source: Ken Zielke (used with permission).

Developing a silvicultural system is an integral part of stand management planning. In any stand, the first step in silvicultural planning is to envision a desired future condition, the potential management pathways to get to that condition, and the options for silvicultural systems.

4.1 FROM THE LANDSCAPE TO THE STAND: CONSIDERING MANAGEMENT OBJECTIVES FOR STAND-LEVEL SILVICULTURAL PLANNING

In silvicultural planning, the forest professional's role is to closely examine and consider site-specific features of site ecology, stand conditions, local ecosystem values, the surrounding stand neighborhood or general area, and how the current and future management of that area can be envisioned and planned in a manner consistent with higher-level objectives and goals for the landscape.

In carrying out this essential role, the forest professional needs to ask and understand two fundamental and related silvicultural questions: *"In this place on the land, what site and stand conditions and values do I need to identify, enhance, protect, and conserve, both for the present and the future of this forest and ecosystem?"* And *"How do I clearly define and communicate these goals and actions that describe where, when, and how these goals will be achieved?"*

Answering these intertwined questions requires knowledge of both the higher-level goals and objectives for the area of forest land that consider the "bigger picture," and local information about the sites, ecosystems, and stands being managed in the silvicultural decision-making process (Figure 6).

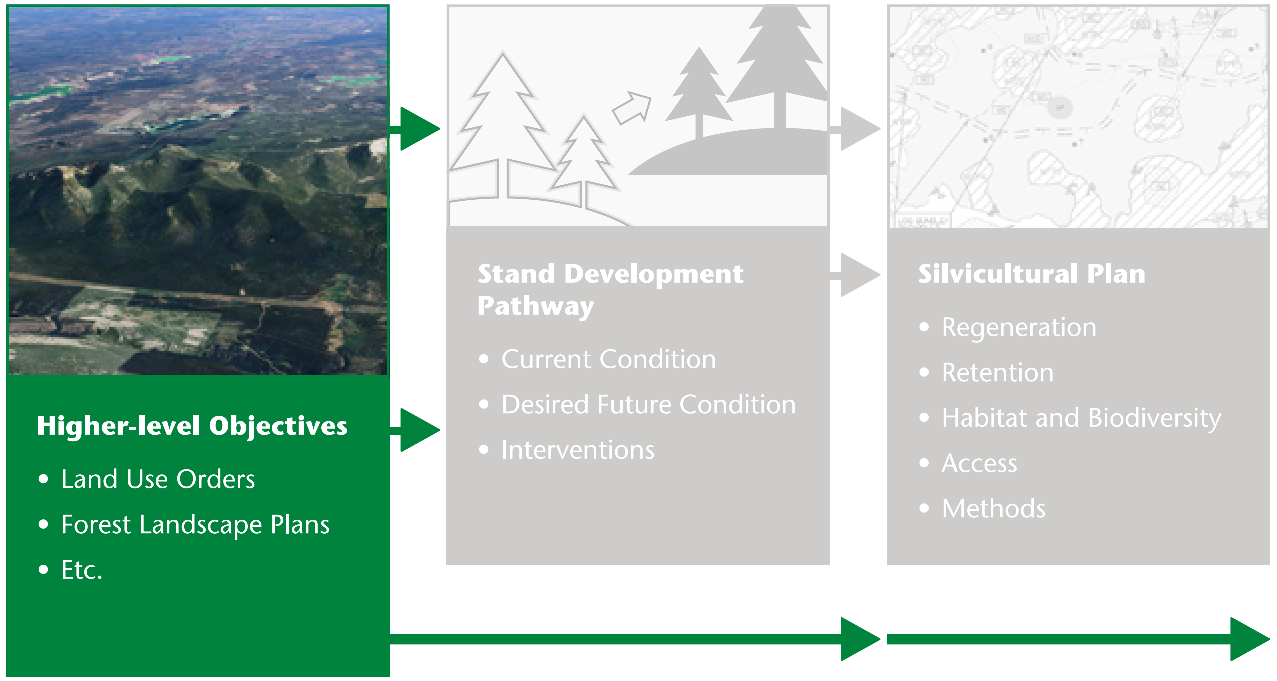
TERMINOLOGY: HIGHER-LEVEL GOALS AND OBJECTIVES

Higher-level planning: A collective term for all the various planning activities that set expectations for land management at the provincial, regional, and landscape levels. These planning activities result in goals and objectives to which silvicultural planning must respond.

FIGURE 6 *A silvicultural plan for a particular cutblock requires an understanding of the higher-level objectives, which influence the desired future condition for a given stand. The stand development pathway conceptualizes how to move from the current condition to the desired future condition, and a silvicultural plan is conceived for the next intervention(s) on the pathway. For more discussion, see Section 4.1.1 (higher-level objectives), Section 4.2 (stand development pathway), and Section 5.1 (silvicultural plan).*

This section of the Handbook explores in detail the links between higher-level landscape objectives and stand-level objectives (desired future condition) as compared to the current condition. It provides a framework for considering and incorporating higher-level objectives in a stand development pathway through implementation of interventions to achieve stand-level objectives in a silvicultural plan.

4.1.1 Best Practices for Developing Silviculture Objectives at the Site and Stand Level



Silvicultural objectives for a stand, and the "stand neighborhood" (see Figures 7 and 8) surrounding it, need to be site-specific and time-specific. Silvicultural objectives must be context-dependent and, for best results and adaptability, should not be standardized.

Best practices for the development of silvicultural objectives (Table 2, p. 19) will be similar for all stands and management areas and will require common issues to be considered. The following framework should be used when developing silvicultural objectives at the stand level.

East Twin Watershed, Robson Valley, British Columbia. Image source: Aleza Lake Research Forest Society.

STAND VS. STAND NEIGHBORHOOD

Stand

A stand is defined as "a community of trees sufficiently uniform in species composition, age, arrangement, and condition to be distinguishable as a group from the rest of the adjacent forest or non-forest areas, and thus forming a silviculture or management entity."

Adapted from BCMoF Glossary 2008 www.for.gov.bc.ca/hfd/library/documents/glossary/Glossary.pdf

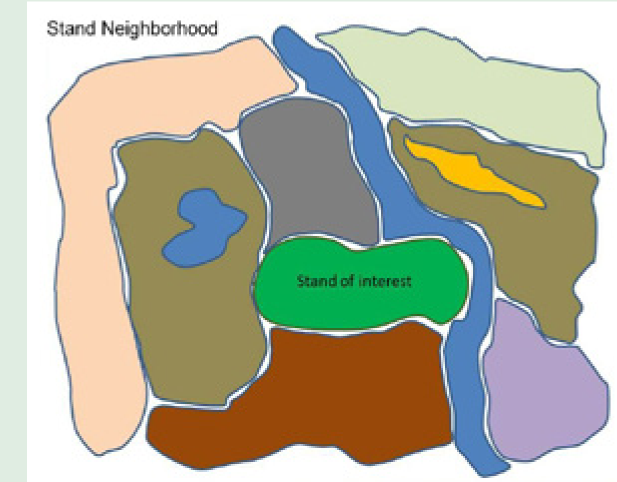


FIGURE 7 *Conceptual representation of a stand of interest and surrounding stand neighborhood of adjacent stands and forested/non-forested ecosystems. Image credit Mike Jull.*

Stand Neighborhood

A "stand neighborhood" includes a stand, several stands, and/or denuded areas within and surrounding the area under the silvicultural plan, and includes adjacent forested and non-forested ecosystems that may be influenced by silvicultural and management interventions. The stand neighborhood concept reminds land managers and forest professionals to consider localized values and landscape context near or adjacent to their silvicultural plan area. The spatial scale within which this concept is applied will depend on the values and context within which it is used and will vary from place to place.

FIGURE 8 *The stand neighborhood is influenced by biophysical factors, overlaid by the disturbance history, in this valley in the West Kootenay, British Columbia. Image source: Ken Zielke (used with permission).*

A **silvicultural plan** needs to:

a) explicitly state the higher-level goals and objectives for forest management;
b) explore the application of higher-level goals and objectives in the context of the surrounding stand neighborhood, to provide direction for a specific stand;
c) closely examine the stand of interest, its site conditions, and the stand neighborhood, (as illustrated in Figure 7) to define what silvicultural objectives are suitable and feasible;
d) explicitly identify the multiple objectives for which a stand is being managed. Consider if they conflict, and if so, apply judgement to rank and/or apply trade-offs;
e) consider how anticipated changes in climate may affect the suitability and feasibility of silvicultural objectives;
f) specify targets for each specific objective being managed at the stand and site level; and
g) define the timeframe by which targets for the above objectives are expected to be achieved.

TABLE 2 *Framework for linking higher-level objectives to the stand level for silvicultural planning*

Silvicultural Plan Needs	Source	Considerations
a) Explicit higher-level goals and objectives	Higher-level planning Community Regulatory direction	Objectives, spatial and temporal scales
b) Consider stand neighborhood	Regulatory direction • Local knowledge • Community perspectives	Ecological and edge effects (e.g., wind, connectivity of habitats) "Good neighbour" considerations, visual impacts Community relationships, other factors
c) Current stand and site conditions	Inventory, reconnaissance	Are the objectives suitable and feasible?
d) Overlapping suitable and feasible objectives require judgement—ranking, trade-offs	BMPs, expert input, peer review Policy barriers	Objectives: • Conflicting or compatible? • Equally suitable and feasible for the stand of interest? • Relative importance? • Are conflicting interests possibly affecting your judgement?
e) Anticipate impacts of climate change on suitability and feasibility	Best management practices (BMPs), expert input, research, monitoring, modelling	What effects are occurring now? Impacts of increasing disturbance? Opportunities?
f) Specify targets for each specific objective	Stand and site level Site capability and productivity Modelling	What is feasible and achievable?
g) Defined timeframe to meet targets	Modelling, monitoring	What models are available and accessible? When can we reasonably expect achievement? Pass the plan on to successors.

Silvicultural plans need to clearly describe the existing site conditions (Figure 9) and adjust the prescribed silvicultural treatments to achieve the desired objectives after harvest, and over defined timescales. Stand-level silvicultural plans must be clear and succinct to present expectations for the outcome of the activity in a way that those implementing the activities can understand and carry out reliably and with precision.

Note that in silvicultural planning, steps will not and should not always occur in a simple sequential manner. In many cases, this silvicultural decision-making process will be iterative. For example, once the current stand conditions are considered, the ability of the stand to adhere and contribute to higher-level objectives may need to be reconsidered, or alternative silvicultural strategies developed. The following section discusses what should be considered in each step.

FIGURE 9 *Carefully consider the current condition of the stand of interest, the neighborhood of stands, and the desired objectives to develop a silvicultural plan. Unthinned stand with abundant western hemlock, West Kootenay, British Columbia. Image source: Ken Zielke (used with permission).*

The following (a–e) expand on the silvicultural plan needs from Table 2, p. 19.

a and b) Consider Spatial Scales - Higher-Level Goals to the Stand Neighborhood to the Stand

Clear higher-level objectives are necessary to contextualize stand-level objectives based on landscape factors, landscape position, and the attributes of adjacent stands. These can be rationalized with all relevant economic, social, and ecological goals established by higher-level plans, considering the stand neighborhood context.

For a simple example of this hierarchical planning, consider a management goal to reduce the size and intensity of wildfires over time. Broad objectives may be set to reduce fuel hazard classes and create landscape-level fire breaks. Both objectives would then be considered and prioritized in time and space, considering local ecological, social, and economic goals and objectives to establish explicit strategies that might direct tree species preferences, retention priorities, and stand density management over time in specific areas. These management decisions will affect the options available for silvicultural systems on the ground when considering the larger landscape and the local stand neighborhood.

The context for land management in British Columbia is continually evolving, as landscape planning processes proceed and are updated from time to time. While the specific documents defining legal obligations and objectives will change through time, they may include the *Declaration of the Rights of Indigenous Peoples Act, Forest and Range Practices Act, Forest Planning and Practices Regulation, Wildfire Act, Range Act, Land Act* orders, and *Government Actions Regulation* orders.

The sources of higher-level objectives for silvicultural practices may, in many cases, incorporate a combination of both defined legal objectives and non-legal objectives, with the caveat that the latter need to be consistent with the former. Through regular communications, First Nations, tenure holders, communities, and local and regional stakeholder and interest groups may provide forest professionals or land managers with input on community concerns and preferences. Such communications and discussions are important in considering a wide range of views in forest management decision making at the stand level, and building community trust and engagement, often referred to as social licence.

An underlying premise of higher-level objectives is that they cannot all be realized everywhere, on every hectare, all the time. Some values or issues are more important in certain areas than others. Silvicultural planning is necessary to allow for higher-level objectives to be distilled into more localized stand-level objectives and treatments.

Many, but not all, objectives have a spatial component. The scale at which an objective should be defined, and can be managed, will often depend on the objective itself. Tree growth potential can be evaluated at a tree, plot, or stand level, while other objectives such as wildlife habitat or carbon storage may be managed and evaluated at a stand, landscape, or regional scale.

A simple example is objectives concerned with trout in headwater streams, which may be focussed on the riparian zones and drainage areas that support those streams. At the other end of the spectrum, objectives concerned with grizzly bears will necessarily have a large spatial scale because of that species' occurrence in many different ecosystems and its ability to move widely across the landscape.

Some objectives are broad in nature and spatially ubiquitous—such as the desire to restore ecosystem integrity (Banner et al 2024). While it is impossible to provide a definitive statement on the exact spatial scales that should be considered when planning forest management, in most cases the determination of objectives should consider the stand, stand neighborhood, and forest landscape scales. The stand neighborhood (see Figure 7, p. 18) is important because the objectives being pursued are frequently influenced by the values present outside or adjacent to the stand of interest.

TEMPORAL SCALE: DEFINE THE TIMEFRAME FOR ACHIEVING SPATIAL OBJECTIVES

Good objectives are time bound so that we have an idea of when they will be achieved. In silviculture, objectives may be achieved immediately after an intervention; for example, regeneration of Douglas-fir after a shelterwood seed cut. However, we can also make a silvicultural intervention in anticipation of future benefits, such as achieving objectives in several decades through expected improvements in stand conditions resulting from treatments. An example may be commercial thinning to increase piece size and log quality in the future (Figure 10).

Forests are dynamic and change over time. This means that their ability to contribute to an objective can and will change over time. The dynamic nature of forest objectives needs to be explicitly noted and considered when identifying objectives. This will often involve identifying those objectives that are inherently dynamic (e.g., habitat quality that is dependent on stand development stage) and explicitly clarifying how they are expected to change over time.

FIGURE 10 *Commercial thinning interventions are an investment in the future value of a stand, such as this spruce stand near Hixon, B.C. Trees were uniformly thinned from below by a harvester forwarder system to a target basal area. Image source: Aleza Lake Research Forest Society.*

FIGURE 11 *Open drybelt Douglas-fir stand treated to reduce fuels. Very Dry Interior Douglas-fir ecosystem (IDFxm) southwest of Williams Lake EP 1367. Image source: Forest Practices Board.*

c) Using Current Stand Conditions to Help Set Objectives

Current stand conditions will define the opportunities and limitations that relate to achieving stand-level objectives. In other words, you need to know where you currently are before you can know where you can go. Achieving some objectives may be suited only to certain ecological conditions. For example, we might have an objective to create a particular condition (e.g., open forest) (Figure 11) in a certain ecological situation where the desirability of this outcome has been identified.

Many objectives may be stated at the forest or landscape level but must be implemented at the site level. For example, riparian protection principles or guidelines may be described with principles or best practices for a defined landscape but would be implemented at the site level in the vicinity of watercourses and wetlands, for example, and more specifically or locally within a site planning area. Similarly, an objective to protect stick or platform nests (for raptors such as eagles or hawks) could be described for the whole landscape but would be implemented at the site level in places where stick nests exist.

In some cases, the current condition of a forest or stand does not satisfy the objectives of the land manager's higher-level plans. This is central to the silvicultural planning process. The forest professional now knows what they are expected to achieve in the context of higher-level values and planning objectives. By identifying a more desirable stand condition (the desired future condition) and comparing that to the current condition of a stand, the forest professional can determine what steps they need to take to develop a course of action—a stand-level plan—to influence stand development to a more desirable future condition.

Bear in mind that the current condition is not static, and neither will it be when we arrive at the desired future conditions.

TERMINOLOGY: STAND CONDITION

Desired Future Condition: The stand condition that will provide the values and meet the objectives established in higher-level planning.

Current Condition: The condition of the stand under consideration at the time of planning—species composition, health, productivity, habitat, and biodiversity will be some of the variables of interest.

Comparing the desired future condition with the current condition gives rise to a stand development pathway and a conception of the first intervention.

"When it is obvious that the goals cannot be reached, don't adjust the goals, adjust the action steps."

Confucius

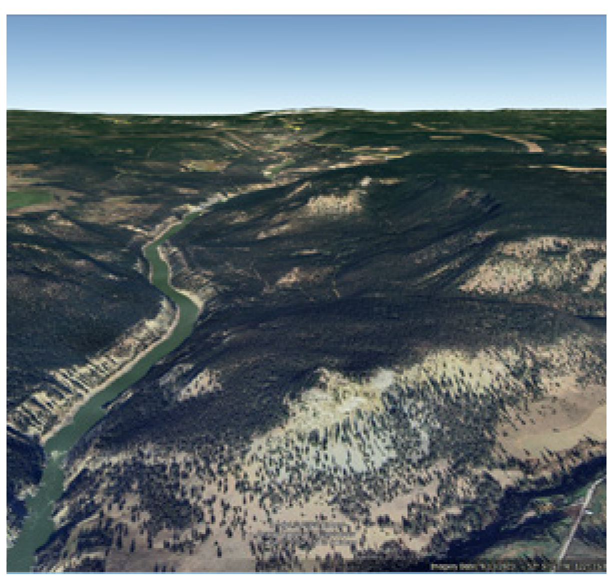


FIGURE 12 *Open stand conditions on warm and hot aspects in the IDFxm seem likely to expand in the face of climate change. 2023 image looking north up the Fraser River near Williams Lake, B.C. Image source: Google Earth, Airbus, Landsat/Copernicus.*

d) Defining Complex, Overlapping Objectives for Multiple Values

In their development over the last two centuries, silvicultural systems were generally designed purely as stand-level approaches to secure regeneration of desired tree species and ensure a predictable flow of timber over time. Those contexts defined the stand trajectory and outcomes for management. However, modern forest management in British Columbia has evolved to the point where timber may not be the primary focus for stand trajectories. In some places timber may be a lower-priority objective than it has been historically. For some stands or ecosystems, timber (regeneration and management) may not be an objective at all (e.g., grassland restoration).

Objectives are seldom singular. Most places in our complex world have multiple values and objectives co-occurring or "laying over top of each other." Modern forestry is multi-objective, and silvicultural planning needs to reflect this. However, silvicultural planning will not be able to promote all forest values, in all operating areas, all the time. There needs to be explicit identification of what objectives are relevant in a silvicultural plan, and how the selected silvicultural methods will explicitly advance these objectives.

e) Considering Effects of Climate Change

Climate change is affecting current stands and site conditions and may therefore affect the applicability/feasibility of an objective set out in the higher-level plan. For example, the feasibility of maintaining high crown closure on south-facing slopes may be declining in some ecosystems (Figure 12). Some tree species may be projected to be under significant stress over time in certain ecological settings. What was ignored in the past when it came to fuel loading conditions, may now be a significant concern.

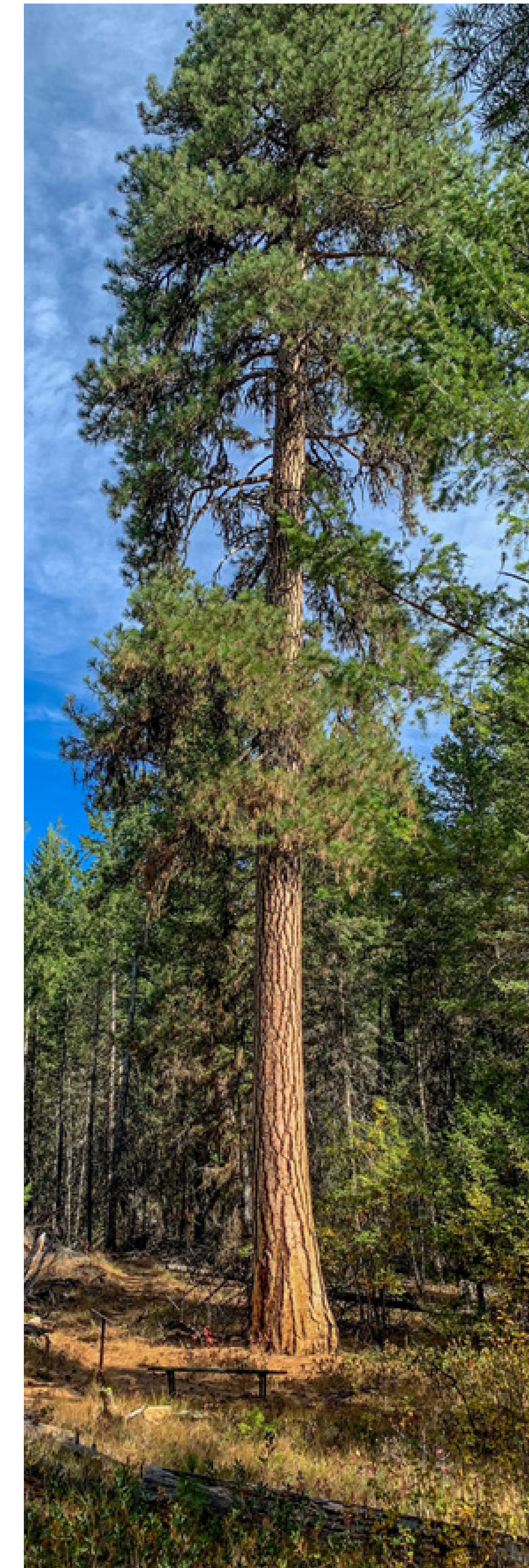
It is important to consider if impacts of climate change are likely to affect the suitability and feasibility of silvicultural objectives in the stand of interest. If so, how and where those objectives are accommodated needs to be considered in on-going landscape-level planning.

Douglas-fir veteran trees, Central Interior, British Columbia. Image source: Mike Nash (used with permission).

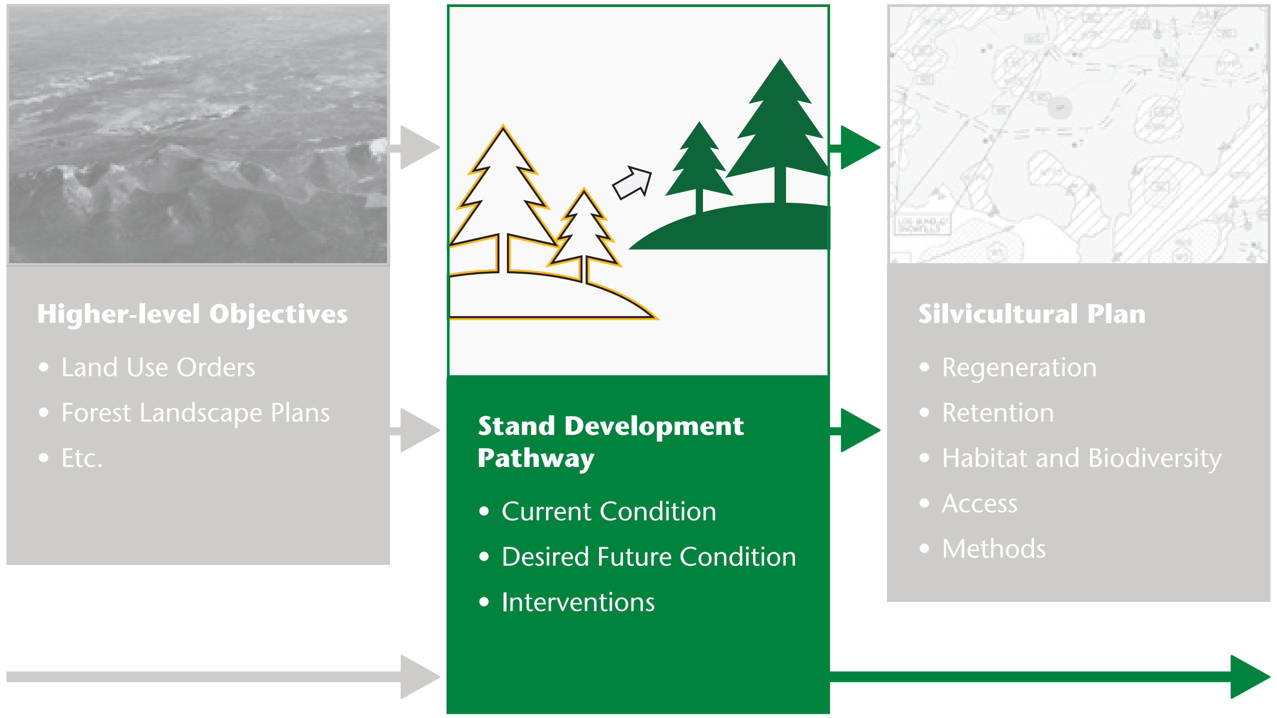
f and g) Specify Quantitative Targets and Timeframes for the Site and Stand Level

For each defined objective there should be clear quantitative targets. Quantitative targets contribute to the development of suitable silvicultural systems in several ways. First, quantitative targets are the indicators that will be used to evaluate whether management objectives are achieved. Second, quantitative targets make communicating the objectives easier and contribute to transparency of the forest management process. Third, quantitative targets, and clear descriptions of the silviculture decisions implemented, are required for adaptive management and for the improvement of silvicultural systems over time.

This section has identified key considerations for developing silvicultural targets. The following sections of this Handbook guide the **land manager** and forest professionals through the steps necessary to consider and design stand development pathways and silvicultural systems that will set timeframes to meet diverse goals and objectives.



(RIGHT) Mature ponderosa pine, southern interior British Columbia. Image source: Ken Zielke (used with permission).



A WORD ABOUT WORDS

The language of silvicultural systems describes a very specific area of practice infused with long tradition and arcane administrative systems. Engage in respectful listening and dialogue as you seek to understand the meaning behind the words others use. Use the language carefully.

FIGURE 13 *A clear vision is critical to achieving the desired condition. Fuel reduction thinning, IDFxm. Image source: Williams Lake Community Forest.*

Once silvicultural targets have been defined, the forest professional needs to determine what types of **stand interventions** are needed and develop a schedule for those interventions to best achieve the desired values and objectives along a stand development pathway.

The starting point for a stand development pathway is to envision desired conditions for the stand at various points in time from the present to the future (Figure 13). The forest professional should also envision the stand interventions to create those desired conditions at those points in time, following a process that incorporates three separate elements:

1. The desired conditions and associated interventions for the values and attributes of interest.
2. A description of what is to be retained for a defined period.
3. The treatments necessary to create the desired regeneration outcome and stand structure.

The envisioning of desired future conditions and the schedule and type of interventions to get there, come together to form a silvicultural system. When the current stand does not have the required characteristics for achieving the desired future conditions in the short term, there may be numerous steps necessary to reach success. For example, in Coastal British Columbia where old-forest stand structure naturally dominated but is now lacking, extensive second-growth stands may benefit from **thinning** to promote old-forest structure and attributes more quickly. In the dry Interior Douglas-fir zone where mule deer winter range has been harvested and regenerated to lodgepole pine, many interventions, such as thinning pine trees to open up growing space for existing Douglas-fir trees and seedlings, may be required to meet the objectives over a long timeframe.

This section provides forest professionals with a structured decision-making framework to help envision the stand development pathway and design the program of interventions to achieve it.

4.2.1 Principles for Successful Silvicultural Planning

Successful silvicultural system decisions will set out a pathway between the current condition and the desired future condition. Along that pathway are as many interventions as necessary to influence the development of the current stand towards the desired future condition. Silvicultural decision-making will need to adhere to a set of principles by which one can assess the probability of success.

1. **Clearly stated silvicultural goals describe the desired future condition one wishes to create through prescribed silvicultural interventions.**
   The task of the forest professional is to devise a methodology to achieve the direction coming from land management planning, given the particulars of the current conditions at the site level.
2. **Descriptions of ecosystem conditions (current, desired future, and anticipated at each intervention) include trees, snags, understory, forest floor, dead wood, and habitat features.**
   Current and target species assemblage, size distribution, and habitat characteristics are part of the stand inventory and description of the target conditions.
3. **Descriptions of ecosystem conditions include the site limiting factors, forest health and other risks, and opportunities to mitigate those risks.**
   Understanding the ecological site conditions, forest health **risks,** and limiting factors points a silviculturist towards operational and structural decisions for least-regret outcomes.
4. **Planned interventions align with the silvics and autecology of all the species under management (overstory and understory).**
   Understanding the **silvics** and autecology of both overstory and understory species is necessary to develop interventions that have a good outcome for a broader range of values, or at least to understand the trade-offs of decisions. For example, what level of light is needed to support fruiting of soopallalie *(Shepherdia canadensis)*?
5. **Planned interventions are conceived to make the future better than the present.**
   "High grading" of stands (meaning logging the best and leaving the rest) is not an acceptable practice when planning sustainable harvesting interventions over time. The priority should always be to improve stand conditions for the key values and objectives. For example, thinning from above can increase the risk of wind or snow damage and may retain trees with little ability to respond to additional growing space, while thinning from below increases the stability and resilience of the residual stand.
   The intent with stand interventions is always to manage the available growing space to best meet the objectives. Where timber is a primary objective, this means providing space for trees of a desirable species, size, and condition to grow or establish and develop over time. Where other values are at play, some space may be needed to grow shrubs and other plants, to create specific fuel conditions, or to maintain a component of trees with specific characteristics such as high wildlife or biodiversity values.

TERMINOLOGY: STAND DEVELOPMENT PATHWAYS

Stand Development Pathway: The course of stand development towards the desired future condition, as influenced by interventions through time.

Intervention: Any management activity within the stand that changes the stand development trajectory. Interventions are planned to influence the stand development towards the desired future condition.

4.2.2 General Design of Stand Development Pathways

Stand development pathways (Figure 14) describe the evolution of a stand toward the desired future condition and stand outcomes, in terms of the desired composition, structure, and attributes that align with stand objectives and ecological realities. These pathways represent sequenced stand development phases, designed to meet objectives driven by local values. The pathway generally includes regeneration, but not necessarily as the first intervention. Stand development pathways are essential to explain the intent, form, function, and implementation of a silvicultural system, which is often much more than a simple naming label can convey.

A stand development pathway is not intended to be a rigid or fixed prescription and the long planning horizons create uncertainty. Prescriptive details at this point should be considered fluid with the potential to be altered as outcomes become clear through time. However, the pathway is repeatedly updated to ensure that it approaches the desired future condition. Recognize that the silvicultural journey is as important as the destination, because stand conditions created by an intervention will last a long time, potentially decades. There may be several options for stand interventions to meet the pathway envisioned. There are also other uncertainties over time such as growth and mortality, climate change, natural disturbances, and changes in values and corresponding objectives. All these may divert the pathway in a slightly different direction.

A pathway generally represents a forecast of when and how stand management interventions are envisioned to nudge the stand in a particular developmental direction, or to maintain particular stand features. Forecasting with stand development models can be a useful tool in designing stand development pathways. Understanding the strengths and weaknesses of the model being used is critical to temper assumptions and interpret the results to fit with local ecosystems and stands. Climate change is a big source of uncertainty, and it must be informed using the best information available on important trends over time. The key is understanding potential future impacts on the various constituent tree species in the stand and impacts on the stand as a whole. Building these impacts into forecasts will be important.

The short career span of forest professionals in one locale underscores the importance of clear stand development pathways as a statement of original intent and understanding. Different forest professionals will likely undertake different interventions in a stand development pathway and values, ecological influences, and knowledge will likely evolve and could alter the management direction.

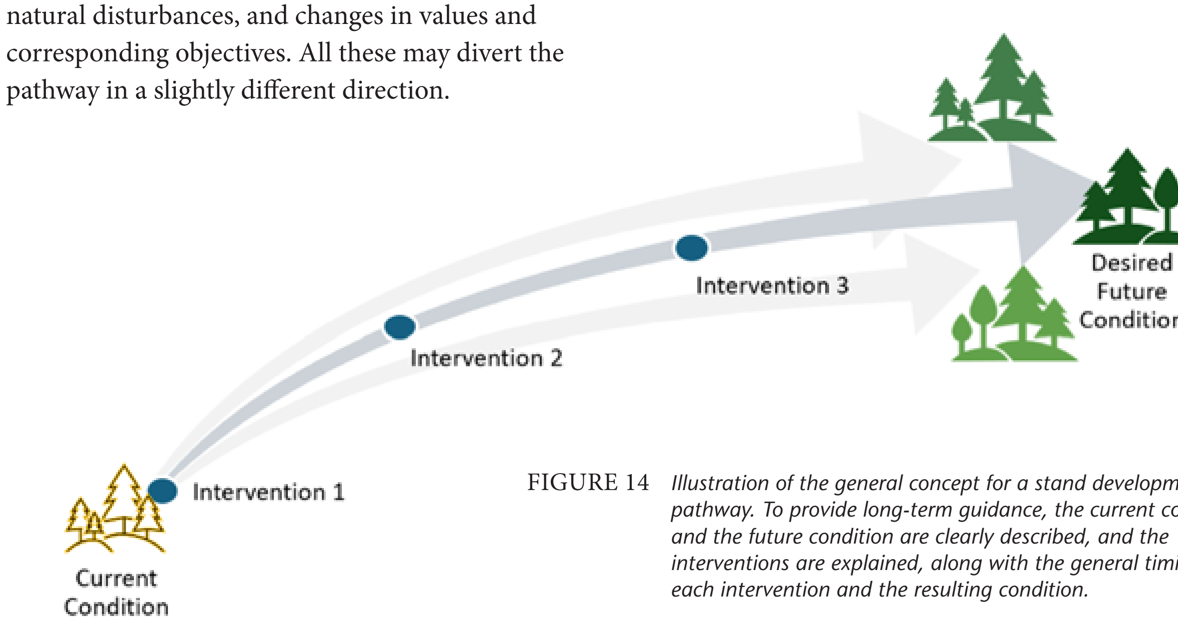


FIGURE 14 *Illustration of the general concept for a stand development pathway. To provide long-term guidance, the current condition and the future condition are clearly described, and the interventions are explained, along with the general timing of each intervention and the resulting condition.*

The starting point for stand development pathways is a clear statement of the desired future condition at a point in time when it is anticipated the stand-level objectives can be achieved. Beyond this point, maintenance activities may be needed to maintain some of the conditions or stand-level objectives may have changed due to the evolving conditions at the landscape level, and due to changing values and priorities.

A WORD ABOUT ENVISIONING STANDS OVER TIME: MODELLING

To envision a stand development pathway, a forest practitioner needs to think in time scales that extend beyond the duration of most careers. The further out in time one tries to envision, the less defensible the plan is due to required assumptions and uncertainties. For this reason, practitioners will benefit from using models to test their stand development pathways. Does stand development through time require additional interventions? Is the desired future condition attainable by this pathway?

Models need to be built to be both available and effective to help practitioners make decisions.

Stand development pathways will most often extend out for the equivalent of one even-aged rotation to a desired future condition (e.g. 50–100 years). However, this is not set in stone. The desired future condition may be achieved sooner or later (beyond a rotation) and the pathway to get there should be continually revisited over a much shorter time period.

A stand development pathway is a powerful communication tool to illustrate a clear vision for the future and the pathway to get there. A key focus should be the nature and the timing of the anticipated intervention or interventions over the next 20 years to ensure these are scheduled and planned. The silviculture plan will build on the stand development pathway with more prescriptive detail for these interventions. At the time the next interventions are undertaken, the desired future condition and the associated stand development pathway should be checked to ensure they are still relevant and sound based on available data and knowledge.

Stand development pathways should be flexible to allow practitioners to be nimble and adapt to changing conditions and values. A target stand composition, structure, and function may be described for decades down the road, yet in some cases only some of the interventions required to get the stand to that point may be described. In these cases, the tactical objective might be to improve the stand composition and structure and the ecosystem conditions up to a point at which time a decision on one of several options can be made. The forest professional may wish to describe those alternative pathway options, illustrating how each will still attain objectives over time. The suggestion of some options may be helpful to future forest professionals who will inherit the stand, but the most useful direction will be the management intent for the stand over the rotation (Figure 15, p. 31).

In some cases, it may be useful for a forest professional to describe a stand development pathway beyond one rotation, but this will involve further uncertainties. If at any time in the actual development of the managed stand on the ground there is an unexpected disturbance that significantly affects the stand condition, it will be important to reassess the stand development pathway and modify it or develop a new one.

EXAMPLE OF A HYPOTHETICAL STAND PATHWAY IN THE BOUNDARY AREA – DRY HOT INTERIOR DOUGLAS-FIR ECOSYSTEM (IDFxh)

Linked stand and landscape-level objectives relevant for this example:

- Maintain some mature forest attributes from current stand to retain old-forest stand attributes and increase foraging habitat for a species at risk (e.g., Lewis's woodpecker) at the landscape level.
- Maintain understory stand-level fuels at low levels (by removing the fine fuels) anticipating that fire seasons and severity of burns will continue to increase, considering the proximity of the stand to nearby lakeside residences (landscape level).
- Increase the current proportion of ponderosa pine in the stand and maintain it over time (stand level) to improve resilience in anticipation of greater drought and high summer temperatures in lower-elevation stand types (landscape level).
- Maintain a higher degree of early seral open conditions (stand level) for local First Nations berry and medicinal plan production objectives in these lower-elevation accessible sites (landscape level).

Current condition for this example:

The current stand of mixed conifers has a high degree of stocking through all stand canopy layers including the understory.

Desired Future Condition

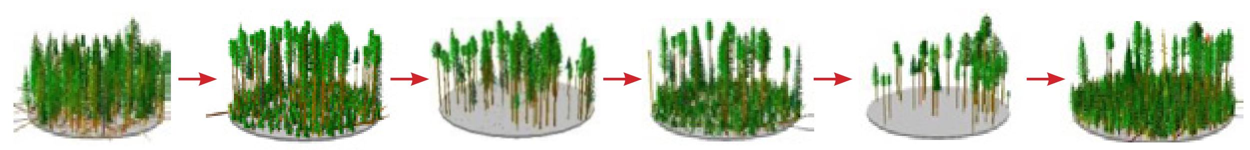
The open overstory will be dominated by large ponderosa pine (with a minor component of Douglas-fir and larch) having old-growth characteristics and providing sufficient overstory gaps to allow for adequate growth and development of the understory. The low-density understory (<300/ha) will have clumpy stocking also dominated by ponderosa pine and low levels of fine woody fuels (mostly removed).

Stand Pathway Narrative

The priority will be to maintain open stocking conditions, reduce associated ladder fuels, and thin the overstory to increase taper (and vigour) and resistance to bark beetles. This would be followed by **variable density thinning** while maintaining as much mature ponderosa pine as possible in the overstory and creating growing space for ponderosa pine (Py) in the understory.

FIGURE 15 *Building a stand management narrative and stand development pathway based on stand condition. Narrative based on current stand condition. Pictorial and stepwise descriptions clearly describe the intended interventions through early years and later decades.*

Year 0 | **Year 5** | **Year 6** | **Year 30** | **Year 31** | **Year 60 - 100**



Fd Lw (Py Pli)

Fully stocked at 48 m^2/ha BA with multiple stand layers occupied (mostly Fdi in the understory).

- Reduce overstory BA by 30% but increase % of Py.
- Thinning to reduce fire risk and start to increase light penetration into the understory.
- Follow with a reduction in understory fuels by cultural or prescribed fire, which will also help restore key Indigenous food plants.

- A second thinning combined with the creation of gaps for regeneration of trees over 25–30% of stand area.
- Followed closely by a second fuel reduction in understory, with cultural or prescribed fire, perhaps with pre-treatment.
- The thinning will increase the effective gap size by reducing shade from the side, allowing penetration of full sun for a portion of the day over much of the stand.

- Significant % of Py regeneration in gaps. More gaps created on another 30–35% of area.
- Variable density thinning to provide more space for Py, followed by fuel reduction with fire.
- A further cycle of thinning, gaps, and fuel treatments would then continue at age 90.

Fdi – interior Douglas-fir | Py – ponderosa pine
Lw – western larch | BA – basal area (m^2/ha)
Pli – lodgepole pine

There are three key components to a stand development pathway, as shown in the example above.

1. Objectives - to start with, describe both the landscape- and stand-level objectives driving the desired development pathway.
2. A narrative - a background narrative tells the "story" of the tactical management intent linked to both the objectives and the current conditions on the land base (at the stand and landscape level). If objectives tie into existing guidelines, standard operating procedures, or management regimes, this linkage should also be recognized.
3. The detailed stand development pathway - should provide a description of the interventions envisioned, the timing of the interventions, and the resulting stand conditions. Diagrams, photographs, or model forecasts showing what those conditions might look like are helpful, but a detailed description is the most critical feature.

To translate a stand development pathway into a silvicultural plan, the intentions of each intervention need to be translated into harvesting direction and stocking targets, as shown in Table 3 below. Because most of these pathways will rely heavily on assumptions about stand development, monitoring will be essential to ensure that the stand is developing as expected. To be clear, the stand development pathway informs the silvicultural plan.

TABLE 3 *Extending the stand development pathway into a silvicultural plan requires the formulation of harvesting direction and stocking targets*

Intervention	Retention Stocking			Regen. Stocking
	L1	L1 Vets	L2 and 3	L4
Year 5: Restoration thinning to reduce overstocking in L1 and L2 (7.5–30 cm dbh)	30 m^2/ha Preferred (80%) Py, Lw Acceptable Fd, Pl	4 m^2/ha Preferred (80%) Py, Lw Acceptable Any	Target 0 sph Max 500 sph Preferred Py Acceptable Lw, Fd, Pl	Target 0 sph Preferred Py, Lw
Year 10: Understory burn to reduce surface fuels	30 m^2/ha Preferred (80%) Py, Lw Acceptable Fd, Pl	4 m^2/ha Preferred Py, Lw Acceptable Any	Target 0 sph Max 500 sph Preferred Py Acceptable Lw, Fd, Pl	Target 0 sph Max 500 sph Preferred Py Acceptable Lw, Fd, Pl
Year 30: Group selection with thinning in the matrix followed by understory burn	Matrix: 70% of Area			
	20 m^2/ha Preferred Py, Lw Acceptable Fd, Pl	4 m^2/ha Preferred Py, Lw Acceptable Any	Target 0 sph Max 500 sph Preferred Py Acceptable Lw, Fd, Pl	Target 0 sph Max 500 sph
	Groups: 30% of Area			
		4 m^2/ha Preferred Py, Lw Acceptable Any		Target 1600 sph Min 1200 sph Max 3000 sph Preferred (80%) Py, Lw Acceptable Fd, Pl
Year 60: Group selection with thinning in the matrix followed by understory burn	Matrix: 40% of Area			
	20 m^2/ha Preferred Py, Lw Acceptable Fd, Pl	4 m^2/ha Preferred Py, Lw Acceptable Any	Target 0 sph Max 500 sph Preferred Py Acceptable Lw, Fd, Pl	Target 0 sph Max 500 sph
	Groups: 60% of Area			
		4 m^2/ha Preferred Py, Lw Acceptable Any	Target 1000 sph Min 800 sph Max 1600 sph Preferred (80%) Py, Lw Acceptable Fd, Pl	Target 1600 sph Min 1200 sph Max 3000 sph Preferred (80%) Py, Lw Acceptable Fd, Pl

4.2.3 A Checklist of Considerations for Building Stand Development Pathway Options

There are many considerations that lead one to choose a stand development pathway. To simplify the process, it is helpful to start with the structural considerations important to developing options to meet objectives. Once options are developed, another set of considerations, many of which are operational, will help work through the options to help choose the best one (see Figure 16 and Section 4.3, p. 46 – Evaluating the Chosen Stand Development Option).

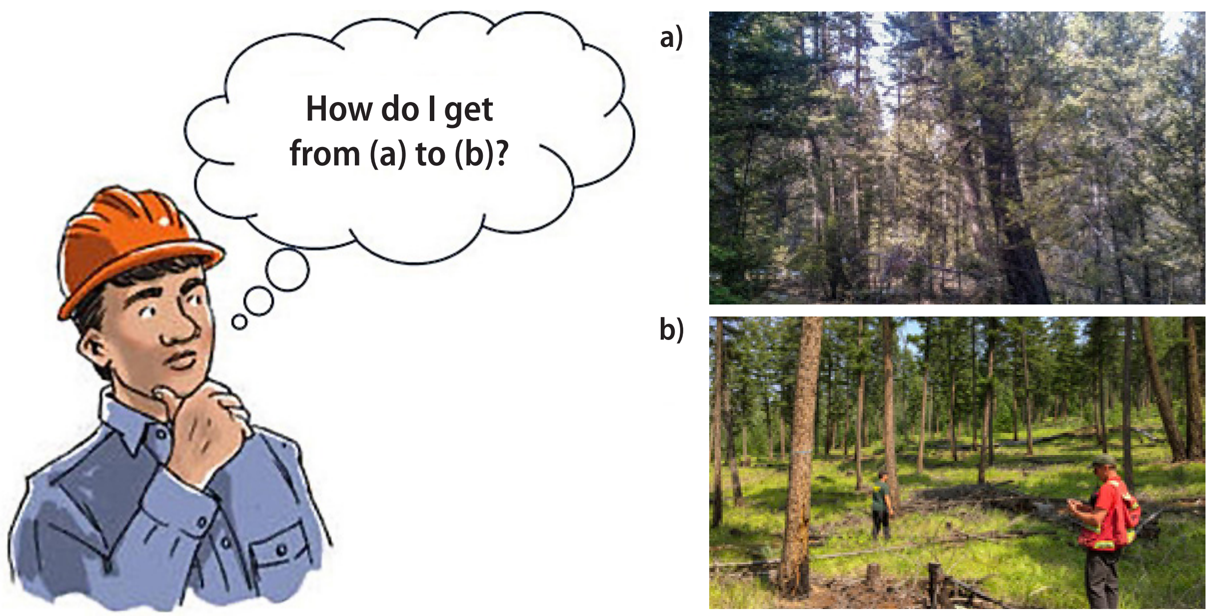


FIGURE 16 *Considering your stand management options: the stand development pathway from the current stand structure to another very different desired future condition may be somewhat long and complex, and it needs careful consideration of interventions, growth and development, and vulnerabilities or risks along the way. EP 1367. Image source: a) Ken Zielke (used with permission) and b) Forest Practices Board.*

When developing stand development pathway options, the forest professional needs to focus on the desired stand composition and structure and ecosystem features (desired future conditions)—why you want these elements, what you want (the exact nature of the stand elements and features), when you want them (the pathway timeline), and where (within the stand) you want them. This is when the forest professional should be thinking about interactions between various tree species and stand layers over time as well as site-level ecological processes and relationships. All these considerations need to be explored in the context of the objectives, the current stand and ecological conditions, the landscape context, and the potential for surprises from a changing climate.

✔		**Stand Development Pathway Checklist**
	1	Is stand regeneration desired?
	2	Is overstory retention desired? For the short term or the long term?
	3	What is the nature of the desired overstory retention? Form and function?
	4	Gaps in a retained stand matrix?
	5	What interventions will advance stand development?
	6	Flexibility to keep options open for different pathways, perhaps even unanticipated at the current time
	7	Will we meet the stand objectives?
	8	What are the growth and yield implications?
	9	Are the cumulative treatments financially feasible?

The answers to the questions provided in this checklist need to be considered together with one another and the stand conditions, site characteristics, and objectives. Each of these questions needs to be considered in the context of the desired future condition—the values in place, the objectives being pursued, the ecological conditions of the site, and the silvics of the species under management.

FIGURE 17 *Larch shelterwood system, southern interior British Columbia. Image source: Ken Zielke (used with permission).*

1. Is stand regeneration desired at some point?

In the old European traditional approaches, the focus for stand development pathways was often about creating the best conditions for regeneration. A good starting point in designing stand pathways still is first to consider if you are trying to promote regeneration at some point along the pathway timeline (Figures 17 and 18).

Determine:

- if relatively even regeneration is desired by clearing most of the stand at a single point in time, or is there a desire for regeneration to occur over relatively short cycles in smaller cleared gaps to create a mix of ages and sizes?
- the type of environment required to best promote regeneration and subsequent growth of the preferred species. Can the regeneration withstand an open environment, or do you need to provide shelter from excessive heat, drought, or frost damage?
- if there is established advanced regeneration that is viable and suitable to help attain the desired future condition.

The amount and type of shelter will depend on the silvical characteristics of the regeneration species, the type of ecosystem, and the orientation and general slope of the stand. Historically in British Columbia, a requirement for shelter was limited to the dry interior, but with newly recognized values and climate warming this concern may expand.

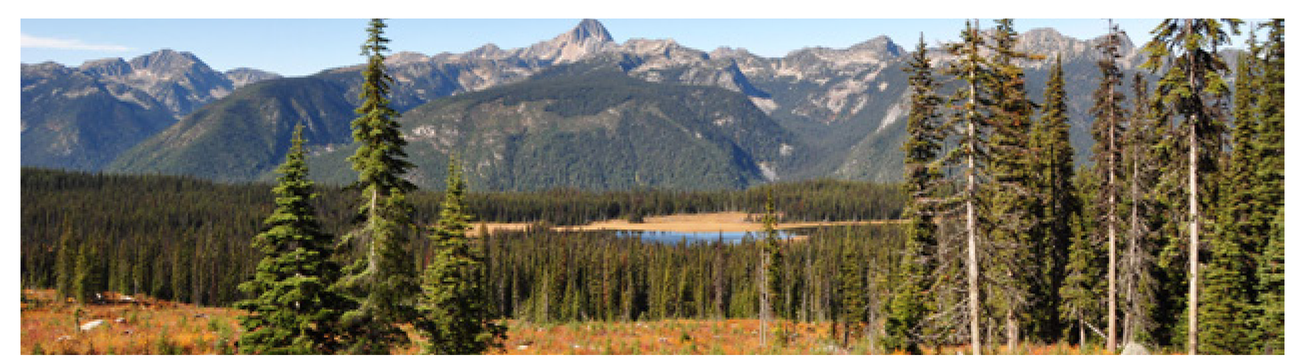


FIGURE 18 *Reforested cutblock at high elevations near Clearwater, B.C. 2011. Image source: Forest Practices Board.*

☐ 2. **Is some overstory retention desired? For the short term or the long term?**

Some portion of the original stand may be desired for retention to address an objective for a particular value over the short term, or functionally to assist in securing or sheltering regeneration. Consider the species and structural attributes that are most desirable in the retention and how long it should be held onsite.

Some questions to think about:

- Is the value of the retention for specific objectives relatively short term? For example, is it only to help establish adequate regeneration? If so, when and how should it be removed?
- Is the value of the retention for specific objectives achieved beyond the short term but not over the long term? Is it to allow new regeneration to achieve an adequate height to meet visual or hydrological objectives? Is it to achieve a moderate size most suitable for local First Nations cultural use or some other value?
- Is the value of the retention for specific objectives relatively long term? Is some amount of retention to remain for a long time to enrich the biodiversity of the developing stand with old forest habitat structures? Is a large tree size desired for specific local First Nations cultural values or some other value?
- Is there a desire to maintain continuous cover across a balance of age classes, whereby stand management continuously recruits trees from one class into another? Or is there a desire to keep the retention across some size classes sufficiently low to maintain semi-open conditions using interventions such as thinning and cultural and prescribed fire?

FIGURE 19 *Examples of dispersed retention (A), retention of intact groups (B), and a mixture of both (C). The evolution of retention for ecosystem restoration around Williams Lake in the IDF (D) has quite complex mixed retention rules: 10% unthinned patches in clumps of about 0.25 ha, retention of about 24 m²/ha in the matrix in a clumpy arrangement according to ICO method (individuals, clumps, and openings). Aerial photos from Google Earth such as this one can be instructive. (A, B, C) Image source: Ken Zielke (used with permission). (D) Image source: Google Earth, 2024 CNES/Airbus.*

☐ 3. **What is the nature of the overstory retention (if desired) – form and function?**

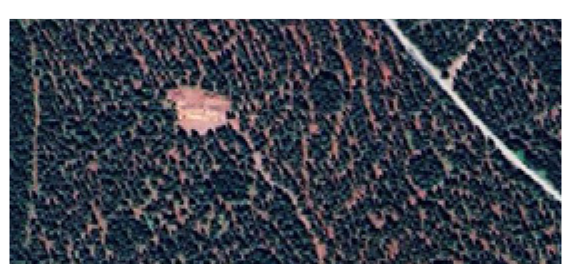
Are dispersed leave trees, intact groups, or both desired? Are dispersed individual trees desired or are intact groups of trees (patches of the original stand) desired (Figure 19), based on the mix of objectives, stand condition, and site features? Is either an option or are both desired? Are both desired at some point over time, just occurring at different time periods? For example, several commercial thinnings may be required to slowly increase stand windfirmness on selected dispersed leave trees, later allowing for regeneration cuts to increase available sunlight for the most desirable species while retaining some groups or individuals over the long term.

A

B

C

D



Pattern and composition of dispersed retention: If **dispersed** retention is desired, several considerations are necessary, including tree crown classes, vigour classes, species, and residual stocking in basal area (m²/ha), considering all the objectives. Observations and measurements in similar existing stands (managed or natural) may help with these determinations. Some local or regional research data may be available. Also, as regeneration is generally a goal at some point along the pathway, timely removal of some overstory trees will be required to open up growing space for the regeneration as it develops (Figures 20 and 21).

FIGURE 20 *(ABOVE) EP 1104.01 Uniform shelterwood in the sub-boreal spruce dry warm subzone (SBSdw) during second-entry thinning. Leave trees were chosen to provide quality seed for regeneration, shelter the naturally established regeneration from frost, and allow enough light for establishment and early growth. Image source: UBC Alex Fraser Research Forest.*

FIGURE 21 *(LEFT) The characteristics of dispersed leave trees will depend on management objectives and current stand conditions. But they will need to be windfirm, such as this large Douglas-fir that has developed with significant wind exposure over its life span. Also, if trees are intended to provide seed for regeneration, mature attributes desired in next stand should be present in the current leave trees. Image source: Ken Zielke (used with permission).*

FIGURE 22 *Planned retention will use the values and structure of the current stand to set out the size, pattern, and distribution of retention on the site. Image source: Bill Beese (used with permission).*

Pattern and composition of retained intact patches: If intact patches are a desired option (Figure 22), is the pattern or distribution of retained patches across the stand important? Does it matter if the patches are small, large, or shaped in a particular manner? How should these patches be distributed? Is the distance between patches and from the cutblock boundary important? How important is the pattern of intact retained patches in the next stand? If pattern is important, some patches may not have the optimal composition for the desired structure so you need to work with what is available on the site.

☐ **4. Is there an intent to create canopy openings in a retained stand matrix[4]?**

In some cases, an intervention is intended to create cleared openings within the **retained stand matrix**. The following will be important considerations in the design of openings:

FIGURE 23 *Small canopy openings in an unharvested matrix. To fit with the objectives, gaps are relatively small in all dimensions (0.2–0.4ha in area) and distributed throughout the stand. Image source: Jim Smith (used with permission).*

- Size of openings – There is a continuum of opening sizes that can be used from single-tree gaps to patches of several hectares. The choice will be driven in part by the objectives, other site factors such as natural disturbance regimes, and the silvics of the regeneration species. Height and density of the matrix overstory will influence choice of opening sizes for a number of reasons (Figure 23). If regeneration is desired, the quality and intensity of sunlight for regeneration and growth will be a consideration that may influence both initial opening size and location of future opening (if planned). Thinning in the matrix can increase the effective size of an opening as sunflecks are able to arrive into the opening angled through the trees in the matrix. The amount of shade cast by the retained matrix may be desirable or not. Windthrow concerns could also drive the size or width of the opening in the prevailing wind direction.
- Shape and orientation of opening – For some objectives and site/stand conditions, including prevailing wind loads, elongated canopy openings or directionally oriented strips can be advantageous (Figure 24). Orientation of openings relative to the south (highest sun angle) will help modify the influence of aspect if shelter for regeneration is the goal. North–south orientation increases sun exposure, and east–west orientation decreases exposure, but both are relative to aspect and the steepness of the slope.
- Quantity and distribution of canopy openings – These may be informed by objectives, natural disturbance regimes, stand condition, and site characteristics. Long-term goals for stand structure and age classes may require multiple harvesting interventions over time, which could influence decisions regarding the balance of openings and forested matrix and the distribution of openings at various points over time. Thus, timing of overstory removal to promote growth of the newly established tree species is a key consideration, as well as the silvics or autecology of the species that are being managed.

When gaps are harvested in a mature or old-growth retained matrix, the difference between the gaps and the matrix will be simple and obvious. However, in clumpy multi-cohort or multi-aged stands, the difference between the harvested gaps or **patch openings** and the matrix can be subtle. In either case, the retained stand matrix includes all portions of the stand that will not be cleared for regeneration. This does not preclude planning of thinning or other interventions within the matrix or portions of it.

A

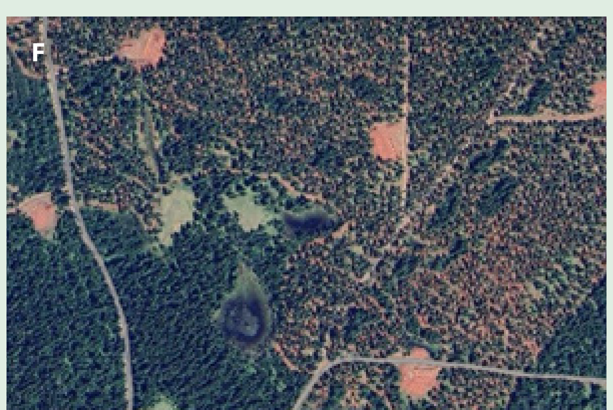
B

FIGURE 24 *Two examples of openings elongated as strips. (A) shows an initial strip intervention where the strips are oriented as waves to disrupt sightlines for hunters. (B) shows strip interventions being used with skyline cable systems over a long period of time in Austria, progressively advancing the strips into the wind to reduce the occurrence of freshly exposed edges to prevailing storms (and reduce windthrow). These types of uniform geometric patterns may not be desirable where visual objectives from distant viewpoints exist. Image source: (A) B.C. Ministry of Forests; (B) 2009 Google, 2010 Geoimage Austria, 2010 Tele Atlas.*

[4] The retained stand matrix relates to the rest of the forested stand where gaps will not be created.

EXAMPLE OF A MIX OF THINNING, GROUP RETENTION, AND GAPS

Williams Lake First Nation is working to implement ecosystem restoration and community protection in the dry-belt forests of the Interior Douglas-fir (IDF) biogeoclimatic zone within their traditional territory. They are thinning stands to approximately 24 m²/ha with a feller buncher (Photo A), including non-commercial understory trees (Photo B). Cut trees are removed with a grapple skidder (Photo C) to a landing for processing (Photos D, F). Retention of uncut groups (Photos E, F) of about 0.25 ha occupies 10–20% of the area. Thinning results in clumps, individual trees, and gaps (Photo G) to retain the historic clumpy arrangement of the IDF overstory and viable regeneration clumps while removing suppressed understory and intermediate trees. The thinning is followed by either cultural or prescribed fire or by surface fuel removal. Objectives include low-density regeneration, returning the overstory to a resilient condition, and providing an open understory for the rejuvenation of culturally important plants. This approach ensures that hiding cover and visual screening are available for wildlife, resilience is improved, fire risks are reduced, and growing space is available.



(A, C, D, E, G) Image source: Ken Day (used with permission).

(B) Image source: Williams Lake First Nation.

(F) Image source: Google Earth, 2025 CNES/Airbus.

☐ **5. What type of management interventions are envisioned to advance stand development?**

Regeneration Cutting

An important step is establishing and tending regeneration, whether across the whole stand, or in canopy openings distributed across the stand either at present or over time. Regeneration cuttings are intended to provide a regeneration environment (Figure 25). They could be accomplished by clearfelling or by thinning, depending upon the required regeneration environment and the desired future condition. After these cuttings, regeneration may be by planting, natural regeneration, or a combination of both. These interventions provide an opportunity to change the species composition if required by the stand pathway The seedling environment will be modified by retention, and it is important to match the silvics of the regenerated species to the environment they will occupy.

TERMINOLOGY: REGENERATION

Regeneration: The process and actions of establishing young trees on an area after a disturbance, such as removal of overstory trees. Regeneration is an important element of a stand development pathway. Whether by natural regeneration, direct seeding, planting, or a combination of any or all approaches, regeneration by the desired species at appropriate densities is critical to achieving the desired future condition. Regeneration will consist of a wide variety of species, including culturally important shrubs and forbs, conifers for timber, important forage and habitat species, and invasive species. Competition between regenerating individuals begins early, and the desired future condition should guide understanding of which species are important to the objectives, and which are deleterious.

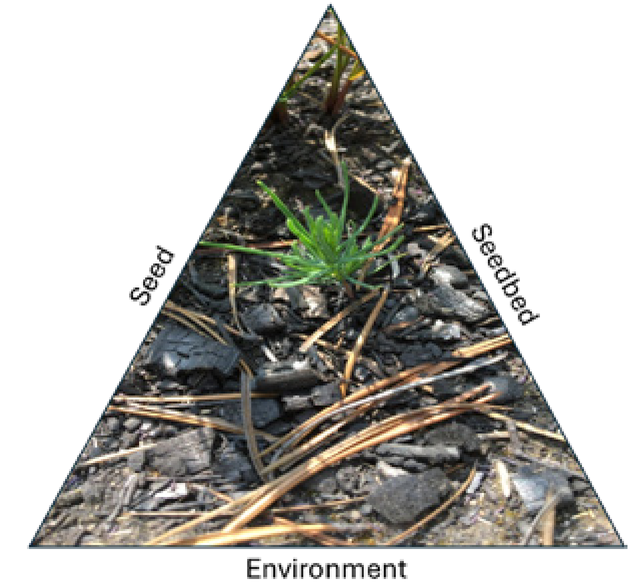


FIGURE 25 *The regeneration triangle concept communicates that seed, seedbed, and environmental conditions must all be present and appropriate for effective regeneration. Regeneration in partial-cutting silvicultural systems relies heavily on seed from retained trees falling on an appropriate seedbed in an environment conducive to germination, survival, and growth. Image source: Ken Day (used with permission).*

Regeneration cuttings are planned disturbances that release growing space from the overstory by cutting (see above) and provide a seed source, seedlings, or stump sprouts to repopulate the growing space (Figure 25). If the regeneration cutting creates an environment that is mismatched with the silvics of the desired regeneration species, a regeneration failure could result, or unexpected species may establish.

As competition between the new trees proceeds, the silvical characteristics interact with the environment in complex ways, resulting in species mixtures and arrangements that could depart from the desired pathway. Consider the potential for high establishment densities to help address this issue. For example, if we establish an intimate mixture of lodgepole pine and interior spruce at 1800 stems/ha, the expected result may be 900 stems/ha of lodgepole pine overtopping 900 stems/ha of interior spruce in what Oliver and Larson (1996) call a “single cohort stratified

mixture" (Figure 26). In some ecosystems this might be an effective strategy (e.g., to limit spruce terminal weevil), but for timber values we should expect that it could result in branchy, open-grown low-quality lodgepole pine over a slow-growing spruce understory. Further intervention(s) such as thinning may be necessary to stay on the stand development pathway. As well, longer rotations may be required to grow the understory species to target sizes and quality attributes.

FIGURE 26 *An intimate mixture of western larch, lodgepole pine, spruce, and Douglas-fir in the SBSmm near Mahood Lake. The rapid early growth of larch and pine results in a stratified mixture, which will result in the pine and larch growing with poor form. Image source: Ken Day (used with permission).*

A WORD ABOUT MIXED-SPECIES STANDS

Single-species monocultures are a mechanistic approach to forest management aimed at efficient timber production. Over the last decade, practices have moved towards establishing mixtures to maintain an aspect of stand-level biodiversity. However, administrative rules that seek to establish mixtures without paying attention to silvics and stand dynamics will take stands in unforeseen directions.

Consider:

Establishing single-species cohorts within ecologically appropriate site conditions; for example, put the spruce on the fresh and wet ground, the lodgepole pine on the mesic ground, and the Douglas-fir on the upper slopes and dry ground. This approach provides a species mixture at the stand level but single-species cohorts at the strata level.

Or

Establishing multi-species cohorts where the species have similar early growth and environmental tolerances, such as Douglas-fir and spruce, redcedar and spruce, lodgepole pine and aspen, or Douglas-fir and white pine on the coast.

And

Plan for an intervention to brush, space, or thin the mixed stand as necessary to fit with natural stand dynamics and stand-level objectives.

FIGURE 27 *Managing mixed-species stands can help increase stand resiliency, mitigate biotic and abiotic risks, and enhance within-stand biodiversity and ecosystem functions such as nutrient cycling. Pictured: Post-treatment mix of about 300 stems per hectare (sph) of deciduous trees (aspen, cottonwood, and birch) in a 35-year-old stand manually brushed for conifer release of spruce (1400 sph). Image source: Aleza Lake Research Forest Society.*

Brushing and Spacing

Brushing and **spacing** are powerful tools to nudge stands onto a new pathway or to stay on the current pathway to meet future objectives. This is accomplished by reducing stand density and favouring specific species and quality of trees (Figure 27). Brushing and spacing are conducted in juvenile stands too young or too small to provide commercial products. Both reduce inter-tree competition, with brushing focussing on species that are less desirable in the future stand, while spacing removes competition among individuals of the desired species. Sometimes both brushing and spacing occur simultaneously and may just be called "spacing."

Thinning

Thinning is normally conducted in stands with trees large enough to provide commercial benefits. It might only be intended to reduce stand density, thereby focussing growth on selected trees and tree species (i.e., commercial thinning). However, it may also be prescribed to remove unhealthy or non-vigorous stems and create growing space for development of important understory plants and plant communities (i.e., restoration thinning). Thinning could also be preparatory to a regeneration event, stabilizing the overstory and opening up regeneration space (i.e., a preparatory cut or a seed cut) or removing the overstory from amongst established regeneration (i.e., a **removal cut**). Some thinning interventions may have several or all of these stand structure goals. Where a dynamic mix of species, age classes, and other specific structural objectives are desired over a long time, multiple thinning interventions may be used with a relatively short cutting cycle between them.

In the traditional approach to thinning, silviculturists sought to keep growing space uniformly occupied by the crop trees. More recently, silviculturists are finding benefits from less rigid application of spacing rules and indeed moving the condition of the stand to clumpy and gappy arrangements in favour of stand-level diversity (Churchill et al 2016; Palik and D'Amato 2024).

TERMINOLOGY: THINNING

Brushing, Spacing, and Thinning: Density management interventions are important cut phases in any silvicultural system. In ecological terms, these activities apply a disturbance to remove some individuals while leaving others to take up the newly available growing space. Preference is expressed by leaving individuals with desired characteristics of species, distribution, and quality.

Brushing: Is done shortly after regeneration (+/- 10 yr) to adjust the species composition of the young stand. May be in conjunction with spacing.

Spacing (or pre-commercial thinning): Is done shortly after regeneration (+/- 15 yr) to favour the growth of desirable individuals, as an investment in the quality and growth of the stand (Ashton and Kelty 2018).

Thinning (or commercial thinning): The removal of individual trees from a stand to maintain or improve the health of remaining trees by providing more space and resources to grow (e.g., sunlight, water, and nutrients). The choice of trees to be retained and the resulting stand density or structure will be based on the management objectives for the stand (Ashton and Kelty 2018). Commercial thinning yields a commercial product from the thinning.

Variable density thinning: A commercial entry that varies the intensity of removal across the stand, to create gaps, thinned areas, and unthinned areas. The purpose is to accelerate the development of complexity and heterogeneity, including the regeneration of new cohorts in gaps (Palik and D'Amato 2024).

Complex thinning prescriptions to move a stand along its stand development pathway will need careful planning and layout. It will be helpful to have more detailed stand data before making key prescriptive decisions and to clearly communicate intentions (e.g., by tree marking) to ensure proper execution. Discussions between forest professionals, planners, layout crews, and logging contractors will be helpful at this stage. See the Implementation subsection for more information on considerations and criteria to help with these activities (p. 65).

Other Stand Management Interventions

Other tools can be used, beyond thinning, to change stand development pathways or move the stand along on its current pathway. Cultural and prescribed burning can be very powerful to initiate regeneration or remove unwanted understory stocking of trees and to encourage traditionally important species that might help address specific objectives, such as traditional food resources for local First Nations, species-specific habitats, or biodiversity. Note that fire exclusion has also excluded important plant communities. If a balance of younger trees and open area with exposed sun for traditional-use plants is desired, prescribed fire as an intervention will need to be carefully designed and implemented.

Fertilization is an opportunity to temporarily increase site nutrient availability and derive a resulting increase in volume growth. Timing fertilization after thinning ensures that the benefit accrues to crop trees and the understory beneath the crop trees. Growth effects of fertilization taper off at around 10 years.

Some of these other stand management interventions may need to be closely timed with other interventions such as thinning and regeneration felling. For example, **cultural or prescribed fire** usually cannot be applied until fuel reduction treatments have been undertaken, often involving thinning, spacing, and pruning treatments to modify fire behaviour. Some of these other interventions may be applied because of previous interventions. For example, some topping or top pruning of leave trees on the edges of retained patches may be needed to increase individual tree windfirmness.

☐ **6. Is a degree of flexibility desired to keep options open for the use of different pathways, perhaps even unanticipated at the current time?**

Climate change and its influence on weather extremes, wildfire management, and insect infestations may completely change the stand of interest, the landscape context around it, and possibly the management objectives associated with it. The potential for these sudden and unpredictable changes may prompt planners to initially design stand pathways to maintain some options over time, providing more flexibility to deal with surprise events when they occur.

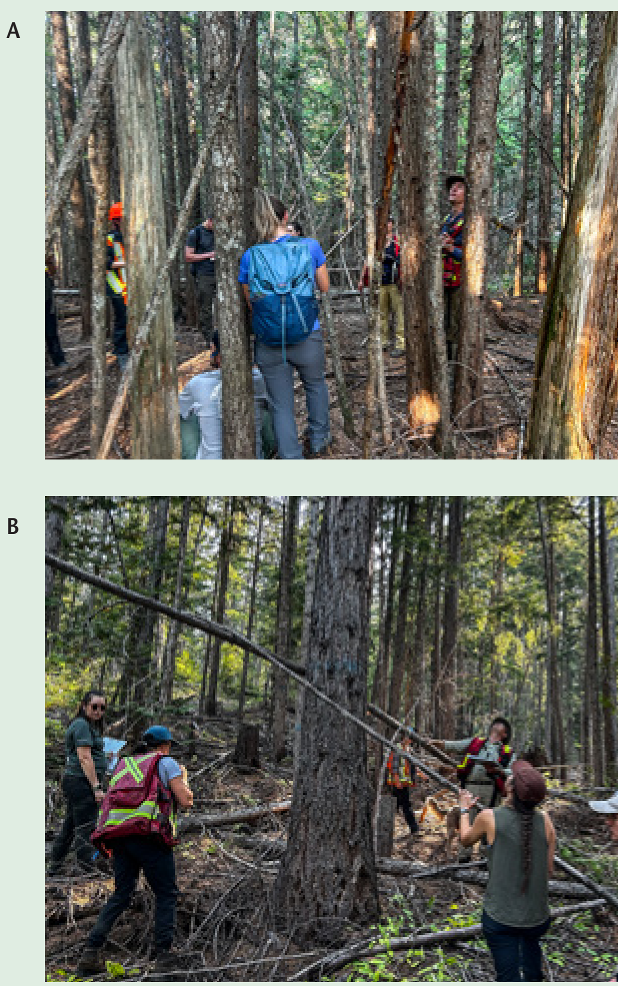
To help deal with uncertainty, the preferred option for a stand pathway does not need to be precisely determined over an entire rotation period upfront. It may be better to focus on improving the stand over the next 20– 30 years, to put it in a condition that will allow more flexibility for management over the long term. In 30 years, values and objectives themselves may change, but acting now to provide a range of opportunities for future forest professionals will be helpful. The Climate Change Species Selection Tool may be a useful resource. See Appendix 2.

KEEPING OPTIONS OPEN

A forester in the West Kootenays had some challenging stand types on his relatively small area-based tenure. The ecological conditions indicated a warm productive site. The stand condition was mid-seral to mature, healthy, and fully stocked with 50–60 percent of the stocking in a dense mid-story of marginally merchantable and slow-growing hemlock – see image (A).

The overstory was a mix of larger Douglas-fir, spruce, western larch, and white pine. The proximity to town and the recreational use of the roads in the area prompted a desire for some retention in the stand for visual objectives. Timber management objectives showed a preference for Douglas-fir and western larch on the site, but that would require open conditions. The forester also wanted to reduce the hemlock stocking to reduce ladder fuels for wildfire. An unusual, once-in-50-year market for small hemlock sawlogs provided an incentive to push this stand along on its pathway by thinning out most of the hemlock. With an overstory still providing close to full stocking, options remain open for choosing a silvicultural system option in the next couple of decades together with another harvesting entry – see image (B).

A



B

(A, B) Image source: Ken Zielke (used with permission).

☐ **7. Objectives check – Are the stand objectives still being met?**

At this point, the forest professional should check to ensure that the favoured pathway, or pathways, align with the objectives for the values present both at the landscape and stand level. The forest professional should also consider the current stand conditions, the characteristics and dynamics of the ecosystem, the influence of climate change, and the silvical characteristics of the tree species (both present and future). Any pathway not aligned with those key factors should not be considered a viable option.

The forest professional should consider the integration of landscape-level objectives with the stand-level realities using the following questions:

- How likely is it to attain the landscape-level goals using stand-level practices described for the stand development pathway within the desired timeframe—do any of the practices and desired timeframes need to be altered?
- If all the stands in the landscape are treated the same way through time, will the landscape-level goals be attained?
- Do the planned interventions create risks to values and objectives that need to be mitigated?

☐ **8. What is the anticipated outcome in terms of growth and yield?**

When the stand development pathway is developed, it will be important to model the various stand structures created by the interventions and understand the growth and yield implications of the intended post-intervention stand composition and structure. A variety of stand models is available in British Columbia but, clearly, forest professionals will need improved access to models and model interfaces to understand and account for the impacts of the foregoing process. Stand modelling will help forest professionals make decisions upfront, particularly where timber is a primary objective. As well, it will help build realistic assumptions into timber supply forecasts for the management unit.

Harvester working to commercially thin a spruce stand near Hixon, B.C. Image source: Aleza Lake Research Forest Society.

☐ **9. Will the costs of the interventions be covered by the anticipated revenue streams?**

Some stand interventions will result in a positive financial outcome and others will be cost-neutral or need financial support. Forest professionals need to provide a rationale for the stand development pathway that demonstrates that the approach will achieve the objectives at justifiable cost. Are the anticipated costs supportable by the revenues? Do the returns on the investments justify the costs?

4.3 EVALUATING STAND DEVELOPMENT PATHWAY OPTIONS

There may be several stand development pathway options to get to the desired future stand condition. Building a preferred stand development pathway is not usually a linear process, although it may appear as such here. Ensuring the best stand development pathway becomes something forest professionals are often doing in their heads as they consider what opportunities are available to them. Sometimes, for more complex stands and decisions, completing a more formal exploration and analysis is useful, particularly if others need to be convinced that the best option has been chosen.

4.3.1 Exploration of Available Options

Evaluating stand development pathway options is not a simple or easy process. Yet, there are key considerations that need to be included in any decision-making process. These considerations may be similar for a set of common stands in a landscape. Essentially, a forest professional needs to envision implementation of the stand development pathway over time. More detail on these considerations is found in Part 5 *Best Management Practices for Implementing Silvicultural Systems.*

Examining a large paper birch as a potential leave tree for retention or biodiversity objectives. Image source: UBC Alex Fraser Research Forest.

Mix of single-tree (Douglas-fir) and group retention in a winter sub-boreal logging operation. Image source: Aleza Lake Research Forest Society.

Consider the Principles of Successful Silvicultural Planning

Checklist - Based on the principles of successful silvicultural planning (Section 4.2.1), does the proposed silvicultural option consider the following questions:

- Is the desired future condition established in higher-level planning? Does it consider an understanding of First Nations and other values, the condition of those values, and the current goals and objectives set for them?
- Are the desired stand conditions well defined (current, future, and anticipated at each intervention) including trees, snags, understory, forest floor, dead wood, and habitat features?
- Are the risks, including forest health risks, site limiting factors, and opportunities to mitigate those risks well-considered?
- Do planned interventions align with the silvics and autecology of all the species (overstory and understory)?
- Will the planned interventions make the desired future stand better than the present, relative to the objectives?

Consider Existing Information or Modelling Results for Similar Stands with Similar Development Pathways

Explore similar stands and past treatments with other forest professionals in your area, especially if they have tried similar interventions. Explore these stands carefully on the ground, if possible, at different development phases since the last intervention. Review existing data for these stands if available, and/or collect some yourself. For example, there may have been good data collected before the last intervention, but no measurements since.

Explore the literature to see if you can find similar approaches to stand interventions and development pathways in a similar context in other places outside of your area. It may be helpful to discuss the results and the stand itself with the author or other experts.

Available stand development models can also be useful to project the results of interventions over time and examine the impacts on harvest yield over time. Always be very aware of the assumptions made to provide results down the line. No model is perfect, assumptions will be necessary, but models can help provide useful insights into the projected stand development pathway and inputs to the forest estate plan.

Consider Feasibility

Feasibility should be considered in the context of the stand objectives. Many of the interventions in the stand development pathway will occur at some point in the future when costs may be different. However, costs and logistics should receive some consideration upfront in the development of the pathway. (For more information see Section 5.4.1, *Financial Analysis*, p. 101.)

When envisioning a stand development pathway, consider which harvest systems and equipment are both suitable and available for interventions that include some tree harvesting or removal. For future interventions, new equipment may emerge to access the future timber supply, but forest professionals need to be realistic. It may be possible to encourage local contractors to purchase some new equipment, but between the capital costs and the learning curve to optimize its use, they will need to be confident there is enough timber available over time to justify its purchase.

The availability of harvest equipment and expertise is also a consideration for other types of interventions, such as cultural or prescribed fire treatments. There may be a learning curve locally and an economy of scale for application of such interventions. See *Choosing Contractors and Logging Systems* (section 5.4.4, p. 108). Ensure that the methods selected for interventions provide a feasible solution.

Consider Hazards and Risks

What are the **hazards** and potential risks for the various intervention options? What are the hazards and **risks** of no intervention? Are there ways to manage those risks?

Hazards are intrinsic stand or site characteristics that increase the vulnerability of a specific stand in a specific location to threats from biotic or abiotic damaging agents. Hazards relate to the likelihood of a threat becoming an impact, but it is also influenced by how the stand is managed with harvesting and other interventions and the timing of these interventions.

Risks are a combination of the likelihood of an impact and consequences of that impact. Hazards and risks can be broadly classified as abiotic and biotic, but they are not mutually exclusive. For example, some insect (biotic) outbreaks can produce extensive stand mortality and subsequently create a fire (abiotic) hazard. Conversely, wind damage may trigger insect outbreaks in fallen and dead timber. Both abiotic and biotic risks may be altered or amplified by external influences such as climate change and non-intervention–related disturbances (e.g., landslides, anthropogenic).

Common abiotic risks include fire, heat damage, drought stress, frost damage, wind, snow, and ice damage. These can exist independently or in conjunction with other abiotic or biotic risks such as insects and disease. Interventions need to be evaluated in the context of risks that may negatively affect the progression of the planned stand development pathway.

Climate change is a significant factor that needs to be accounted for in any treatment through a vulnerability assessment and mitigation process. This process needs to be part of a larger framework to identify all hazards and risks coupled with proposed actions required to eliminate or at least reduce the associated impacts. Follow-up activities may become important to stay on track. Examples include fuel reduction if a harvesting intervention has unacceptably increased the fire hazard, or an annual inspection of stands deemed at a moderate or higher risk of windthrow to ensure that damage can be mitigated before bark beetles infest the stand.

Forest professionals designing stand development pathways should understand and apply the best available tools, protocols, checklists, guides, and handbooks for these hazards and risks, designed based on the latest science and applicable in the local area. An example of these types of references (for Coastal windthrow hazards and risks) is the *2022 Windthrow Management Manual for Coastal British Columbia* (Zielke et al. 2022).

Other Considerations

These will vary by tenure type, the legislation in place, and other variable factors. Consider for example the administrative ability to return at the anticipated intervention intervals to implement the plan. Not all tenure types on Crown land may allow for this. Road tenures and road access limitations or rehabilitation may also challenge future entries.

4.4 DESCRIBING A SILVICULTURAL SYSTEM

Preceding sections of this Handbook introduced the concept of stand development pathways and interventions, which are a silvicultural plan to move from the current condition to a desired future condition. Forest professionals first develop a plan of treatments to fit the circumstances (the stand development pathway or SDP) and then describe that plan with a name. Applying a name is the final step in this planning process but is nevertheless an important one.

Describing a silvicultural system is a vital step because the name is a critical "shorthand" of terms that clearly describes and communicates the silvicultural intentions and sequence of actions in the stand development pathway towards a desired future stand condition. It needs to communicate silvicultural intent accurately and consistently not only for present-day forest practitioners and publics, but also people in the future who will be managing the same land area.

Partial harvesting in a montane West Kootenay mixed conifer stand to promote growth and release of high-value cedar pole trees. Image source: Rainer Muenter (used with permission).

The name of a silvicultural system also needs to meet the professional forestry practice requirements of being clear, correct, and complete. Descriptions must therefore follow a consistent process that is transparent, has a clear rationale, and is defensible. Simplicity and consistency in naming will help practitioners to clearly understand each other and express their intentions.

Key elements of silvicultural system nomenclature are the:

- basic character of retained tree age and size classes and, if applicable, spatial arrangement of age or size mixes;
- distribution and pattern of proposed tree removals and expected regeneration;
- distribution and pattern[5] of proposed retained forest structure (dispersed, group, patch, mixed); and
- rationale and intent for the proposed **stand intervention**.

In this Handbook, the current silvicultural systems terminology draws from historical origins elsewhere in North America and Europe (although **variable retention** and the **retention system** originated in British Columbia). As greater experience is gained in managing diverse silvicultural systems and objectives in British Columbia, terminology is expected to evolve to incorporate more forest management approaches, especially First Nations approaches, ecosystem restoration methods, and unique British Columbia ecosystem management objectives. Terminology aside, the central elements of any silvicultural system and plan are defined by its stand development pathway and how the proposed interventions affect the ecosystem to be treated.

[5] Pattern in this sense describes the visual design or configuration of the retention, but not how well it covers the entire harvested area.

4.4.1 Describing the Silvicultural System

FIRST DESCRIPTIVE ELEMENT:
Define the Basic Character of Cohorts and Retention of Stand Influence

Consider the stand development pathway already carefully defined. Over the entire stand development pathway, broadly consider the following defining characteristics of silvicultural systems:

A. **Multi-cohort** – Is the desired future condition a multi-cohort stand created over at least three interventions resulting in a mix of at least three cohorts—regeneration, young and/or mid-aged, and mature/old components?

Selection System

B. **Two cohort** – Is the desired future condition formed by the creation of two cohorts, widely separated in time (> 20% of the rotation or one age class)?

Irregular System

C. **Single cohort** – Is the desired future condition a single cohort arising from one of potentially several interventions?

Even-aged System

a. **Clearcut** – Is the desired future condition a single cohort, where establishment is by seed on site (natural regeneration) or by planting?

Clearcut System

b. **Coppice** – Is the desired future condition a single cohort, where establishment will be by sprouting from existing root systems and/or stumps, after an intervention?

Coppice System

c. **Shelter** – Is the desired future condition a single cohort, where regeneration establishment is challenged by environmental conditions, such that shelter is required?

Shelterwood System

d. **Seed** – Is the desired future condition a single cohort, where establishment is challenged by seed availability, such that mature trees are required to provide seed?

Seed Tree System

D. **Retention** – Is the desired future condition a complex stand for ecological objectives where permanently[6] retained individuals, groups, or patches, or a combination thereof, are distributed[7] such that their influence[8] affects more than half of the harvest area? (See sidebar on p. 58.)

Retention System

[6] Permanently retained trees – in this context means for the entire rotation. Beyond one rotation we are into another planning period.

[7] Distribution describes how well the pattern of retention is distributed over the harvested area in a cutblock, which will become a stand over time.

[8] Forest influence is defined as the total area of the intervention that is within one tree-length from the base of a tree or group of trees, whether the tree or group of trees is inside or outside the cutblock.

SECOND DESCRIPTIVE ELEMENT:
Add a Prefix to Make Distinctions for Distribution and Pattern of Cutting

Again, considering the stand development pathway, describe your intentions for the pattern and distribution of the intervention to achieve the desired future condition. For descriptions of the following systems beyond the distribution and pattern of cutting, see Table 1 on p. 7.

A. Group or Strip – does the intervention create gaps that are sufficiently large and discrete to be stratified and tracked spatially (see sidebar on p. 52)?

Group or Strip Selection
Group or Strip Shelterwood
Group Irregular Shelterwood
Group Seed Tree
Group Retention
Patch Cut

B. Uniform or Single-Tree – does the intervention create indistinct gaps that are not of sufficient size to stratify or track spatially?

Single-Tree Selection
Uniform Shelterwood
Uniform Seed Tree
Uniform Irregular Shelterwood
Dispersed Retention

Cutting to create open area within a stand sets up a complex of ecological conditions. These stand-level choices are sensitive to the ecosystem (i.e., subzone variant and site series), site, slope and aspect, canopy height, and species autecology, and are therefore judged site-specifically. Ecologically, stand interventions that implement harvesting using harvested groups or patches create a spectrum of conditions between open and closed forest.

Once opened, the surrounding trees extend their roots and branches into the created gap, group ,or patch. Airflow, sunlight, temperature, humidity, precipitation, and seedfall are all increasingly influenced as you move into more open space (from a gap to a group to a patch), varying the environmental conditions and favouring species with ecological tolerances suited to the various niches created.

There is a myriad of ecological and microclimatic interactions between the trees and vegetation from a gap, group, or patch edge moving into the adjacent stand. While stratification and mapping are administratively necessary, it is important to remember that the boundary is an ecotone where forest influence wanes and more open conditions predominate. Sometimes this ecotone will require special management considerations.

In areas where stands are thinned more uniformly (i.e., without gaps or groups), the retained overstory takes up the released growing space quite rapidly, and the ecological changes are greatly moderated compared to the situation where cutting creates gaps, groups, or patches of open area.

CONSIDERING DIFFERENCES IN GROUPED VS. UNIFORM CUTTING

In forest ecology and silviculture, professionals sometimes struggle with the definitions of what constitutes a “gap,” “group,” or “patch” opening in the forest, whether it is created by natural processes or by tree removals via harvesting. Administratively, forest professionals need to make a choice whether to control harvesting by area (e.g., group shelterwood) or by density (e.g., uniform shelterwood).

(ABOVE) A group shelterwood in montane forests of Austria. Image source: Ken Zielke (used with permission).

Cutting can create open areas of various sizes within a stand, changing the proportion of edge influence on the harvested area. (Figure 28)

- **A gap** in the domination of growing space by the overstory is interrupted by cutting, allowing enough growing space for a clump of regeneration to occur. Gaps are relatively small and not more than a tree-length across. Gaps are normally unmappable operationally.
- **A group opening** has a maximum width of two mature tree-lengths across the open area (Ashton and Kelty 2018); groups are large enough to be mappable operationally.
- **A patch opening** has a width greater than two mature tree-heights across the open area (Ashton and Kelty 2018), but a harvested patch has more than 50% of the area within a tree-length of an edge (Keenan and Kimmins 1993).
- **A clearcut** has a width greater than two mature tree-heights and less than 50% of the area is within a tree-length of an edge.

FIGURE 28 *Conceptual differentiation of opening size based on proximity to an unharvested edge helps to understand the ecological conditions created by cutting (following Keenan and Kimmins 1993). Estimating a mature canopy height (30 m in this example) allows one to estimate the area of an opening that will create the desired ecological conditions. Dark green represents uncut forest, the mid-shade of green represents the cut area under the influence of an edge, and light green represents the open conditions outside the influence of an edge.*

THIRD DESCRIPTIVE ELEMENT:
Add a Suffix to Make Distinctions for Distribution and Pattern of Reserves or Retention

Based on the stand development pathway, describe your intentions for the pattern and distribution of long-term retention you intend to leave to achieve the desired future condition.

A. Retaining some pattern of mappable intact parts of the original stand.[9]

With Group Reserves
With Group Retention
With Patch Retention

B. Retaining scattered individual or small clumps[10] of trees (several).

With Dispersed Reserves
With Dispersed Retention

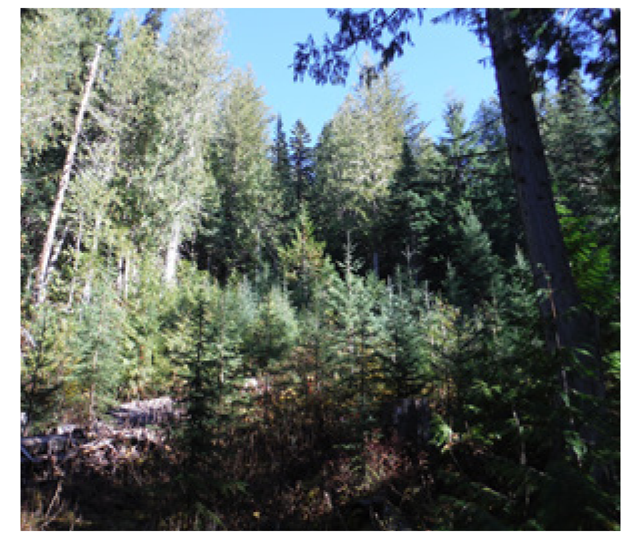
C. Retaining a mixture of group and dispersed individual trees.

With Mixed Reserves
With Mixed Retention

It is worth noting that there are many different ways these terms can be used, and their creative use is important to the development of the ecosystems and values we manage. For example, single-tree selection with group retention, where the matrix of the stand is thinned to individuals, clumps, and openings (the ICO method as described by Churchill et al. 2014). While clear communication of details is important in the silvicultural plan, it is beyond the rational development of a naming system to encompass all the potential systems that creative people can conceive and implement.

[9] Typically, intact groups approximate a portion of the original stand, with an intact overstory, understory, and environment (at least in the middle of the group). To meet these criteria and be operationally mappable, they are typically at least 0.25 hectares in area and are often larger.

[10] Clumps of individual trees are small enough; they do not approximate a "group" and are typically only three to four trees growing relatively closely together.



WHAT IS THE DIFFERENCE BETWEEN RESERVES AND RETENTION?

Both *reserves* and *retention* refer to intact portions of the pre-harvest stand or individual trees maintained on a cutblock post-harvesting.

Reserves – are required by regulation (e.g., wildlife tree reserves, riparian management areas) or practice standards (e.g., dispersed reserves or large veteran trees). Legal reserves are generally intended to be long term.

Retention – is left for specific objectives, most often conservation of biodiversity, and can be left for varying lengths of time, but is often long term.

The patterns of retention or reserves can be described as *dispersed, group,* or *patch.*

Dispersed – refers to scattered individual trees or small clumps of several trees.

Group – intact portions of the pre-harvest stand up to and including two mature tree-lengths in width.

Patch – intact portions of the pre-harvest stand more than two tree-lengths in width.

(See Figure 28 and p. 52 for further detail.)

FIGURE 29 *(TOP) Single-tree selection treatment with dispersed leave trees, Summit Lake, B.C., SBSmk subzone EP 1162. Image source: Aleza Lake Research Forest Society.*

FIGURE 30 *(MIDDLE) Regeneration in 0.24-ha group selection operation, Minnow Creek, Robson Valley, B.C. EP 119.03. Image source: Aleza Lake Research Forest Society.*

FIGURE 31 *(BOTTOM) Thinning in single-tree selection in Dry Interior Douglas-fir ecosystem (IDFxm) EP 903. Image source: UBC Alex Fraser Research Forest.*

Fuel reduction thinning in the ICHdw at the Slocan Community Forest. Image source: UBC Alex Fraser Research Forest.

FOURTH DESCRIPTIVE ELEMENT:
Describe the Phase of the Intervention Currently Being Planned

Many stand development pathways will require multiple interventions to move from the current condition to the desired future condition. An activity or phase describes the planned intervention in the context of the stated silvicultural system. Some interventions are part of the regeneration/revegetation process, but others are more about managing the growth and development of the vegetation community.

Examples include:

Spacing (or pre-commercial thinning) is done shortly after regeneration (+/-15 yr) to favour the growth of desirable individuals, as an investment in the quality and growth of the stand (Ashton and Kelty 2018).

Thinning (or commercial thinning) is the removal of individual trees from a stand to maintain or improve the health of remaining trees by providing more space and resources to grow (e.g., sunlight, water, and nutrients). Commercial thinning yields a commercial product from the thinning. The choice of trees to be retained and the resulting stand density or structure will be based on the management objectives for the stand (Ashton and Kelty 2018).

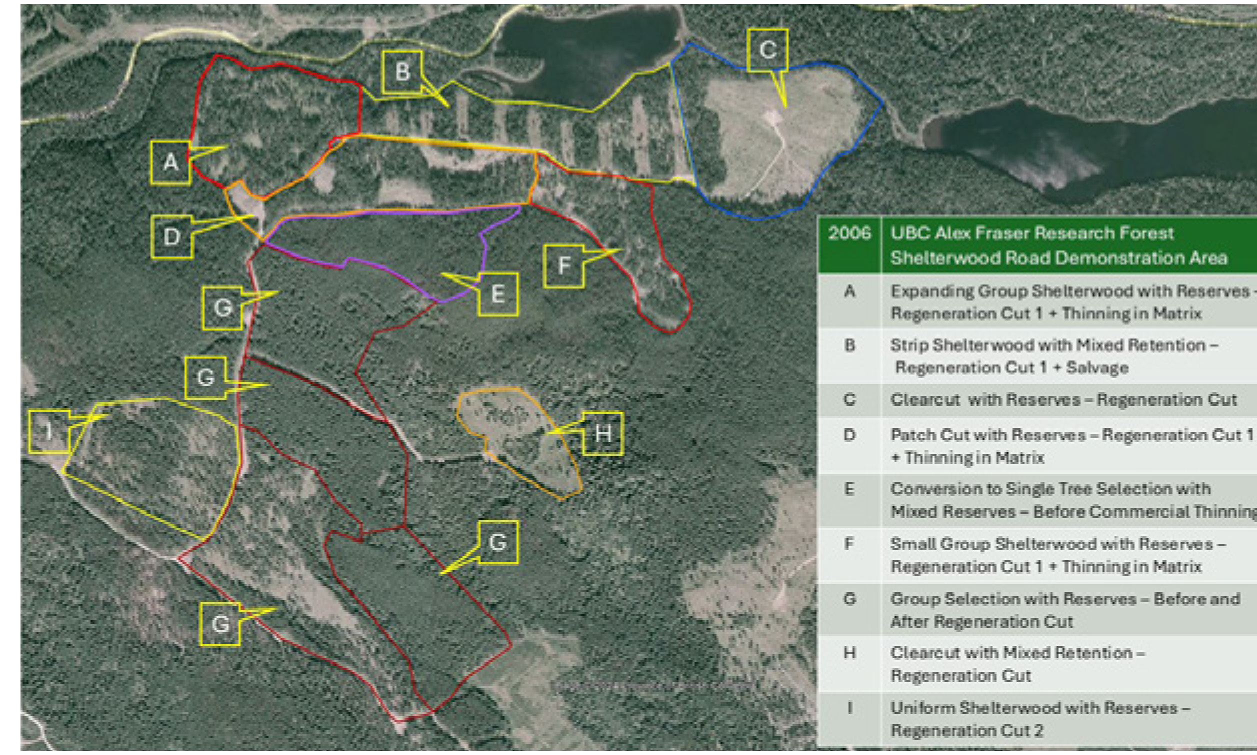
Variable density thinning is a commercial entry that varies the intensity of removal across the stand, to create gaps, thinned areas, and unthinned areas. The purpose is to accelerate the development of complexity and heterogeneity, including the regeneration of new cohorts in gaps (Palik and D'Amato 2024).

Removal cut – an intervention designed to release regeneration (i.e., enhance growing conditions of trees and/or other target vegetation) from the overhead shade of the retained overstory by reducing or removing overstory trees.

Variable retention harvest – an intervention that emphasizes the permanent retention of mature canopy trees—as well as other important structural legacies—at the time of regeneration harvest (Palik and D'Amato 2024).

Cultural or prescribed fire – an intervention intended to reduce vegetation and surface fuels, releasing growing space and supporting traditionally important plants.

4.4.2 Examples of Application for Describing Silvicultural Systems



2006 - UBC Alex Fraser Research Forest Shelterwood Road Demonstration Area.
Image source: Google Earth, Province of British Columbia.

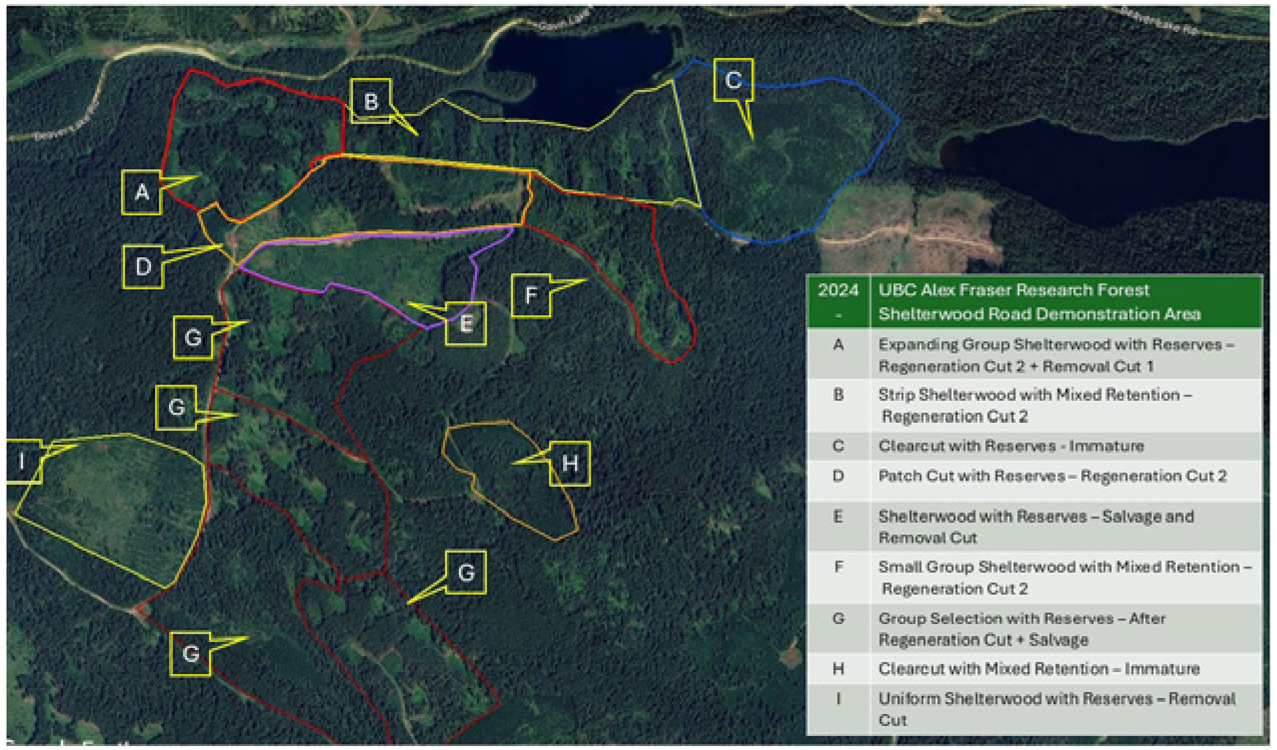
The photo above and on the following page (Figure 32) show the implementation through time of a wide variety of silvicultural systems in a demonstration of systems thinking in the SBSdw1 and ICHmk3 northeast of Williams Lake.

FIGURE 32 *Description of nine silvicultural systems and intervention phases in a Douglas-fir forest in the SBSdw1 and ICHmk3, on the UBC Alex Fraser Research Forest. Matrix stand age is approximately 140 years in 2020.*

The photo on the following page demonstrates that an intervention may not play out as planned. (K. Day, pers comm, Mar. 25, 2024)

For example:

- Stand D was intended to be a shelterwood (i.e., even aged). However, other priorities delayed the second entry for approximately 20 years, and the third entry is not yet planned. The resulting stand will now be comprised of more than one age class, meaning it should be considered an irregular group shelterwood.
- Stand E was intended to be an example of a conversion from even-aged to uneven-aged condition—the desired future stand condition was determined to be single-tree selection. However, 3 years after the initial thinning, the stand suffered about 30% damage from wind and snow, and subsequent infestation by bark beetles was under way. Salvage and a removal cut released the established natural regeneration.



2022 - UBC Alex Fraser Research Forest Shelterwood Road Demonstration Area. Image source: Google Earth, Airbus 2024.

- Stands B, E, G, and I all had salvage as a part of their intervention histories, demonstrating that windthrow and snow damage are a real risk, particularly when planning harvest for mature and old stands. Planning should account for those risks, and monitoring should ensure that necessary salvage is implemented.
- Wildlife-tree patches and other reserves contiguous to the harvest area are considered permanent reserves.

DEFINING VARIABLE RETENTION AND THE RETENTION SYSTEM

Variable retention: A general approach to forest planning, forest harvesting, and silvicultural systems across a landscape. This approach maintains structural elements of the pre-harvest stand throughout a harvested area to achieve specific objectives for conservation of biodiversity. Variable retention follows a natural disturbance–based management paradigm—recognizing the importance of structural complexity to forest ecosystem function and biological diversity. Variable retention is used to describe the overall approach to forest harvesting that requires long-term retention of trees and associated habitat. As a landscape-level approach, variable retention is not itself a silvicultural system, but it can utilize traditional silvicultural systems, such as shelterwood, selection, clearcut with reserves, or the retention system, to meet its objectives. (Beese et al. (2019) and Palik and D'Amato (2024)).

The retention system: A specific silvicultural system designed to meet the ecological goals of variable retention, while also managing for timber (Mitchell and Beese 2002; Beese et al. 2019). The system is applied by retaining individual trees or groups of trees with targeted attributes (Figure 33) to maintain structural diversity and forest influence over most of the harvested area (>50%) for at least one rotation. Retention is intended to be long term, with no intention of removal over the rotation. The retention may be held beyond this time period but the end of the rotation clearly ends a planning cycle and the stand will need to be viewed with fresh eyes at this time.

Forest influence: the total area of the intervention that is within one tree-length from the base of a tree or group of trees, whether the tree or group of trees is inside or outside the cutblock.

Many ecological factors (e.g., microclimate, hydrology, soil processes, soil properties, soil biology, forest productivity, plant diversity, and wildlife) are influenced by forested edges. Keenan and Kimmins (1993) found that this influence extended approximately one tree-length into the forested opening. They concluded that when an opening was large enough that forest influence no longer covered most of the opening (i.e., more than 50% of the area), it was ecologically considered a clearcut.

It follows that retention systems can be differentiated ecologically from a clearcut if the forest influence from the retention combined with adjacent edges covers more than 50% of the harvested area.

FIGURE 33 *Application of retention system in British Columbia coastal forests. Image source: Ken Zielke (used with permission).*

HISTORY AND USE OF VARIABLE RETENTION AND THE RETENTION SYSTEM

The "War in the Woods" between forest companies and environmentalists came to a boiling point in Clayoquot Sound near Tofino, B.C. in 1993. More than 850 people were arrested, tried, and convicted in British Columbia Supreme Court—one of the largest acts of civil disobedience in Canadian history.

In late 1993, the Nuu-chah-nulth First Nations and the British Columbia government signed an interim agreement for land management in Clayoquot Sound. A scientific panel was established to ensure "the best forest practices in the world." It was this panel that first coined the term "variable retention."

In 1997, forest company MacMillan Bloedel (MB) (later Weyerhaeuser B.C. Coastal Group) hired a new president and CEO, Tom Stephens, who was well-respected in the mining industry for his leadership and innovative thinking. Stephens challenged MB's forest professionals to come up with a strategy to address old growth and clearcutting, two issues that were limiting market access abroad. In 1998, Stephens announced an end to clearcutting on MB-managed lands, with variable retention and the retention system as the centerpiece of a MB forest strategy. The retention system, as designed in British Columbia, was established in the forestry literature as the first new silvicultural system in a century (Mitchell and Beese 2002). MB and Weyerhaeuser implemented the retention system across their tenures over the next 6–8 years. In 2006, Western Forest Products (WFP) acquired most Crown tenures previously held by MB. In 2007, WFP unveiled its own biodiversity strategy, building on MB's strategy and subsequent work by Weyerhaeuser and Canfor. In 2023, the Great Bear Rainforest explicitly incorporated the retention system into its approach to manage biodiversity across its landscape units.

There is a growing body of science, locally and internationally, supporting the use of variable retention (Figure 34), using the retention system for integrating management of biodiversity and timber. Use of the retention system started in the Pacific Northwest of the United States and in Coastal British Columbia in the 1990s, spreading across the boreal forest to Canada's prairie provinces and Ontario. It was adopted in Chile, Argentina, and parts of Australia by 2007 (Baker 2011; Densmore 2011; Gustafsson et al. 2012). Sweden, Finland, and Norway were the first European countries to use variable retention, and it then spread to the Baltic States and Germany (Rosenvald and Lohmus 2008; Gustafsson et al. 2012).

Studies across the globe show that variable retention with the retention system is providing refugia for a range of species through the intervention stage of stand development; enriching cutblocks with structure and forest influence and increasing connectivity for widely dispersing species (Baker 2011; Baker and Read 2011; Beese et al. 2019). To be most effective for conservation of biodiversity, variable retention is best integrated with a multi-scaled program, linking to planning for biodiversity at a landscape level.

FIGURE 34 *Group retention in eucalyptus forest in Tasmania, Australia. Image source: Ken Zielke (used with permission).*

Application of the Retention System to Interior British Columbia

Historically, in the interior of British Columbia, the term *retention system* has rarely been used to describe a silvicultural system. The dominant system has been *clearcut with reserves*. Reserves have often been aggregated for particular purposes such as riparian protection and legal wildlife tree retention requirements. Frequently, dispersed reserves are also left (images A and B). The reserves might be large live trees that are too big for the mill, or a species that does not fit the proponent's product profile. The density and location of the dispersed reserves are often left to chance. Consideration of the spatial distribution and location of group reserves would improve achievement of biodiversity objectives and could fit the definition of *the retention system*.

The clearcut with reserves approach to final harvest in many parts of the interior has strong similarities to the retention system (image C). The objectives for the trees retained and the distribution pattern are the defining differences. A review of retention strategies as part of the stand development pathway may offer opportunities to utilize the retention system in the interior, if conservation of biodiversity is a primary driver.

Similarly, where practicing partial cutting in the interior, retention may form a component of the residual stands across broad landscapes even though few true retention systems are being used. As a general approach to silvicultural systems (Beese et al. 2019) and a harvesting method (Palik and D'Amato 2024), variable retention offers an alternate pathway to the usual clearcut with reserves harvest method.

A

B

C

(A – TOP) Deciduous reserve trees near Phillips Lakes, B.C. Image source: Forest Practices Board.

(B – MIDDLE) Mixed-species reserve trees near Vernon, B.C. Image source: Ken Day (used with permission).

(C – BOTTOM) A mosaic of cutblocks with mixtures of group and single-tree retention, West of Nakusp, B.C. Image source: Ken Zielke (used with permission).

A WORD ABOUT CLEARCUT WITH RESERVES

Clarity of language is important to communicate intentions between practitioners, and to the public. So, when is a clearcut not a clearcut? It is common practice in the interior of British Columbia to call everything a clearcut with reserves. That might imply wildlife tree patches on the edge of the clearcut, or it might imply leaving 30% of the stand volume as permanent reserves of aspen. In the former case, we obviously have a clearcut with adjacent reserves for wildlife trees. But in the latter case we have not created the ecological condition of a clearcut. Given the charged meaning of that word in the public discourse, why would we choose to call anything a clearcut if it is not? Furthermore, if we trick ourselves or our peers into believing it really is a clearcut, then we will make bad silvicultural choices, such as planting a lodgepole pine stand in the shelter of an aspen overstory.

It is time to transition *clearcut with reserves* to the *retention system* where the area and distribution of the residual structure supports that change, and in the process better conservation of biodiversity will result.

4.5 SILVICULTURAL SYSTEMS AND ADAPTIVE MANAGEMENT

Silvicultural systems decision-making is challenged by multiple and sometimes conflicting management objectives, complex and dynamic ecological systems, and uncertain responses to management interventions over time. The pathway to success is through continual learning and improvement over time.

Adaptive management is a systematic process for continually improving management approaches and practices by learning from the outcomes of operations. A well-conceived and supported adaptive management framework enables forest professionals to determine if their stand-level interventions are influencing the stand development pathway as intended so they can adjust, if need be, in a timely fashion.

4.5.1 The Adaptive Management Framework

The learning process created by an adaptive management framework must be well organized, focussed, efficient, and supported to be successful. It should keep land managers and forest professionals focussed on what they are ultimately trying to achieve, why that is important, and what gaps and unanswered questions obstruct achievement of their objectives.

A sound adaptive management framework undertakes to answer emerging questions associated with intended stand development pathways and silvicultural systems to learn from results on the ground and improve outcomes over time.

BRITISH COLUMBIA'S LONG-TERM SILVICULTURAL SYSTEMS RESEARCH TRIALS:

Testing management approaches across diverse regions and ecosystems

Since the early 1990s, British Columbia's Ministry of Forests and many partner forest research organizations, including universities, have made substantial and enduring investments in the establishment, maintenance, and measurement of many long-term silvicultural system research trials throughout the province (Vyse et al. 2005; Wiensczyk 2012).

These trials are scientifically designed experiments focussed on a variety of integrated resource management issues, and they provide critical insights on the stand- and landscape-level forest attributes that are vital for timber production, species' habitat conservation, biodiversity, and resilience. Many of the trials are maintained and re-measured by the Ministry of Forests Research Program and are catalogued with the Experimental Project (or "EP") designation. This program of long-term testing and monitoring of different silvicultural systems has provided essential opportunities to enhance our scientific knowledge and demonstrate how different silvicultural approaches can assist our management of British Columbia's forests.

Long-term trials have been established in a wide variety of different ecosystems throughout the province and have generated a wealth of experience, data, and published information on the impacts of the various silvicultural systems (e.g., shelterwood, single-tree and group selection, clearcut) on harvesting costs, growth and survival of residual overstory trees, advanced regeneration, and planted and naturally regenerated seedlings. In addition, these trials have advanced our understanding of wildlife values, biodiversity and coarse woody debris, levels of vegetative competition and understory vegetation diversity, and forest health agents both biotic (e.g., insect and disease) and abiotic (e.g., windthrow).

Wiensczyk (2012) documented 23 large-scale replicated experimental trials and 11 smaller-scale demonstration areas testing diverse silvicultural systems across coastal, southern interior, and northern interior regions of the province. The number of long-term trials has increased since 2012 as innovative silvicultural applications have increased across the province and in First Nations territories.

British Columbia's network of silvicultural systems research trials, and allied demonstration projects, are a tremendous resource providing important sources of scientific knowledge, demonstration, and operational experience to support evidence-based applications of innovative silvicultural practices to meet long-term forest stewardship goals in our diverse ecosystems.

Information on long-term trials can be accessed through the B.C. Ministry of Forests (2024) Silvicultural Systems Research and experimental projects (EPs) website. https://www2.gov.bc.ca/gov/content/industry/forestry/managing-our-forest-resources/silviculture/silviculture-research/silvicultural-systems-research.

Sources / Citations

Vyse, A., A.K. Mitchell, and L. de Montigny. 2005. Seeking alternatives to clearcutting in British Columbia: the role of large-scale experiments for sustainable forestry. In C.E. Peterson and D.A. Maguire (editors). Balancing ecosystem values: innovative experiments for sustainable forestry. Proceedings of a conference. USDA Forest Service, Pacific Northwest Research Station, Portland, Oreg. General Technical Report PNW-GTR-635. www.fs.fed.us/pnw/pubs/pnw_gtr635.pdf

Wiensczyk, A. 2012. Status of British Columbia's long-term silvicultural systems research trials. FORREX Forum for Research and Extension in Natural Resources, Kamloops, B.C. File Report 12-01. ISBN 978-1894822-08-4

4.5.2 Elements of a Sound Adaptive Management Framework

1. Objectives express management needs for identified values toward a desired future, considering current landscape conditions, and anticipated changes over time.
2. Performance indicators are tracked based on reported data to provide clarity regarding progress toward a desired future for identified values. Normally, assumptions must initially be made regarding the linkage between these indicators and a desired future for certain values.
3. Measures of indicators are designed to improve the understanding of cause-and-effect linkages between performance indicators and management practices, including the use of certain silvicultural systems in particular areas.
4. Implementation monitoring evaluates whether management practices (such as silvicultural systems) are being implemented as intended.
5. Effectiveness monitoring helps ensure that management practices, performance indicators, and objectives are effectively linked as intended and assumed.
6. Further monitoring, research, and development will answer additional questions to better understand our ecological systems and objectives, ensuring an improved application of silvicultural systems.
7. An iterative management planning and implementation process will support #1 to #6 on a regular cycle.

For stand development pathways and silvicultural systems, elements #3 to #6 will be particularly relevant and #7 is critical for an effective adaptive management process to endure.

4.5.3 Maintaining Perspective

Most people have heard the excuse, "We tried that before and it didn't work." With adaptive management, new approaches and practices are not just arbitrarily abandoned when unexpected outcomes occur. A sound adaptive management framework encourages examining those different outcomes and learning from them to adjust and improve approaches. Collaboration with research organizations, local subject matter experts, First Nations knowledge holders, and others in the design of monitoring and research projects will help.

For stand development pathways and silvicultural systems, adaptive management monitoring and learning is a long-term commitment that requires periodic data collection and observations through time. Above all, it requires a curious and open mind, and a commitment to individual and organizational learning.

For more information on adaptive management see:

Province of British Columbia. 2008. Introduction to adaptive management. Forests for Tomorrow extension note. Apr. 2008.

www2.gov.bc.ca/assets/gov/environment/natural-resource-stewardship/land-based-investment/forests-for-tomorrow/forests-for-tomorrow-_extnote1_apr-29-2008.pdf

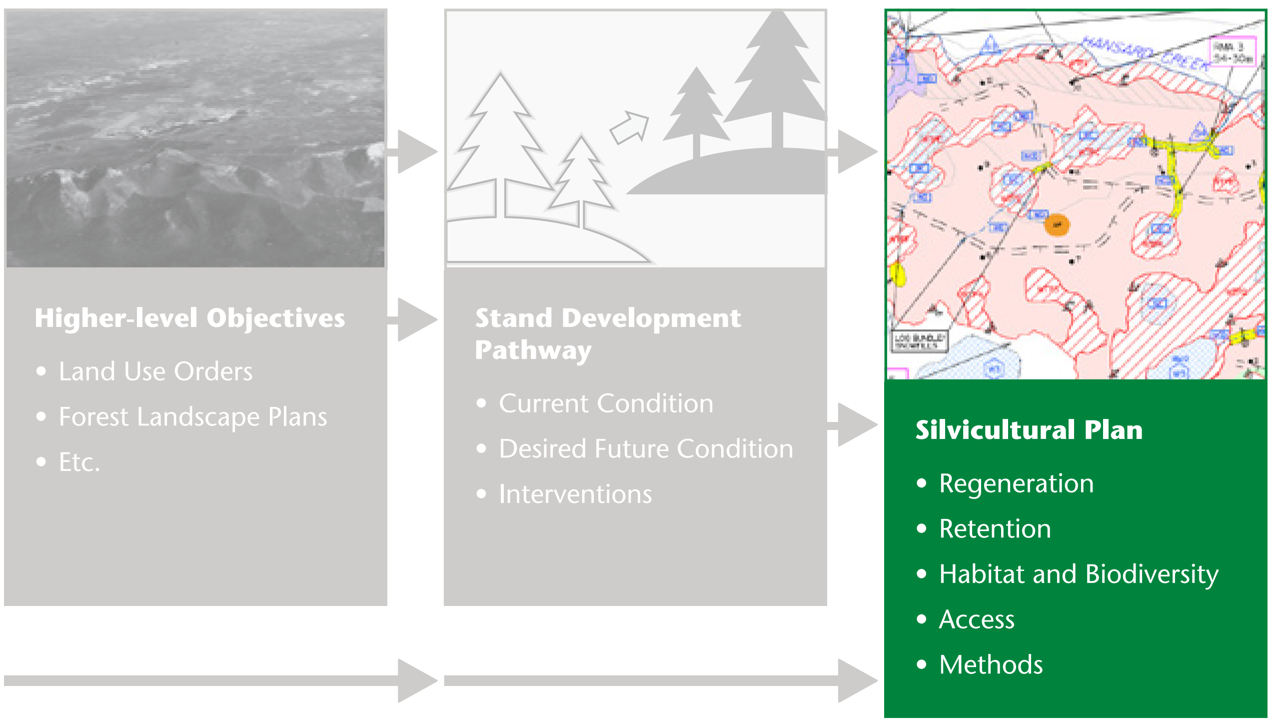
Williams, B.K., R.C. Szaro, and C.D. Shapiro. 2009. Adaptive management: the U.S. Department of the Interior technical guide. Adaptive Management Working Group U.S. Department of the Interior, Washington, D.C.

www.doi.gov/sites/doi.gov/files/uploads/TechGuide-WebOptimized-2.pdf

Field data collection in survey quadrats. Image source: Forest Practices Board.

PART 5 – BEST PRACTICES FOR IMPLEMENTING SILVICULTURAL SYSTEMS

5.1 BUILDING THE SILVICULTURAL PLAN



"A goal without a plan is just a wish."
Antoine de Saint-Exupéry

Earlier sections of this Handbook explored the key principles, concepts, and ideas that are important to consider in choosing a silvicultural system or "pathway" that will, over time, meet site- and stand-level objectives established through higher-level planning. Through this process, a forest professional first builds a vision of a desired future condition for a local area of forest; second, builds a stand development pathway for achieving those objectives; and finally builds a detailed silvicultural plan for the next intervention on the pathway.

This section of the Handbook defines the concept and scope of silvicultural plans in a professional context and provides best-practices guidance for forest professionals in building silvicultural plans in a manner that will clearly and effectively guide site-level application, field implementation, and assessment of diverse silvicultural systems in British Columbia.

This section provides professional and technical guidance and is intended to support and complement, but not supersede, additional direction on site-level silvicultural planning from land managers, and statutory requirements provided by the Province.

Partial-cut silvicultural system, during the harvest phase in a mixed conifer stand to release and grow second-growth cedar poles, West Kootenay, British Columbia. Image source: Rainer Muenter (used with permission).

5.1.1 Definition and Scope of the Silvicultural Plan

This Handbook defines a silvicultural plan as a site-level plan prepared by a qualified forest professional that details prescribed silvicultural interventions (also known as treatments) to influence the development of a stand on a pathway from current pre-treatment condition towards a desired future condition.

The key function of the silvicultural plan is to provide essential descriptive and prescriptive detail on silvicultural objectives, treatments, and site-level opportunities and constraints that are consistent with, but at a finer spatial scale than, higher-level plans.

Silvicultural plans address a smaller and more localized portion of a landscape than a higher-level plan. The silvicultural plan may be at the scale of one or several adjacent stands to be managed and may include adjacent reserves (no-treatment zones) or embedded retention and special management areas under the same plan.

The silvicultural plan describes and diagnoses present and anticipated site and stand conditions and sets future stand management direction. It describes the desired future stand and forest vegetation conditions in measurable terms. The desired future condition is a benchmark for planning, treatment, monitoring, and evaluation, as it provides a long-term goal to be achieved over one or more interventions.

Silvicultural plans bring together and communicate descriptive and prescriptive information into one central document that guides the silvicultural management of the stand(s) and sites(s) within the plan area, both for those using the plan in the present day, and for those guided by the plan in decades to come. The plan must be clear and succinct to present expectations for the outcome of the activity in a way that those implementing the treatment can understand and achieve.

5.1.2 Guiding Principles and Perspectives

Well-rounded site-level silvicultural planning considers the forest and stand both spatially and over time.

For spatial descriptions of pre-treatment and immediate post-treatment stand and site conditions, a forest professional needs to map and document the nature and character of a given stand and site, and understand its existing characteristics and variations in:

- forest and tree size, structure, and species;
- ecosystems and particularly soils;
- site hydrology and drainage; and
- terrain.

The forest professional must also understand the relationship and significance of a silvicultural plan area to the surrounding stands and landscape and any other site and stand attributes that may be especially relevant and important to the plan.

Time is the other essential factor that must be considered, not just because forests and trees are long-lived, but also because they are subject to periodic natural disturbances and influences and change over both short and long time-periods. Considering time in silvicultural planning means looking both backwards and forwards before deciding on a course of action. One needs to consider not only the influence of past disturbances of the stand and site on its current condition, and historical and cultural values of importance, but also how a stand's future development and values may be sustained or diminished under different management approaches.

Silvicultural planning and treatment design is an opportunity for the forest professional to creatively select and combine individual silvicultural choices for different situations as they arise over time, rather than being confined to pre-set silvicultural "recipes" or fixed combinations of treatments. This creative approach allows the forest professional to be flexible and adaptive to different objectives and circumstances found across British Columbia, and to respond nimbly to changing climates and differing site conditions.

Such flexible silvicultural choices may include:

- site-specific decisions around which areas to treat and which areas not to disturb based on a variety of values or concerns;
- which trees to take and which to leave;
- which tree species to regenerate or not;
- what measures to use to promote stand vigour and growth;
- what steps to take to help protect the stand, soil, and watercourses from damaging factors;
- actions to promote habitat quality; and
- many others.

Successful silvicultural planning is guided by the following principles:

1. The desired future condition or silvicultural outcomes—and the methods to achieve them—are clearly described in the silvicultural plan and are consistent with objectives of higher-level plans.
2. The silvicultural plan clearly describes ecosystem conditions at both the site level (soil, water, terrain, and ecosystems) and the stand level, including trees, snags, understory, forest floor, dead wood, and habitat features. Current and target species assemblage, size distribution, and habitat characteristics are part of the stand description and of the target conditions, which include desired future conditions.
3. Descriptions of current conditions include the forest health risks, site limiting factors, and opportunities to mitigate those risks. Understanding the ecological site conditions, forest health risks, and limiting factors points a forest professional towards operational and structural decisions for outcomes that provide benefits with the least risk exposure.
4. Planned silvicultural interventions align with the silvics and autecology of all the species under management (both overstory and understory). This may include both tree species and other species of interest. For example, increased light levels or moisture availability may be needed to promote fruiting of berry or medicinal plants important to local communities, or browse species important to wildlife.
5. The silvicultural plan and its prescribed interventions are conceived to "make the future better than the present" in ecological, social, and/or economic terms. This means balancing current benefits with the sustainability and supply of benefits in the future, and improving, not diminishing, opportunities for future generations on the land.

5.1.3 Functional and Content Elements

The silvicultural plan is a site-level professional plan that:

- provides the silvicultural vision for the site and stand(s) in the area under the plan;
- identifies values and resources to be conserved or protected on the area;
- explains the rationale for prescribed treatment(s) in the context of the desired future forest condition;
- indicates all the vital detail necessary for treatment implementation;
- defines measurable outcomes of the treatment and plan;
- sets out financial expectations for the plan; and
- names the silvicultural system(s) being used within the plan area, to aid communication of the methods used.

The following activities and content elements form the 11 *building blocks* of silvicultural plan preparation:

1. Examining and mapping the stand and site in sufficient detail.
2. Assessing and documenting important resource values including wetlands, riparian features, biodiversity, habitat, cultural values, and economic values (Figure 35).
3. Determining measures to protect and conserve identified soil and water resources, social and cultural values, biodiversity and ecosystem values, and other identified values during harvesting, access development, or other stand interventions.
4. Determining the spatial arrangement of operations and reserve / special management areas, including considerations of site hydrology, riparian areas, watercourses, culturally significant areas, habitat and soil conservation, and protection zones.

FIGURE 35 *Sub-boreal beaver pond and surrounding wetland and forest. Image source: Aleza Lake Research Forest Society.*

5. Considering access road and trail management including both short-term (temporary) and longer-term access needs, limitations, or restrictions.
6. Assessing and/or modifying potential stand development pathways and proposed silvicultural interventions to manage or mitigate biotic and abiotic damaging agents to the stand, and how the character and values of stand and site will change over time following the treatment(s).
7. Considering economic, logistical, and business factors, including working with operators.
8. Choosing and describing a silvicultural system consistent with all of the above.
9. Determining how best to designate trees and areas to be cut vs. those to be retained.
10. Considering adaptive management and monitoring needs.
11. Ensuring clear and consistent silvicultural and harvest-unit record-keeping, so that current and future land managers and forest professionals can easily refer to and access the plan as needed and use the current silvicultural plan as a benchmark or reference point for future management.

5.2 COMMUNICATING TREATMENT RATIONALE AND INTENT FOR POST-HARVEST RETENTION

The history of the silvicultural plan concept as a site-level professional document in British Columbia includes "silvicultural prescriptions" in the 1980s to early 2000s, and "site plans" from the mid-2000s to the present day.

The Province provides direction on basic legal content requirements for these documents through legislation, regulations, and government policy.

In addition to the basic legal requirements, forest professionals must consider not only the legal and administrative requirements established by the Province, but also professional standards of work and codes of ethical and professional conduct.

Selection harvesting in Interior Douglas-fir stand in mule deer winter range. Image source: Williams Lake Community Forest.

5.2.1 Communicating Rationales for Silvicultural Plans

"The chief virtue that language can have is clarity."

Hippocrates

A rationale is a written description of the reasons and logic used by a professional to arrive at a decision. Clear communication of the stand management and implementation goals in a silvicultural plan will support understanding, interpretation, and application of the prescribed silvicultural treatments by all users and readers of the plan.

A **rationale** explains, in brief, the reasons and logic used by a forest professional to arrive at a silvicultural decision. Users of a silvicultural plan need to understand its rationale and linkages to its proposed actions.

Users of a silvicultural plan need to understand both the rationale and the proposed actions. Both elements need to be clearly communicated to reviewers (be they public or administrative), implementers (e.g., block layout crews, loggers, and silvicultural workers), and assessors of the plan results. Use of plain language and a reader-friendly format will aid in the communication of key plan concepts and actions to this diverse range of plan users.

The following content on professional rationales is adapted from Larock (2021).

In the case of a silvicultural plan and associated silviculture treatment interventions, it is reasonable best practice for the professional preparing the plan to provide sufficient explanation for the users of the plan to complete and/or assess the prescribed work.

In determining what detail should be included in a rationale, it is prudent to take a conservative approach and focus on the most important and relevant details of the plan. This means that one should explain the plan's reasoning and prescribe actions clearly, completely, and succinctly.

A solid rationale in a silvicultural plan will:

- Describe the current stand condition and the context of the situation or problem leading to the need for silvicultural intervention(s) in a particular area.
- Clearly explain the silvicultural objectives and desired stand development pathway, and how decisions or actions that arise from them can be understood and efficiently, effectively, and safely implemented.
- Provide an overview of the key actions in the silvicultural plan, why they are being proposed, and the desired results.
- State the desired treatment outcomes in a manner that is easy to understand, has clear direction for implementation, and is measurable and verifiable.
- Be supported and justified by information in the rationale statement.

Coastal cedar and hemlock forest. Image source: Forest Practices Board.

5.2.2 Communicating Intent and Direction for Post-harvest Retention and Reserves

Desired outcomes for post-harvest retention need to be communicated in a manner that is clear and unambiguous to all users of the plan, provides adequate direction for implementation, and is measurable and verifiable.

The methods and style by which this intent and direction are communicated by plan preparers may vary but should be based on the circumstances and characteristics of the plan area, the intent of the silvicultural treatment, land manager discretion, and higher-level direction if applicable.

The following examples encompass diverse stand treatment planning approaches across a range of silvicultural systems including dispersed retention, group retention, and mixed retention.

These examples are not definitive, but rather illustrate some different approaches that may be created or adapted for use in different circumstances. See sections 5.3 and 5.4 of this Handbook for more detailed discussion of these topics.

Individual Leave-tree Retention from Lower to Higher Densities

In some silvicultural plans, a forest professional will prescribe the retention of individual leave-trees, describing the desirable tree characteristics and the pattern and density of cut and leave. This approach can be applied in diverse silvicultural interventions such as thinnings, single-tree selection, uniform and irregular shelterwood and seed-tree treatments, dispersed retention treatments, and clearcuts or patches with individual-tree reserves.

A necessary part of the silvicultural plan is to clearly identify which trees in a stand should be retained, and which trees should be removed. This direction must be clear, measurable, and verifiable. Well-crafted direction promotes clear understanding of stand management goals by all those delegated to implement the plan and supports the achievement of management goals and objectives identified in the plan.

Important questions to consider when specifying leave-trees include:

a) What are the objectives of leave-tree retention? Future timber growth? Wildlife habitat? Visual quality? Other objectives?
b) What tree species are suited to the site, and preferred for retention as leave-trees, based on the objectives of the silvicultural plan?
c) Which species and attributes will be most resistant to wind and snow damage, and to other potential damaging agents?
d) Which trees have desirable ecological or biodiversity values?
e) Which trees have characteristics that make them good wildlife tree candidates, either now or in the future?
f) Which trees have heritable traits that are (un) desirable in the next cohort?
g) Which trees have stem and crown characteristics that suggest potential for both good future tree growth and timber/log quality?
h) How is workplace safety factored into leave-tree selection or removal choices?
i) How many suitable leave-tree candidates are present on the site?
j) How many leave-trees do you need to retain? What proportion of the ones present on the site?
k) How will the silviculture plan clearly identify these preferred trees?

Following are two examples that illustrate how such approaches may be communicated in order to guide implementation. The first example describes dispersed retention of individual trees in open conditions, and the second describes a higher density of overstory stocking, such as in a single-tree selection or commercial thinning application.

Example 1: Dispersed Leave-tree Retention in More Open Conditions

Planning direction for leave-tree retention can often be stated in a manner that communicates broad management intent. For example:

"Retain mature Douglas-fir in the plan area, and promote regeneration opportunities for Douglas-fir, if or where opportunities exist."

However, while such a statement communicates broad intent, it does not translate this intent into meaningful stand-level objectives within a silvicultural plan. Further details are required. Silvicultural plan areas differ from each other, as do the populations of Douglas-fir within them. To achieve Douglas-fir retention objectives on a specific area, one needs to consider the characteristics and variability of the actual population of Douglas-fir trees existing in the stand, and whether those trees, or a subset of those trees, are suitable for retention. (See Figure 36, p. 72 for examples.)

How might one communicate which Douglas-fir trees are to be retained or left in a particular area? Consider the following operational example of leave-tree specifications for a retention system area applied in the SBSwk subzone near Prince George, B.C.:

Leave-tree Specifications:

- Retain Douglas-fir veterans (> 50 cm dbh) both as marked and where they exist in the stand.
- Retain > 75% of paper birch > 12.5 cm dbh outside of roadside processing areas.
- Retain deciduous (aspen, birch, cottonwood) and western hemlock (> 40cm) where safety and operability permit—do not stub.
- Snags shall be cut at about 5.0 m in height if safe to do so, and/or as per WorkSafe BC requirements.
- Leave-trees assessed as dangerous (e.g., by a certified Danger Tree Assessor) may be removed or retained if alternative safe work practices are developed and followed.
- Harvest plan should direct roadside processing and decking areas away from high-value leave-trees where possible.

These specifications communicate to everyone the desired results for leave-tree retention in this area, including: (a) species of trees to be retained, (b) preferred size of trees to be retained, (c) operational and safety constraints on trees to be retained, and (d) direction on "stubbing" of trees with hazardous tops to retain some habitat values.

However, these specifications could be improved by considering additional details or possibilities:

a) Whether the leave-tree specifications actually refer to live trees, dead trees, or both.
b) Acceptability criteria for leave-trees based on crown size, vigour, or health concerns. What if a leave-tree has only 10% live crown or is beetle-attacked, for example?
c) Whether the leave-trees are clumped together or spaced out.
d) Contingency planning for the loggers if the locations of potential leave-trees conflict with road locations and clearing widths or log decking areas.
e) Are terms or jargon such as "snags" clear and commonly understood?

A

B

FIGURE 36 *Suitability of leave-trees needs to be considered. For example, the Douglas-fir tree (A) has a shrunken live crown and a dead and probably unstable dead top. The Douglas-fir trees (B), in contrast, have well-developed vigorous live crowns and no evidence of top instability or other hazards. The value as potential leave-trees will depend on factors such as why they are being left, habitat values, potential safety hazards, and the risks they face post-harvest. Image source: Aleza Lake Research Forest Society.*

Example 2: Higher Overstory Retention in Thinned Forest Conditions

This second example illustrates how to communicate the intent of a silvicultural plan seeking to reserve a well-stocked overstory in a spruce–subalpine fir partial-cut (in this case via a single-tree selection system). This approach leaves substantial basal area stocking to meet the objectives for the stand.

In this case, the objectives are:

1. To manage a multi-aged spruce–subalpine fir–birch stand with a wide range of tree sizes from regeneration through to mid-canopy and dominant trees, and good tree and stand vigour, while allowing a sustainable periodic harvest.
2. A target post-treatment basal area objective of 22–24 m^2 per hectare.
3. Harvesting to remove poorer-quality conifers and retain better-quality conifers (spruce and subalpine fir) with superior form and vigour across all diameter classes, while opening up growing space for regeneration and improved growth of understory and mid-canopy trees.
4. To improve stand quality and vigour, the initial stand intervention will strive to retain vigorous spruce growing stock, and remove declining overmature subalpine fir and spruce trees.
5. To retain paper birch within the stand, other than incidental harvest, to maintain the diversity, cultural values, and ecosystem functions of deciduous trees in this coniferous-leading stand.

Table 4 shows tree harvesting and leave-tree specifications intended to guide tree marking and harvesting and specify desired leave-trees, to achieve Goals 1–4 above. Figures 37 and 38 show the stand after treatment.

TABLE 4 *Harvest-tree and leave-tree specifications to promote stand quality and vigour in a multi-aged spruce–subalpine fir stand in the SBSwk subzone*

Silvicultural Choices	HARVEST Priorities (Marked to Cut)	RETENTION Priorities (Trees with no markings)
Description	Removing trees of priority species and size classes, with a preference towards trees with:	Preference to leave-trees of priority species and size classes, especially for trees with:
Stem Defects	1. Poor form 2. Overmature or poor vigour 3. Major scars 4. Frost cracks 5. Conks 6. Broken tops 7. Major forks in lower 1/2 to 2/3 of tree	• No significant stem defects • No evidence of stem decay or heart rot • Good tree form • Good vigour and crown • No forks except in top 1/3 of tree
Crown Vigour	a) Fading crown and thin crowns b) One-sided crowns c) < 30% Live Crown as % of tree height d) Major crown damage e) Generally poor crown vigour	A. Full green crown B. Greater than 30% Live Crown as % of tree height C. Minor crown damage only D. Generally healthy/robust crown vigour

FIGURE 37 *Aerial drone view of the treated stand about 1 month after selection cut completion, highlighting tree crown characteristics and post-harvest spatial distribution of leave-trees. Image source: Aleza Lake Research Forest Society.*

FIGURE 38 *Resultant post-treatment stand in the June following logging in winter on snowpack with a harvester and forwarder equipment combination. Image source: Aleza Lake Research Forest Society.*

EXAMPLE OF A RATIONALE FOR A SILVICULTURAL PLAN

The following is one example of a rationale for a silvicultural plan in the Wet, Cool Sub-boreal Spruce subzone (SBSwk), which includes both harvesting treatment areas and prescribed reserve (non-harvest) areas.

Rationale: summary of stand management and silvicultural goals

The higher level forest landscape plan for this area (XYZ landscape unit) specifies objectives for promoting high-quality timber production while retaining: (a) suitable thermal and foraging cover for moose, (b) stand-level diversity of habitat for cavity-nesting birds, and (c) protection of cultural heritage sites where these occur.

This stand within the plan area naturally regenerated after forest harvesting and broadcast burning in 1948. It is a mix of spruce, subalpine fir (balsam), and 10–15% deciduous trees including aspen, birch, and cottonwood. The stand has reached crown closure and as of 2023 is undergoing density-dependent mortality or self-thinning.

One unharvested reserve area conserves riparian and aquatic ecosystem features and protects an included area of archaeological interest.

The stand management objectives for treatment within the plan area are to undertake a commercial thinning (via 'thin-from-below' methods) of a spruce–subalpine fir–deciduous stand to remove poorer-quality coniferous trees and retain better-quality conifers (spruce, balsam) with superior form, crowns, and future growing potential.

Seed-tree systems, UNBC John Prince Research Forest. Image source: Aleza Lake Research Forest Society.

Winter access, SBSwk1. Image source: Aleza Lake Research Forest Society.

Key harvest direction includes:

- Retain >55% of the coniferous basal area, to a minimum average basal area of 20 m^2/ha (acceptable range of 16–24 m^2/ha.)
- Retain live deciduous trees, except where necessary for the removal of safety hazards (danger trees) as per defined protocols, create harvester-forwarder trails, and thin clumps to release conifer understory trees and salvage incipient tree mortality.
- Protect tree roots and fine-textured (silty loam) soils by operating under winter conditions and frozen soils with snowpack >0.3 m. Maximum allowable machine trail width is 4 m, and machine trails must be a minimum of 25 m apart except at trail junctions.
- The stand is scheduled for a future partial-cut harvest entry in 25–35 years as the retained trees reach economic maturity. To retain structural characteristics consistent with higher-level plans for this area, the stand will be regenerated via uniform or group shelterwood systems.

Patches, Groups, and Clumps

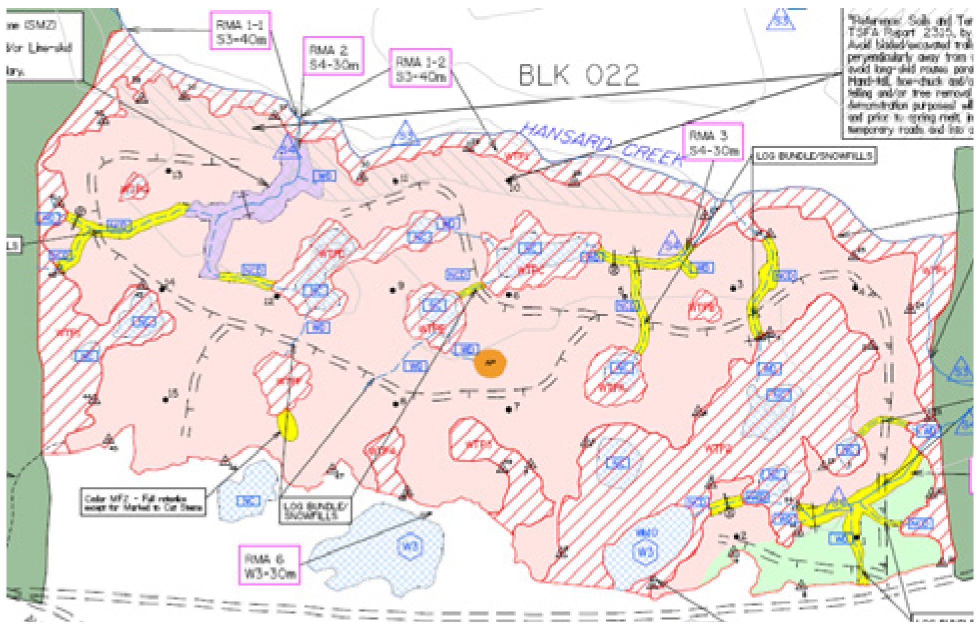
In contrast to dispersed stand-structure retention approaches, group retention strategies achieve retention objectives by mapping out or "stratifying" the plan area into distinct harvest and retention (no-harvest or restricted-harvest) areas.

This group retention approach includes riparian management and wildlife tree retention areas. Historically it has often been used where site- and/ or stand-level factors (such as shallow soils or higher windthrow risk) limit the use and effectiveness of dispersed retention, or areas where current harvest methods have limited the feasibility or desirability of dispersed retention.

The map and the aerial photo in Figure 39 show an example of this approach implemented with a ground-based harvest system in an area of gently to moderately rolling terrain on silty clay soils.

FIGURE 39

The top image shows an excerpt of the standards-unit map for the area indicating cut and leave areas and special site requirements. The bottom image shows the same block 12 years later, following harvesting and regeneration. Image source: Aleza Lake Research Forest Society.



Mixed Retention (individual trees, clumps, and groups)

Dispersed and **group retention** strategies can be used together (in combination) where desirable and appropriate.

On forested areas with a range of stand characteristics, soil types, or risk types, mapping out or stratifying the plan area can identify different areas with different opportunities for retention treatments. Some areas may be most suitable for group retention while others may be suitable for dispersed retention of certain tree species and tree size classes more adapted and resistant to wind exposure (Figure 40).

In other cases, it may be that most of the plan area is suitable for dispersed leave-tree retention, but smaller mapped-out areas within the unit are more suited to group or patch removals treatments for a variety of reasons or risk factors.

FIGURE 40 *Example of mixed individual-tree and group reserves in the SBSwk1 subzone. Image source: Aleza Lake Research Forest Society.*

Forest land managers may seek to create and maintain greater heterogeneity (or variability) in silvicultural outcomes for ecological or biodiversity objectives (Figure 42). In the past, many silvicultural practices tended to create simpler stand structures for timber management objectives. A silvicultural objective to create more variability in stand characteristics and values can be implemented at a range of spatial scales, including within-stand variability, and variability between different stands in that landscape.

One way to create more fine-scale variability is the ICO (individuals, clumps, and openings) method developed by Churchill et al. (2016) for dry-belt fire-adapted stands in Washington State and Montana. An example of a product from the ICO method is shown in Churchill et al.(2016).

Creating planned variability is challenging and is more than just an ad hoc approach of "doing a little bit of everything, everywhere." Sound planning principles, consideration of sensitive areas, and setting quantifiable, verifiable objectives are key (Figure 41). To consciously prescribe for and establish variability in forest stands for a range of objectives, including dispersed and group retention, land managers and forest professionals are increasingly incorporating modern GPS-aided digital technologies and algorithms for on-the-ground block layout and silvicultural decisions.

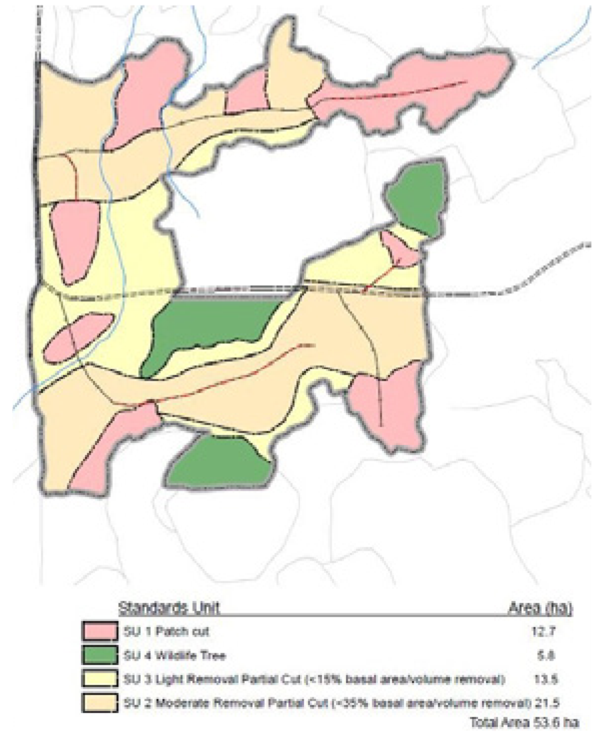


FIGURE 41 *A harvest plan map showing a combination of small patch cuts (0.8–3 ha, pink), wildlife tree patches (green), and single-tree selection (yellow and tan) at the Aleza Lake Research Forest. Patch cuts were targeted to areas of trees with declining vigour and higher windthrow risk, while selection areas were located in areas of the stand with better tree vigour and upland soils. Image source: Aleza Lake Research Forest Society.*

FIGURE 42 *Examples of different silvicultural approaches to retain stand-level biodiversity and heterogeneity, including (TOP) Douglas-fir seed-tree or shelterwood with longer-term retention, Image source: Ken Zielke (used with permission), and (BOTTOM) partial-cut spruce–balsam stand with understory trees 25 years after a partial overstory removal to remove beetle-killed spruce trees, Image source: Aleza Lake Research Forest Society.*

5.3 GATHERING AND CONSIDERING SITE DATA

"If you don't know where you've come from, you don't know where you're going"

Maya Angelou

5.3.1 Stand and Site Inventory

The purpose of gathering site data is to clearly understand the site, its values, and the attendant risks. More importantly, collecting data improves a forest professional's understanding of the starting conditions by challenging assumptions and intuition. While inventories provide a starting point, the unique characteristics of a site and the important features located there require that a forest professional be intimately familiar with the site and communicate that information (Figure 43). Detailed fieldwork and effective planning ensure that the silvicultural approach to an intervention is implemented effectively and safely.

FIGURE 43 *Paul Lawson, RPF works with UBC forestry students to interpret site data and formulate a harvest plan in the CWHdm2. Image source: UBC Research Forest.*

Site Ecology

Understanding site ecology is foundational to planning a silvicultural intervention—where are the boundaries of the plan area, and important transitional boundaries within it? Where are the sensitive sites? What needs to be avoided? How much fine-scale variability is there? Where are the opportunities?

Sufficient fieldwork should be undertaken to confirm the biogeoclimatic and ecosystem association (site series) boundaries and assess the soil moisture and nutrient regimes. At the same time, the forest professional should identify sensitive sites (e.g., culturally important areas, wetlands, hygric and hydric sites, rock outcrops, stoney ground) and site features (e.g., stick nests, dens, licks, cultural features, ecosystems at risk). This information will form the basis for describing **standards units** in the silvicultural plan, because the ecological conditions drive the development of the plant community and some of the disturbance risks that plant community faces.

Some land managers may have access to site-series mapping (e.g., predictive ecosystem mapping or PEM) deduced from digital terrain models of surface shape and therefore soil moisture regime. These are very useful aids but always need "ground-truthing" and field assessment to verify accuracy on each **standards unit**.

Safety Features

Safety features are locations or strata of concern that present a significant hazard to workers or the public in all circumstances or in certain situations. Examples of safety features include dangerous trees, cliffs, unstable rock, and sudden drop-offs. Larger safety features include slopes that are too steep for the harvesting equipment, unstable slopes, or any other areas or conditions that expose workers or the public to hazards.

FIGURE 44 *Different silvicultural treatment units identified in a sub-boreal spruce/subalpine fir stand affected by spruce bark beetle. Treatment units include A) Douglas-fir retention, B) reserve for wetland protection, C) clearcut with dispersed Douglas-fir and birch trees, D) single-tree selection for protection of research area, E) older immature stand retained for next harvest pass, and F) private land excluded from stand. Image source: Aleza Lake Research Forest.*

Slope and Terrain Considerations

Steep slopes need to be considered when selecting harvesting methods and therefore affect silvicultural options. Certain areas of steep slopes may be managed as no-harvest reserves to anchor retention patches for biodiversity objectives, but larger steep areas targeted for active harvesting will require appropriate harvest and silvicultural plans.

Unstable terrain within a plan area or adjacent access routes has the potential to present risks to public safety, infrastructure, site productivity, and water quality. Look for signs of historic or recent slope movement and engage qualified professionals to advise on these very significant hazards.

Stand Description

Use of partial-cut silvicultural systems with retention and complex stand structural goals requires detailed knowledge and description of the stand to consider harvesting options for the stand. Ask questions such as: *What species are present and in what proportions? What is available for retention of large old trees? What is the age and vigour of the species within the stand? Which trees have the best opportunity to respond to new growing space? What biological or physical risks are present in the stand?*

The following section explains why detailed pre-harvest stand information is necessary, what data to collect, and how to collect and compile the data.

a) Stand Description Objectives

To obtain a clear idea of potential management options for a stand over the long term, one must have a clear understanding of current stand conditions at the treatment-unit level (Figure 44). This understanding can be facilitated by gathering stand information to build stand and stock tables and other summary information.

Timber cruising is a long-established procedure to assess timber and related resources, and in British Columbia it is strongly governed by policy through the cruising and appraisal manuals. Cruising in our usual context seeks to accurately estimate stand volume and value. It is important to realize that your needs may differ from the information provided in standard appraisal cruising.

Stand and stock tables are the summary of average tree numbers or tree volume (respectively) by diameter class. These data summaries will be helpful in several ways:

- Understanding the current structure of the stand and the trajectory of the untreated condition.
- Understanding the risks of various potential prescriptions, to support decision making.
- Making decisions on the silvicultural pathway you plan to use and the intent of the current intervention—residual basal area, leave-tree characteristics, etc.
- Estimating the piece size, volume, assortments, and potential value of the material (logs, biomass) to be produced, to support financial and operational planning.
- Monitoring the implementation of the intervention and reporting the post-treatment condition into the forest-level record-keeping and inventory.
- Supporting the modelling of the expected growth and development of the stand into the future, leading to forecast outcomes in terms of growth, yield, and development of stand structure.
- Providing a rationale and justification of your silvicultural plan/prescription to a supervisor, client, or regulatory official.

b) Gathering and Compiling Stand Description Information

Can stand inventory be gathered through appraisal cruising? Yes, but with important caveats. To build a complete picture of the stand development pathway and the silvicultural system, the stand may also need to be viewed through the eye of a silviculturist. The silviculturist's perspective is shaped by the long-term management perspective of a stand development pathway; the cruiser's perspective is shaped by current stand volume and value and is a snapshot in time.

Standard cruising procedures in British Columbia are primarily focussed on valuation, but if procedures are augmented, they can yield information to support setting of partial-cutting prescriptions (Table 5). Consider the example of cruising to plan a partial-cutting opportunity, but only compiling the trees with diameter greater than 17.5 cm dbh (diameter at breast height). The standard cruise needs to be augmented by gathering data from the trees not intended to be cut (e.g. > 7.5 cm dbh).

Sampling for stand structure and determinants of growth and quality in complex stands may require a different sampling regime. This is a complex problem that may best be solved with methods (e.g., Smith and Iles 2012) that are not compatible with the methods set out for appraisal cruising.

Cruising for partial cutting needs to tally both tree vigour and the defects that impact residual stand quality (Figure 45). Form or forest health issues that need to be considered in the silvicultural plan should be tallied to distinguish between acceptable and unacceptable growing stock. Ignoring the prevalence of stem cankers (Figure 46), for example, ignores a primary risk factor that could diminish the future value of your efforts.

Cruising for partial cutting needs to generate all the information required as input to growth and yield models that will be employed to forecast plan outcomes in the residual stand.

It is usually best to prepare the prescription and determine the silvicultural system and harvesting system before cruising, but the stand description information is critical to those considerations. Planning based on reconnaissance information would likely adjust boundaries and decide if a block is infeasible before the expense of cruising is committed.

TABLE 5 *Stand description information for silvicultural planning*

Consideration	Purpose	Data Type	Collection Method	Comments
Merchantable and total density by species and size	Stand and stock table	Random or systematic plots or Subjective plots to estimate conditions by standards units	Variable radius for trees ≥ 12.5 cm dbh and height for each tree. Add a nested fixed radius for saplings and regeneration < 12.5 cm dbh	• Primary information • Smaller prism size or additional plots to increase trees sampled
Proportion of trees with capacity to respond to the new environment	Understanding vigour status and opportunities for leave-trees to thrive	Subjective classification of each sample tree	Added into plot measures	• Good, medium, or poor vigour class called for each tree in the variable radius plot • General vigour class for saplings and regeneration < 12.5 cm dbh • According to a localized classification scheme
Forest health issues in the stand	Acknowledge and address the risk of forest health issues affecting the outcome of an intervention	Random or systematic assessment	Tally trees with symptoms of forest health factors in sample plots	• Of particular interest—stem rusts, cankers, dwarf-mistletoes, root disease, foliage rusts, defoliators, bark beetles. • Also, windthrow and snowpress risk.

FIGURE 45 *Feller buncher salvaging pine killed by mountain pine beetle in a single-tree selection silvicultural system. Image source: UBC Alex Fraser Research Forest.*

FIGURE 46 *Failure to recognize disease impacts such as Atropellis canker means that treated stands may be substantially comprised of unacceptable growing stock. Image source: Ken Day (used with permission).*

Reliable map stratification of an area is the first step in silvicultural planning and data collection. This informs subsequent data collection. From these, we develop stand and stock tables according to the ecological and silvicultural stratification necessary for the silvicultural planning.

Partial cutting requires an understanding of the vigour profile of the stand. Vigour criteria will usually include a minimum percent live crown, and perhaps crown shape, colour, and density criteria, and presence of forest health factors. Knowledge of stand vigour by species and diameter class is critical so that you have a clear idea of current stand condition and potential leave-trees. The cruise can include such data if the cruisers are suitably trained and sufficient resources are available.

If the above issues can be resolved, it is likely more efficient to gather stand data during cruising. If, however, the added complexity of this information makes cruising too inefficient, then stand data can also be gathered during site planning fieldwork. In either case, the resulting information will need to be compiled[11] into stand and stock tables with additional information about forest health and vigour secured by standards unit. The planner needs to be able to interact with the data compiler to quantify unacceptable growing stock (trees to be cut) versus acceptable growing stock (trees to be retained), set retention targets, and thereby compile the planned post-treatment stand table and the expected harvest volume and piece size. Finally, the planner needs to synthesize those expectations into directions that a logging contractor can understand and implement.

✔		Plot Establishment Checklist
	1	Steel plot centres (10″ nails)
	2	Aluminum plot-centre tags
	3	Aluminum nails
	4	Hammer
	5	Plot map
	6	GPS

Plots established to gather stand data, for planning or for cruising, should be permanently established so that they can be re-visited after treatment. The re-sampling after treatment will suffice for reporting activities and should be re-compiled and reported as a stand table to be carried forward into the forest inventory. The same plots can serve as monitoring samples through time to observe outcomes and adjust strategies.

c) Interpretations of Stand Description Data

In silvicultural prescription development, decisions need to be made (and clearly communicated) regarding how much can be cut, which trees are to be retained post-harvest, and which are to be cut. It is helpful to model planned post-harvest stands to understand the implications of alternative prescriptions. This may be best accomplished during the development of stand development pathways rather than for each stand individually, but tools to make growth and yield models available and interactive for practitioners will be necessary.

Maintaining sufficient density of acceptable growing stock requires controlling the harvest volume and tree choices made by a logging contractor. That control may be applied through different approaches, by training, instructing, and supervising the logging contractor to make appropriate choices, or potentially by marking trees to cut or leave (see section 5.4.3).

The density of the stand after cutting will depend upon the intent of the intervention.

If the intention is to thin a stand to manipulate the species composition and improve future tree quality and size, then the forest professional needs to prescribe a density that opens enough growing space in the stand to accumulate future growth on fewer high-quality trees. Keep the stand stocked in overstory trees but below the level where competition-induced mortality is occurring.

[11] At the time of writing, there are two compilation tools. IDF Prescribe is a stand and stock table compiler written by Ian Moss, PhD, RPF, Forestree Dynamics Ltd. PCSim is a compiler written by Mihai Pavel, RPF, FPInnovations. Effective tools such as these need to be widely available and well supported.

If the intention is to allow regeneration to establish or release, then the intensity of thinning needs to be high enough to open growing space in the understory, so that regeneration of the desired species can survive and grow until the next intervention. Gaps can be opened to create space for regeneration while the matrix of the stand remains stocked in the overstory.

For More Information on Thinning

There is a large body of literature around the quantitative guidance of thinning. For further reading, see:

Ashton and Kelty (2018), The practice of silviculture: applied forest ecology. 10th edition John Wiley & Sons Ltd., N.Y., New York, U.S.A., chapters 21 and 22.

Farnden, C. 1996. Stand density management diagrams for lodgepole pine, white spruce and interior Douglas-fir. Can. For. Serv., Victoria, B.C. Inf. Rep. BC-X-360. cfs.nrcan.gc.ca/pubwarehouse/pdfs/4605.pdf

Province of British Columbia. 1999. Guidelines for developing stand density management regimes. For. Prac. Br., B.C. Min. For. www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/forestry/silviculture/developingstanddensitymanagementregimes.pdf

5.3.2 Managing Water and Riparian Resources

Water and Riparian Resources

Water and riparian features are the primary framework of landscape connectivity.

The presence and flow of water through an area, including waterbodies, seeps, watercourses, and riparian zones, which are key ecological features, need to be protected and conserved within a silvicultural plan area. Boundaries, access, and retention strategies all need to consider hydrological and riparian features and the context of the watershed within which the proposed development is located. As described earlier in this Handbook, water, and the connectivity it provides, is an important First Nations value.

Water and riparian features serve many important functions, including:

- Providing habitat for many life-forms.
- Supporting biodiversity at the stand and landscape level.
- Connecting different ecosystems throughout the landscape.
- Protecting water quality.
- Regulating stream temperatures.
- Providing woody debris and nutrient inputs into streams.

Waterbodies, watercourses, and riparian features (the latter including interfaces between aquatic and terrestrial) are useful to anchor retention patches to promote connectivity for habitat, energy and nutrient flows, and other ecological processes.

Riparian features can affect (and may be very sensitive to) the risk of windthrow, site disturbance, soil erosion potential, and slope failure. In-stream waterflows and downstream values need protection during road construction, harvesting, site preparation, and road maintenance activities. Planning and implementation must protect these values.

FIGURE 47 *Mule deer winter habitat is a primary management objective in the dry forests of the Cariboo Forest Region. Image source: UBC Alex Fraser Research Forest.*

5.3.3 Managing Biodiversity and Habitat at the Site Level

Wildlife species have three basic needs to survive: cover, forage, and security. Each species meets these needs in different ways and those considerations need to affect harvest planning.

Species and Ecosystems of Concern
It is important to identify species (present or potential) and consider the habitat needs of species and ecosystems that might be present.

Some species and ecosystems of concern are protected by law and may be either present or potential in a harvest area at the time of planning. Species that are seasonal, low density, wide ranging, or cryptic are unlikely to be noted during field work. Consult the Conservation Data Centre[12] for a suite of tools to pursue this line of questions. Consult local experts to understand expectations and best practices to support your analysis and planning.

Other species and ecosystems may be locally important, as indicated in higher-level plans, consultations with First Nations communities or subject matter experts, or based on local knowledge. In such cases, silvicultural plans may need to consider customized habitat management strategies for local conditions (Figure 47).

Wildlife Trees
Wildlife trees are any standing live or dead tree that provides vitally important habitat for the conservation or enhancement of wildlife (Fenger et al. 2006). They are a low-frequency resource that is critical to a wide spectrum of wildlife species.

[12] www2.gov.bc.ca/gov/content/environment/plants-animals-ecosystems/ conservation-data-centre/explore-cdc-data.

A large body of literature and accessible expert knowledge exists on this topic. In general, important wildlife trees often have characteristics that make them undesirable for timber products. Different tree species provide the differing habitat requirements for various wildlife species (Figure 48). Examples include platform nests built by a heron colony in a cottonwood stand, contrasted with the space behind a bark slab where a brown creeper might nest or a bat may roost. The nature of wildlife trees is widely variable, and details are critical to particular wildlife species. Because it takes decades to grow effective wildlife trees, they must be part of the retention strategy devised in the silvicultural plan. Where wildlife trees have been eliminated in past disturbance, it is necessary to promote trees in young stands to grow and eventually take on the characteristics that will make them effective habitat in the future.

For example, research in the Cariboo region looked at the web of species supported by aspen wildlife trees. This research documented that aspen is a critical component of the landscape for cavity-nesting species and found that a long list of species use cavities in aspen trees—woodpeckers, songbirds, ducks, owls, fur-bearing mammals, bats, and squirrels included (Martin et al. 2002). Many of those species are reliant on woodpeckers (particularly northern flicker) to excavate a cavity that becomes available for use in subsequent years.

Some (but not all) wildlife trees may also be hazard trees, so prescribing professionals need to take appropriate measures to balance wildlife tree and habitat retention objectives with worker safety. This may include a variety of strategies depending on the situation and may be determined in consultation with

FIGURE 48 *Wildlife trees support many habitat values: (TOP LEFT) stick nest, Stanley Park in Vancouver, (TOP RIGHT) pileated woodpecker excavation near Fort St. James; (ABOVE LEFT) red-tailed hawk on a perch, and (ABOVE RIGHT) western redcedar with excavated cavities, UBC Malcolm Knapp Research Forest. Image source: (TOP LEFT AND BOTTOM RIGHT) UBC Alex Fraser Research Forest. Image source: (TOP RIGHT AND BOTTOM LEFT) Aleza Lake Research Forest Society.*

a qualified individual with valid wildlife and danger tree (WDT) assessor's certification.

Forest professionals need to develop a strategy to promote wildlife trees on stands and landscapes, and to recruit replacement wildlife trees for the future. Fenger et al. (2006) recommend leaving wildlife tree patches comprising up to 30 percent of the harvest area where landscapes have been strongly affected by harvesting. Grouped and dispersed retention are also viable ways to maintain and recruit wildlife trees.

One example of such strategies is recent operational guidance in the Great Bear Rainforest on the British Columbia coast that encourages professionals to leave more retention with better distribution across cutblocks in landscapes with extensive past clearcutting.

Coarse Woody Debris

Coarse woody debris is a critical element of biodiversity. It provides habitat, stores moisture, and releases accumulated nutrients back into the ecosystem. It allows access to sub-nivean (under snow) habitats for predators and provides hiding cover for prey. Large decaying logs and their moist interiors provide important cover, humidity, and habitat for many animals (such as salamanders) and support food webs for larger predators (such as bears) accessing rotting logs for beetle grubs. For coarse woody debris, size matters, and larger pieces tend to have more habitat value and persist longest in ecosystems; therefore, maintaining large coarse woody debris at the time of harvest is important. Decayed wood should be left as undisturbed as possible, and additional appropriate large coarse wood should be left well distributed on site to decay.

Larger and longer pieces (ideally > 30 cm diameter, 10 m length) have higher and longer-lasting ecological value in the ecosystem than small, short pieces. Their function and management are different from that of fine slash and small woody debris; small logs, tops, and branches decay faster and are relatively ephemeral from an ecological point of view.

From a forest fuel perspective, smaller size classes of woody fuels (< 7 cm diameter) have high wildfire risks. The fine fuels dry quickly and ignite easily, contributing to head fire intensity (the instantaneous release of energy as the fire front passes by), which increases fire hazard.

Conversely, larger coarse wood retained on site may burn or char in a wildfire, but these piece sizes burn quite slowly and contribute very little head fire intensity. Day et al. (2010) recommended retaining 40 m^3/ha of coarse woody debris after fuel treatment in the wildland/urban interface.

Retention Planning

Retention of standing trees, individually or in groups, is an important approach to managing biodiversity and wildlife habitat at the stand level (Figure 49). Retained (unlogged or only lightly logged) areas of forest that contain wildlife features, large coarse woody debris, riparian features, and wildlife trees can all be the ecological anchors around which longer-term retention patches and biodiversity management strategies can be planned.

FIGURE 49 *Retained trees and uncut forest in a developing matrix of young spruce plantation, SBSwk subzone near Prince George, B.C. Image source: Aleza Lake Research Forest Society.*

To create a final block design, these biological anchors can be considered together with normal forest engineering control points, such as rock outcrops, areas of poor deflection for cable systems, and sensitive sites. However, not all forest retention is created equal and care should be taken to consider the merits of different forest retention patches.

Retention patches interrupt sightlines and provide hiding cover for wildlife and refugia for flora and fauna to persist through the harvest disturbance. Retention patches can be planned to inhibit road-hunting by limiting sightlines at roadside, particularly where the treatment is adjacent to a community or heavily trafficked road systems.

Retention of dispersed standing trees in open conditions contributes to many wildlife values, although if the intent is for long-term retention, risk of loss needs to be considered. In parts of the Interior, dieback of dispersed large old trees may occur due to changes in transpiration demands after harvesting or other stresses.

Retention of an overstory in partial cutting also contributes to wildlife values, providing future wildlife trees and coarse woody debris as they weaken and die. Retained trees in a partial cut further reduce sightlines and provide more security cover for wildlife, particularly when the retention is arranged in a fine-scale, clumpy/gappy condition comprised of individuals, clumps, and openings as described by Churchill et al. (2013).

Wildlife Features

Wildlife features (e.g., wildlife trees, dens, raptor nests, mineral licks) are specific point features that need to be located as early as possible in the reconnaissance process and protected through planning and implementation. Wildlife features can anchor retention patches, and some features will require specific strategies such as encroachment distances and timing windows.

5.3.4 Managing Risks

Managing the Risk of Leave-Tree Damage and Loss

Stands can be vulnerable to damage from root disease, defoliators, bark beetles, wind/snow/ice damage, wounding and stem decay, heat damage and drought stress, frost damage, and fire. These can occur independently, or in combination.

Interventions associated with a prescribed silvicultural system have the potential in some scenarios to increase or decrease the vulnerability of stands to these damaging factors. Where hazards are significant and vulnerabilities are high, a forest professional must carefully consider the consequences of potential damage on values to fully understand the existing risks. Conversely, a thoughtful silviculture intervention can significantly reduce the vulnerability of a stand by manipulating the stand structure and vigour profile.

The starting point for managing risks is to identify hazards in the field. The forest professional must first be aware of the potential hazards and vulnerabilities that could be exposed during various interventions throughout the various forest types and ecosystems in the area. Forest professionals require the knowledge and skills to identify these hazards and vulnerabilities in the field. Local subject matter experts and seasoned professionals can provide assistance and training. Being proactive can prevent damaging agents from undermining the intent of a stand intervention.

Importantly, vulnerabilities to post-harvest stand damage and the associated risks should not be exaggerated or assumed to become an excuse not to use certain silvicultural systems, particularly those involving partial-harvesting and retention. Typically, even in regions of the province where some vulnerabilities can be relatively common, opportunities will still exist for a range of silvicultural system choices, depending on the site, the stand conditions, and the values. For example, Western Forest Products Ltd. has a strategy for use of the retention system in its tenures on the British Columbia coast. In the portions of its tenures subjected to some of the most intense winter storm winds in the province, it still intends to use the retention system but at a lower level than in other areas.

The following guidance on forest health issues is provided as an overview, and forest professionals should refer to relevant literature and subject matter experts in a site-specific or regional context.

Root Disease (Armillaria, Laminated, and Tomentosus)
Root diseases, particularly armillaria and laminated, can have significant impacts on stand-level values and associated objectives. These diseases can result in a discernable change in forest cover with diverse stand compositions and structures dynamically changing over time.

Direct control of root disease using stump extraction (stumping) is possible but expensive, creates significant soil disturbance, and should be avoided wherever possible in favour of other options. However, in some areas, root disease is so prevalent that both stumping and other options are used. For more detailed discussion, refer to the root disease guidebook.[13]

Silvicultural options that can be used with root disease include:

- Inoculation of stumps with *Hypholoma fasiculare* as a biological control.
- Favouring isolated identifiable concentrations of root disease for retention patches or reserves where they exist.
- Regenerate to mixtures of tolerant, resistant, or immune tree species when harvesting in root-disease areas is unavoidable. Check local guidance from pathologists for suitable species with such qualities.
- If necessary, direct control with stump extraction.

[13] www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/forestry/forest-health/forest-health-docs/root-disease-docs/rootdiseaseguidebookjune2018_4.pdf.

FIGURE 50 *Dwarf mistletoe–infected Douglas-fir near Westbank, B.C., where retention and regeneration approaches need to be carefully considered given the prevalence of this parasitic plant. Image source: UBC Alex Fraser Research Forest.*

Dwarf Mistletoes
Dwarf mistletoes (Figure 50) can be found in some stand types across the province. Specific dwarf mistletoes can infect western hemlock on the coast and lodgepole pine, Douglas-fir, and western larch in the interior. It is important to identify stands infected with mistletoe prior to developing a harvesting and silvicultural plan.

Silvicultural options to reduce dwarf mistletoe infections in regeneration:

- Design harvest boundaries to reduce the perimeter and use infection-safe edges.
- Regenerate to non-susceptible species, especially when relatively close to infected trees (consult local experts).
- Slash all infected trees over a certain height (consult local experts) upon conclusion of harvesting.

Defoliators
Defoliating insects can significantly damage mature stands and retained trees. There are different defoliator species associated with different stand types and tree species. Most are endemic in stands, periodically building up to epidemic proportions. When these epidemics occur, these defoliators can contribute to significant mortality of trees, normally for a fairly short period. Population growth and collapse also relate to the general vigour of individual trees and the stand as a whole.

Western spruce budworm is a good example of such a defoliator. Western spruce budworm is a significant defoliator of Douglas-fir in the IDF biogeoclimatic zone. Budworm can cause widespread mortality and top-kill in Douglas-fir. A relationship between tree vigour, stand density, and damage to Douglas-fir has been demonstrated in some ecosystems. As the vigour of trees declines, they are more susceptible to damage since their ability to recover foliage biomass suffers, and they have smaller crowns that suffer greater proportional defoliation as a result. In addition, trees with low vigour have few resources to spend on anti-herbivory chemicals and their foliage is more palatable and nutritious for budworms.

Multi-layered stand structures can intensify budworm defoliation by providing several layers of host material under overstory trees for dispersing larvae to land on and continue maturation feeding.

Silvicultural strategies for managing western spruce budworm include:

- Maintain tree and stand vigour through density control.
- Monitor populations and level of damage.
- Cut stands in such a way as to move size classes further apart into groupings by diameter class.
- Spray with Btk (*Bacillus thuringiensis* var. *kustaki*).

Bark Beetles
The most significant pest problem throughout the British Columbia interior has been and continues to be bark beetles. Intensive management of bark beetles includes vigilant detection and aggressive harvesting to mitigate the spread during periods of high beetle pressure.

Mountain pine bark beetle, Douglas-fir bark beetle, balsam bark beetle, and spruce bark beetle are primary disturbance agents, but Douglas-fir and spruce bark

A spruce–subalpine fir stand in the southern interior with mortality from spruce bark beetle in large overstory spruce. Image source: Ken Zielke (used with permission).

beetles, ambrosia beetles, and wood borers are also part of the risk created by windthrow and fire. Other species may arise in thinning slash and can attack and kill standing trees when their populations are high. There is also a concern about native species expanding their ranges (because of climate change) and introducing invasive species to new areas.

Prevention is the best long-term management option. It requires significant conversion of forest cover over long time periods, increasing average stand vigour and decreasing average stand age, to increase resistance to bark beetle outbreaks. Silvicultural systems and re-entry cycles can improve resistance to bark beetle outbreaks in the future.

Silvicultural strategies for managing bark beetles and related hazards such as windthrow (for Douglas-fir or spruce beetle):

- Prompt detection through aerial mapping in late summer.
- Prompt harvest of current and old attack.
- Well-developed and maintained access.
- Thorough ground reconnaissance.
- Deployment of traps, anti-aggregate lures, or trap trees as necessary.
- Thorough cleanup of susceptible or infested material.
- For lodgepole pine, maintain a low beetle population by developing stands of mixed species and high average vigour.
- For Douglas-fir and spruce beetles, maintain a low beetle population by anticipating bark beetle activity, and planning direct control through harvesting each year.
- For Douglas-fir and spruce beetles, suppress beetles during periods of high beetle pressure by harvesting infested areas while the beetles are still under the bark.

Wind, Snow, and Ice Damage

Risk of windthrow is a common concern in forest management. Snow and ice damage may combine with wind damage when snow and ice build up in tree crowns on slender stems, making them more susceptible to breakage in the wind (Figure 51).

FIGURE 51 *Snow breakage in the first winter after a uniform shelterwood preparatory cut in Douglas-fir in the SBSdw1. Tall slender trees retained were most likely to be broken. EP 1104.01. Image source: UBC Alex Fraser Research Forest.*

Windthrow can be an important consideration when planning cutblock boundaries and the type and distribution of leave-trees. Partial-cutting silvicultural systems increase windthrow due to the increased amount of edge relative to typical clearcuts. Yet this vulnerability can be managed in many stands through best management practices.

First, the potential for windthrow must be considered before harvesting. In considering windthrow potential in any area of British Columbia, the forest professional should review and evaluate two sources of information.

The first is local experience. Where and on what kind of sites and treatments has wind damage occurred or been excessive, and, conversely, where has it been minimal or acceptable? Consult with professionals experienced and familiar with partial-cutting systems in an area and seek their advice on dos and don'ts for wind-damage mitigation.

Whenever possible, do site visits and walk through partial-cutting and retention treatments in areas similar to the ecosystems you are working in, and examine areas that have experienced wind damage and areas that have not.

Secondly, review available windthrow risk diagnostic frameworks that may be used to assess windthrow hazards prior to layout based on stand, soil, and topographic features. These frameworks can also assess windthrow likelihood and risk associated with various harvesting design features. The consequences of windthrow for values and associated objectives must also be considered to address inherent risks.

If unacceptable wind impacts are expected, partial-cutting prescriptions may have to be altered to reduce anticipated windthrow risk. In some cases, where technically and economically feasible in high-value areas, this may include prescribing crown modification treatments.

In some situations, a partial cutting prescription may not be practical or feasible without incurring high levels of windthrow even under normal regional wind conditions. It is best if this can be anticipated so that the alternative options can be considered before harvesting. Sometimes a high windthrow risk may be acceptable if salvage can easily be accommodated or if stand structural objectives include absorbing some wind damage. Again, it is best if this is anticipated.

The following section reviews an approach to windthrow risk assessment, discusses potential approaches to reduce risks, and makes suggestions for incorporating these assessments into silviculture plans for complex silvicultural systems.

An updated manual for managing windthrow on the British Columbia coast is available (Zielke et al. 2022). Although it was developed for the coast, this manual has a diagnostic framework, field cards, and decision tools based on 30 years of research, monitoring, and observations, making it also relevant to the interior.

Some general strategies for assessing and mitigating potential wind, snow, and ice damage are to:

- Conduct windthrow assessments during site planning fieldwork.
- Consider windthrow in designing block boundaries, retention, and reserve patches.
- Consider windthrow in prescribing residual stand density and leave-tree characteristics.
- Identify significant damage annually across the tenure, particularly on cutblocks harvested in the past 3 years (when it is most likely to occur) and record amount and orientation.
- Promptly salvage accessible damage, especially where bark beetles are also a concern.

Silvicultural Options to Reduce Wind Damage at the Cutblock Level[14]

1. Choose narrow strips or gaps rather than open, dispersed retention as a harvesting pattern

If overstory harvesting must be significant to increase light penetration, an open stand of uniformly dispersed leave-trees may no longer have the damping effect of neighbouring tree crowns to reduce their crown sway. Opting for small gaps or strips leaves much of the stand in an unharvested condition with mutual protection between trees intact. Exposed edges of gaps or strips can be vulnerable, but this will depend on the location of the edges and the width of the strips or gaps in the direction of the prevailing winds.

As the wind profile travels over a canopy, it can drop down to ground level when gaps are sufficiently large, rebuilding its speed. When it encounters the exposed unharvested edge at the other side of the gap, the wind exerts maximum drag force on those exposed crowns, potentially leading to some windthrow. However, when gaps are narrowed below five tree-lengths in width, often referred to as "reducing fetch," both the penetration of the wind profile into the stand and the subsequent wind loading on the exposed edges start to decline, with major declines below 50 metres (depending on orientation and slope).

[14] For more options and details, see Section 7 in Zielke et al. (2022).

2. Increase group size and reduce fetch in group retention systems

Increasing the size of retained groups decreases edge-to-area ratio (Figure 52), reducing the relative proportion of windthrow in the group. As with gaps and strips, reducing the fetch between groups can reduce damage on edges of downwind groups.

Overall, fewer larger groups and group shapes that consider wind direction and fetch can help address windthrow where it is a significant hazard.

FIGURE 52 *Large groups to reduce edge-to-area ratio and good use of shorter fetch distances to reduce windthrow from prevailing S-SE winds near Quatsino Sound, one of the windier portions of the British Columbia coast. Note: some acute corners of retained groups would be better rounded off to avoid wind damage. Image source: Google Earth, 2025 Airbus, 2025 Maxar Technologies.*

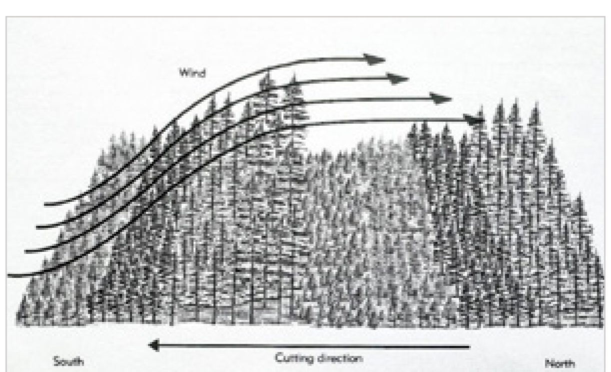


FIGURE 53 *Strip-selection system with cutting into the wind to reduce the edges fully exposed to prevailing winds.*

3. Consider lighter, more frequent entries using group and strip systems

Where group or strip systems are chosen, the re-entry periods and pattern of subsequent entries will be critical in maintaining the wind resistance of the stand. Group and strip selection will provide longer intervals between re-entry and may allow more time for exposed edge-trees to expand crowns and improve taper, rooting, and windfirmness. The use of repeated entries over longer time intervals allows vigorous trees to change allocation of resources from foliage and stem height to the roots and taper as they respond to increased movement from exposure to more wind. Each stand will have to be assessed individually to make this decision and the system chosen must meet other management objectives. Several variations of strip selection were originally designed in Europe to help deal with windthrow problems (Figure 53).

4. Reduce removal levels in systems with uniformly dispersed reserves

Where windthrow is a concern, shelterwoods or other systems with uniform leave-trees may require lower initial removal levels and more gradual entries to open up the stand over time to create appropriate conditions for regeneration. Restricting initial basal area removal levels to 30 percent or less can substantially reduce windthrow risk in uniform stands, since leave-trees are denser and offer greater crown damping. Silvicultural systems that include light harvesting or commercial thinning interventions (thinning from below) with enough time between entries to allow leave-trees to expand crowns and increase taper can reduce losses to windthrow. Remember, however, that quality of leave-trees rather than quantity may be more important (see following point).

FIGURE 54 *A shelterwood system with high-quality dominant and codominant leave-trees. Image source: Ken Zielke (used with permission).*

5. Choose leave-trees with windfirm characteristics

Where uniform retention is planned in a heterogeneous stand, choosing individual trees that are windfirm will greatly contribute to increasing the windfirmness of the stand (Figure 54). Generally, large, mature, dominant trees that have some of their crown above the stand canopy will have lower height-to-diameter ratio and more wind resistance. Since these trees likely developed while exposed to the wind, they are more windfirm than other crown classes when neighbouring trees are harvested.

Conversely, systematically removing most or all of the most windfirm dominant and codominant trees in the stand (as is done with thin-from-above, diameter-limit, and high-grading operations) will reduce the overall windfirmness of the residual stand. Classic examples of this trend were the historical selective logging operations in the spruce–subalpine fir stands of the British Columbia interior in the mid-twentieth century, where extensive removal of large merchantable trees > 40 cm in diameter often resulted in exposure of understory and mid-canopy trees to extensive blowdown.

6. Manage juvenile stands to be suitably windfirm

In juvenile stands, we are establishing the foundations for managing structure in the future. What we do with young stands will influence future options for managing the resulting mature stands with various silvicultural systems. It is important to consider how regeneration species, density, and pattern (uniform or clumpy) choices set the initial trajectory for a stand. As well, thinning regimes may be used to help encourage a more windfirm structure amenable to a wider range of silvicultural systems options.

Wounding and Stem Decay

Clear communication with logging crews and close supervision during operations can reduce damage to leave-trees during logging operations and help avoid wounding and decay of leave-trees (Figures 55 and 56). Despite the best efforts of personnel, some logging damage will occur. It is important to consider the results of that damage and develop a strategy to minimize its impact.

Thin-barked tree species need additional care during thinning and partial-cutting operations. Leave-tree species with thin bark and non-resinous wood, such as the true firs (Abies spp.) and hemlock (Tsuga spp.), are more susceptible to wounding due to machine and log contact during harvesting than thick-bark species such as Douglas-fir. That wounding is also more likely to be followed by significant decay than in highly resinous species such as lodgepole pine or Douglas-fir. The exception to this rule of thumb is the spruces, which, despite being resinous, are very susceptible to infection by decay fungi (Figure 57).

FIGURE 55 *(TOP) Logging damage can be controlled by careful supervision to identify the specific cause, and by operator training to change behaviour. The wounds shown in this photo were likely caused by the swing of the empty skidder grapple when returning for the next turn. Image source: Ken Day (used with permission).*

FIGURE 56 *(ABOVE) An operator-controlled log forwarder loads cut-to-length logs during commercial thinning operations in a 65-year old spruce-subalpine fir stand. Image source: Aleza Lake Research Forest Society.*

Redcedar is similar to spruce in its lack of resistance to decay after wounding, which some professionals have noted in the field.

Season of harvest can affect the amount of damage. Harvesting during periods of spring sapflow and weak inner bark will make even thick-bark species susceptible to wounding.

Non-gouging wounds remove bark and possibly cambium, but do not penetrate the sapwood. Gouges penetrate the sapwood, create potential entry points for decay fungi, and may degrade wood value (Figure 57). See the Tree Wounding and Decay Guidebook (B.C. Ministry of Forests 1997) for recommendations on assessing and managing decay fungi.

Top damage is the most critical type of damage, and crop trees with broken and damaged tops should be cut before logging contractors leave the site (unless they are high-value wildlife trees). In some cases, top damage creates a safety hazard that cannot be left behind. Also, professionals in parts of the interior have noted that wounds in the top of the bole appear to be attractive to bark beetles. Scars in the upper bole also have a higher incidence of infection by decay fungi (Craig 1970). A tree with a broken top or limbs sheared off will not contribute well to the desired stand.

Basal scarring is of less urgent concern than top damage. Often species such as Douglas-fir are quite resistant to decay after such injuries. However, decay and resin-soaked wood caused by basal wounds result in loss of volume and quality in the bottom log—the most valuable portion of the tree. The losses in value are therefore greater than the decay volume alone would indicate.

Trees of small diameter at the time of logging will tend to have only a small volume of rot, due to compartmentalization of decay in the stem. Decay resulting from basal scars affects only the wood that exists at the time of injury (Craig 1970; Allen and White 1997) and does not expand into new stem wood over time.

FIGURE 57 *Decay in Douglas-fir EP 1104.01 (LEFT) and interior spruce (RIGHT) 10 years after logging damage in a uniform shelterwood system in the SBSdw1. Image source: UBC Alex Fraser Research Forest.*

Summary of considerations for risk of loss from wounding and decay:

- Large wounds are more likely to cause decay than small wounds.
- Wounds that gouge the wood are more likely to cause decay than wounds in which only the outer bark is removed.
- A wound on a large tree will cause much greater future volume loss to decay than a similar scar on a small tree.
- Wounds in contact with the ground are more likely to result in decay than wounds higher on the bole, and the decay progresses more rapidly.
- Decay establishes relatively quickly, and 5 percent losses can occur in just 10 years.
- Trees with a broken top or limbs sheared off will impair future tree growth and should be cut if possible.
- Some basal wounding of Douglas-fir or lodgepole pine may be acceptable.
- Severely wounded spruce, subalpine fir, and redcedar should be cut before the end of harvest operations.
- Wounded aspen, birch, and cottonwood should be cut if their contribution to timber values is important.

Mountain pine beetle–affected landscape. Image source: Forest Practices Board.

For more information see:

Province of British Columbia. 1997. The tree wounding and decay guidebook.

www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/forestry/forest-health/managed-stand-pests/tree_wounding_and_decay_guidebook.pdf

Zeglen S. 1997. Tree wounding and partial cut harvesting - a literature review for British Columbia. Pest management report 14.

www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/forestry/stand-tending/treewounding.pdf

Wildfire, Prescribed Burning, and Cultural Burning
High fuel accumulations and a trend towards increasingly challenging fire weather result in a very significant loss of values when a fire occurs (Figure 58). This is particularly true in the interior of the province. Carrying out elegant silvicultural approaches without dealing appropriately with the fuel hazard leaves us all at risk.

In British Columbia, fibre utilization is increasingly moving towards realizing whole-stand values, where biomass and pulp-wood are valued as well as sawlogs and higher-value logs (Figure 59). Harvesting the whole profile helps to merchandize all the fibre cut during harvesting and reduces slash loading and wildfire severity.

In partial-cutting prescriptions, substantial fuel accumulations that have built up at the base of retained trees require careful management of fuels and burning conditions (Figure 60).

Consider All Hazard Factors and Vulnerabilities Together When Considering Risk
Hazards, vulnerabilities, and the likelihood of damage and loss can be assessed independently for the damage factors listed above. However, they must be brought together with the values present on-site and the objectives for the silvicultural system to determine risk. Often, several hazard factors work together (Figure 61), to affect damage and loss of leave-trees.

Contingency planning for salvage may be necessary, and the importance of this contingency planning should be proportionate to the likelihood of tree mortality.

FIGURE 58 *(ABOVE) Wildfire impacts in the ICHmk3, 2017. Image source: UBC Alex Fraser Research Forest.*

FIGURE 59 *(TOP RIGHT) Decking biomass at roadside for delivery to a power facility (where facilities exist) reduces fuel accumulations without pile burning. Image source: UBC Alex Fraser Research Forest.*

FIGURE 60 *(RIGHT) A long time since fire means that fine surface fuels have accumulated under leave-trees, resulting in high fire intensity. Image source: UBC Alex Fraser Research Forest.*

FIGURE 61 *(BELOW) This stand was pre-disposed to wind damage by tomentosus root disease and decay caused by logging damage from frequent salvage entries. If left unsalvaged, this windthrow will likely result in an outbreak of spruce bark beetles. Those hazard factors need to be considered together for a proper perspective on risk. Image source: UBC Alex Fraser Research Forest.*

5.4 OPERATIONAL PLANNING

Defining the appropriate intervention that responds to the current conditions and considers the risks is an important step, but the job is not done until the plan is implemented. All the best intentions can be undone by failing to implement effectively.

5.4.1 Financial Analysis

A Tool for Financial Analysis – the Stand Pro Forma

A stand pro forma analysis is a financial forecast or analysis based upon estimates of volume, selling price, and production cost. The purpose of preparing a pro forma analysis is to decide if the current market values and contract costs will support the planned intervention. Table 6 provides an example of a pro forma analysis for a fictitious intervention in a fictitious tenure. It shows revenues and production costs, differentiated between sorts according to the recent experience for similar conditions. Tenure costs are attributable to all harvest blocks and are based upon factors calculated as cost/ha or cost/m³. This analysis will generally cause a planner to defer a financially negative or marginal activity when market values are low and wait for more favourable market conditions.

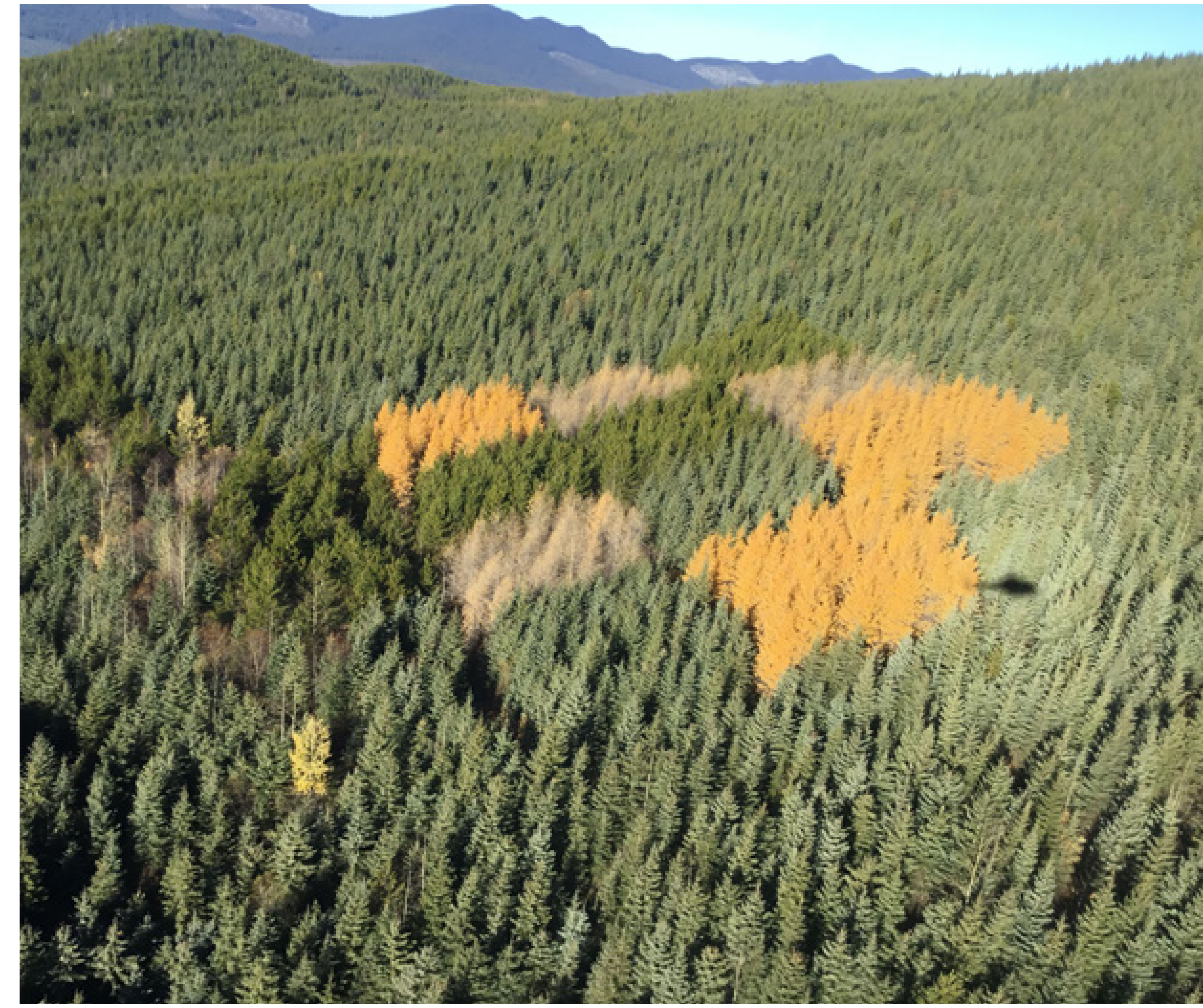
TABLE 6 *An example pro forma analysis for a fictitious intervention by a market-logging operation. When forecast revenues are diminished by production and tenure costs, a planner can decide if the proposed plan is financially viable given the current assumptions. This fictitious example estimates a net profit of $8.35/m³ (before tax).*

Intervention Pro Forma Analysis

Licence	CP	Cutblock	Cruise Vol. Est.	Net Ha	m³/ha
K3A 000	**1**	**100**	**3000**	**50**	**60**

	Revenue Forecast				Production Unit Cost			
	Sort Price $/m³	Sort % of Volume	m³	Gross Sales	Logging	Trucking	Stumpage	Subtotal
Highgrade	$150	5%	150	$22,500	$50	$20	$10	$12,000
Veneer	$125	20%	600	$75,000	$40	$15	$10	$39,000
Saw	$100	60%	1,800	$180,000	$40	$15	$10	$117,000
Pulp	$50	15%	450	$22,500	$25	$20	$1.25	$20,813
Biomass	$25	11%	321	$8,025	$25	$25	$0.25	$16,130
Total		**111%**	**3,321**	**$308,025**				**$204,943**

Tenure Cost ($/m³)							Net Revenue	
Admin.	Road Const.	Road Maint.	Planning	Supervision	Silviculture	Subtotal	Total	$/m³
$2	$3	$2	$8	$3	$6	**$78,044**	**$25,039**	**$8.35**



30-year-old trial of pine, spruce, and larches, Quesnel District. Image source: Forest Practices Board.

5.4.2 General Layout

Access Considerations

Access is a fundamental requirement of timber harvesting. The logs and biomass need to be transported from the forest to the market, involving machinery in the forest to forward logs to the road, and trucks to carry the logs to the destination.

In terms of the logging cost, more access is better. If roads are closer together, the cost of logging goes down. However, building roads also costs money, they have long-standing costs, and the impacts of road placement and road density on other forest values, both in the short term and long term, must also be considered.

While this is a very broad topic beyond the scope of this Handbook, the professional land manager may put their mind to the following considerations:

- Productive land assigned to roads is no longer producing the desired values.
- The capital cost of building roads means that the owner has capital deployed that is not available for other investments.
- Built road requires maintenance expenditures.
- Roads create a real environmental cost that is difficult to quantify, but they contribute to cumulative effects of development on the landscape.

In the interior, mountain pine beetle salvage harvesting gave rise to roadside logging as a means of separating harvesting phases and minimizing wait time in the harvesting process. However, as practices move back to partial cutting in different forest conditions, roadside logging may not be an effective choice. Chosen logging methods need to respond to the silvicultural plan.

Further considerations for road development include:

- Roads should be thoughtfully located to create fuel breaks, providing safe space from which to fight fire or undertake prescribed or cultural fire.
- Old roads should be renovated where possible, rather than building new roads.

In partial-cutting interventions with repeated stand entries, skid trails and landings should be re-used. Planning an effective trail system is important to ensure that subsequent entries do not undo the good work of earlier entries. Ideally, plan the whole trail system at the first entry. A planned skid trail system will reduce the total amount of in-block access trails and will reduce the likelihood of excess logging trails being built.

Unbladed and uncompacted trails that will be available for use in subsequent stand entries remain productive growing space for trees both above and below ground, provided that the trails are not significantly degraded by the machine traffic or erosion (Figure 62).

Bladed and degraded skid trails should be considered permanent access because the construction and use of the trail has greatly diminished the occupied rooting space under the trail. Roads and trails need to be deactivated and remediated where there is potential for concentrated water to flow across or down the structure. Deactivation, at a minimum, requires cross-drainage on sustained grades.

FIGURE 62 *Unbladed trails can be re-used in repeated entries and remain functional growing space provided that soils are not degraded. Logs and biomass are both arranged for forwarding. Image source: Williams Lake Community Forest.*

Layout

Harvest boundaries are mapped based upon the silvicultural plan objectives and constraints, topography, the limits of the logging equipment contemplated, and the harvest chance (or opportunity) for the intended silvicultural approach.

It is a good practice to designate block boundaries at physical limits (e.g., creeks, ridges, roads, property lines) and then designate retention and reserves within the larger gross area. This practice avoids isolating small portions of ground outside the block boundary.

Once the boundary is mapped, it is essential that it be marked clearly for field implementation, harvesting and road operations, inspections, and future stand entries. Field staff may mark the boundary in the field using a variety of approaches, most commonly paint and flagging tape in company-specific colour coding.

Similarly, internal boundaries need to be laid out to mark out changes in silvicultural approach, reserves for biodiversity (i.e., wildlife tree retention), and riparian protection. Boundary layout is a skill resting on understanding of logging engineering, silvicultural systems, safety, and stand-level biodiversity.

Clear communication with logging crews about flagging, paint colours, and protocols is essential.

Increasingly, the forest sector is moving to mapping and field layout approaches that rely upon global positioning system (GPS) technology for spatial control of operations. On-board computers and sophisticated mapping software coupled with good GPS equipment will likely mean that many boundaries will not need to be ribboned or marked as intensively in the future. Both digital and analogue (field marking) methods of boundary control have their pros and cons, and a combination of approaches may be appropriate.

Prescribed fire ignition in the Cariboo Fire Centre near Williams Lake, IDFxm subzone. Image source: Ken Day (used with permission).

A new rationale for boundary location is now emerging, which asks the question:

Where should the harvest unit boundary be to best support firefighting or implement cultural and prescribed fire?

This line of thought will require the collaboration of logging engineers, silviculturists, wildfire managers, and cultural and prescribed fire practitioners.

5.4.3 Leave-Trees and Marking

Identifying, Designing, and Marking Leave-Groups and Clumps

Retained leave-trees, groups, and clumps should be planned logically to fit with the management objectives and all harvesting and engineering considerations. A protocol to approach such marking is:

1. Be very clear about management and structural objectives: "What are we hoping to provide by leaving the areas of retained trees?"
2. During the engineering field assessment stage, identify engineering, economic, and ecological control points. Retention groups or clumps might have specific structural characteristics you want to retain (ecological control points), or limitations of logging and road layout (engineering control points).
3. Because of their biological importance and potential safety concerns, consider using live or dead trees with high wildlife and/or ecological value as the heart or centre of groups or clumps when logistically possible.
4. Map the location of the possible control points.
5. When locating the structural controls on the map, make notes on the values that each area will contribute.
6. Assess for windthrow hazard; rank sites based on their likelihood of remaining standing based on experience and decision-making tools.
7. Assess the clumps and groups for forest health issues such as mistletoe. Recommend options.
8. Determine the area identified and compare it against the desired reserve retention target.
9. If less than the desired reserve amount, use the spatial guidelines and engineering chance to identify candidate areas, field check, and locate on the ground.
10. In all cases, choose retention patches that make the most sense to leave—those with desired structural attributes, those that fit with the engineering plan and chosen harvesting equipment, those that meet the management objectives, and those that support the safety plan.
11. Mark leave-groups and patches using a distinct colour, or special tape created for retention patches to differentiate from outside boundaries.
12. Ensure that all hazard trees have been identified and either have a sufficient buffer around them or are marked and identified for the faller.

Note that marking is just a final phase in the proper planning of these leave-clumps or retention groups.

Choosing Dispersed Leave-Trees – Marking or Faller's Choice?

After writing a silvicultural plan, the intentions need to be clearly communicated to the logging contractor and operators. Tree marking (including faller's choice) is a mechanism that applies stand management objectives to the current stand. Difficulty choosing which trees to retain increases as the complexity of the harvest prescription increases. Day (1998) suggests that "when complex objectives dictate that particular types of trees need to be retained, the benefits of marking will justify the expense."

Marking Crew

Many forest professionals consider the marking of a stand for partial cutting to be one of the most powerful and rewarding experiences in transferring a silvicultural plan to the stand. It is complex work that integrates silviculture, ecology, logging, engineering, and mensuration. It is generally not work for inexperienced personnel.

One distinct advantage of using a marking crew is that the stand can be marked before logging. Ongoing prism sweeps or a re-tally of the cruise plots can tell the markers if they are on the prescription before the trees are felled. Collaborators or concerned individuals have an opportunity to discuss the falling plan before any trees are cut.

The labour cost of marking is not inconsequential. Decision-making is relatively rapid, but the marker needs to walk to every tree requiring marking.

Dunham (2001) reported marking costs of \$1.21/m^3 of harvest volume in a second-entry uniform shelterwood in the SBSdw1. Applications where many small trees are located and marked can be expensive. At the upper extreme, Koot et al. (2015) report that marking-to-cut in a low-volume small piece-size thinning project added about \$6/m^3 to log costs.

Where feasible, a faller's choice approach may be more viable in simpler prescriptions where cutting focusses on one activity and operators have gained experience.

Faller's Choice

Faller's choice may be used where the fallers or operators are accustomed to working with a detailed prescription to implement its intent. The implementation of the prescription is the forest professional's responsibility. Operator training and experience are key to success of faller's choice. Paint-marking a portion of a standards unit can help to communicate expectations to loggers initially. The remainder of the standards unit could then be logged using faller's choice (without marking). The fallers or operators should work with a prism if basal area is their objective and fully understand the objectives of the plan.

Koot et al. (2015) reported that after logging three blocks with complex prescriptions, the logging contractor strongly supported having the stand marked. It is worth considering that faller's choice decisions (in a mechanical operation) occur at an hourly rate approximately three times higher than those decisions made by a marker, and if the decision making consistently slows down production, logging cost will rise.

Faller's choices are final—once the tree is cut it can not be stood back up. It is up to the supervisor to monitor progress frequently and adjust performance going forward.

The issues of tree selection and protection of the residual stand are important to achieve silvicultural objectives, but these activities will reduce a logger's productivity relative to simpler silvicultural approaches. This needs to be recognized in planning. Loggers are operating in a competitive environment, meaning that they are always searching for efficiency and improved productivity. In partial cutting, the logger's financial interests can often be at odds with the intent of the prescription and, if adequate guidance and control are not provided, these considerations may skew their choices within the limits set out by the supervisor.

Harvesting with retention. Image source: Forest Practices Board.

Finally, bear in mind that feller bunchers have a cab configuration that limits the operator's ability to see more than 4–5 metres up the tree. Also, the operator can only see a tree on one side and defects on the other side will not be visible. In this respect, expect that in faller's choice, operators will miss some defective trees and leave some amount of unacceptable growing stock (e.g., dead trees, or trees with poor form, defects, wounds, or cankers on the stem) despite their best intentions.

Organization and Implementation of Tree Marking

Leave-tree selection (however it is being achieved) should focus attention on the quality and vigour of the trees being retained. Species, health, and vigour of the leave-trees are the characteristics informing the marking, regardless of whether you mark-to-leave or mark-to-cut. Choose whether to mark-to-leave or mark-to-cut based on the number of trees that need to be marked. When you consider that the marker must walk right up to every tree needing a mark, most of the marker's time is spent walking. Setting a GPS track while marking helps the marker to see if any areas remain unmarked.

Procedures for Marking Dispersed Leave-Trees

Note: The block boundary, roads, and landings should be laid out and marked before marking the stand. The trail plan should be in hand and can be laid out during marking.

When marking for hand-falling, it is important to understand the capabilities of hand-fallers and the decisions they need to make for safety. The final choice always goes to the faller when considering safety. Remember that a faller's first concern going into an area is to make the area safe for themselves, whether it is a clearcut or a partial cut. This means that the faller must address any hazards first.

When marking for mechanical felling, it is important to understand the reach and side-slope capabilities of the felling machine. Feller bunchers can pick up a tree and place it on a trail, while harvesters can only direct the fall of a tree and slide it over the ground.

When the timber is clumpy and the crowns are interlocked, fallers and machines may have difficulty leaving just a few trees in a clump—this is especially true with mixed-species stands.

Sometimes it is easier to leave all or most of the clump, or alternatively remove a clump. Trees with large, wide crowns are often difficult to fall without damaging many other smaller trees. Consider leaving such trees unless there is an obvious path for them to be felled into.

Day (1998) advises using consistent paint colours and recommends the convention that orange paint marks cut trees, while blue paint marks leave-trees. In this way, complex marking instructions can be rendered with less painting (e.g., "cut all the pine except if marked with blue and cut only the fir marked in orange.")

General Marking Procedures

1. Marking should be done systematically over the entire area and at a constant pace to give full, consistent coverage.
2. A crew of two or three should follow each other in staggered strips, communicating to provide feedback on the conditions of trees chosen.
3. Marking should focus on the objectives of the stand and the tree characteristics specified in the prescription.
4. Marks should be placed as high as possible, using painted dots (or rings of paint) around the tree as high as can be reached. Often a line from the base of the tree up the stem through the maximum stump height is used since it marks both the stump and the butt-log of a marked tree that is harvested. A mark should be placed in the crotch of two roots that cannot be rubbed off during skidding. These stump marks ensure that the supervisor or inspector knows that a tree was intended to be cut (or left).
5. A periodic prism sweep should be done during tree-marking operations to check residual basal area. Mark-to-leave rub trees at trail junctions and bends in the trail. Select trees of a size and value such that they do not need to be salvaged.
6. Generally, a crew of two is sufficient for marking. However, a tally-person may be added to record marked stems for the following reasons:
   a. To gain a total cruise on all marked stems. This is useful for a mark-to-cut approach where you want accurate numbers on the volume to be harvested.
   b. To mark across diameter classes according to marking rules, set to implement a prescription for proper single-tree selection.
   c. To ensure that retained basal area is consistent throughout the harvest block.
7. An alternative to tallying is to return to the cruise plots and re-compile the stand and stock table for harvest vs. retention.

FIGURE 63 *Logging contractor forwarding logs to a landing in a fuel treatment project in the IDFxm near Williams Lake. Image source: Williams Lake Community Forest.*

Marking for Single-Tree Selection

After a prescription is developed to regulate or manage densities across all diameter classes, a set of "marking rules" must be designed to ensure that the structural design can be transferred to the ground (Table 7). Usually, targets for residual basal area in the range of diameter classes are refined to just three (for faller's choice) or four (for marking crew) marking rules in broad diameter classes.

TABLE 7 *Example of marking rules for single-tree selection (mark-to-cut)*

Marking Category	Rule
Wildlife trees (>70 cm dbh)	Leave all (there are only 2–5 scattered through the block)
Large sawtimber (50–70 cm dbh)	Mark 50% – mark 1/leave 1
Medium sawtimber (30–50 cm dbh)	Mark 1 in 3 trees (distribution is clumpy so remove one-third of the basal area in this diameter class in each clump)
Small sawtimber (15–30 cm dbh)	Mark 2 for every 3 (mark 2/leave 1)
Other criteria for all categories	Mark trees to cut first that show defect, disease, or lack of vigour (small crown, high height:diameter ratio)

5.4.4 Harvesting

Soil Conservation

Soil conservation is about using appropriate equipment in a way that is sensitive to the bearing strength (trafficability) of the soil. This means that fine-textured soils or waterlogged soils need to be considered differently from coarse-textured or dry soils.

Harvesters and forwarders (Figure 63) tend to have better soil conservation characteristics than Feller bunchers and grapple skidders because:

- Their articulated frames mean that steering is less likely to tear the surface soil compared to the fixed track of a feller buncher.
- The weight of the logs is better distributed on forwarder bunks over six wheels compared to a grapple skidder that carries the weight primarily on two wheels.
- The harvester can armour soft spots with tops and waste logs, to increase the bearing strength of the trail.

Harvesting in frozen or dry conditions reduces the risk of soil compaction because bearing strength of these soils is much greater than in wet conditions. However, the best-laid plans are subject to the vagaries of the weather. Excessive rain, heat, fire weather, and delayed freeze-up are all examples of weather systems that can interrupt forest operations.

Once the harvesting system, equipment, and season have been decided, the distribution of soil disturbance needs some consideration for spread of invasive plant species. When anticipated exposed disturbance is continuous and linear, as along skid trails, tactics should be adopted to reduce or mitigate the disturbance and prevent invasive species establishment.

Choosing Contractors and Logging Systems

It is important to choose contractors with the best opportunity and skills to complete the work according to silvicultural plan objectives and specifications.

Logging contractors are independent businesspeople who have assembled their capital and human resources to undertake a business. Their business model and available equipment may mean that they are well suited to your intervention, or not well suited at all. They have a plan and expectation from their business, and the work you are offering may not match their expectations.

The equipment owned by a contractor is configured for the kind of work they expect to take on. To try something new, the forest professional or supervisor may have to work with someone who is not ideally equipped or has not done this work before. As a result, the contractor's orientation to problem-solving and logistical challenges, and your ability to create a productive working relationship are critical elements. For both, it really helps to be flexible, open to new ideas, collaborative, and solution oriented.

It is a truism that the operator is more important to your success than the machine. A good, experienced operator who welcomes new experiences and is willing to try something out of the usual will help you achieve your goals, even if operating the "wrong" machine.

Setting compensation rates is challenging, particularly when work is new. It is important to work honestly and collaboratively, particularly at the outset, when the contractor is learning and so are you. One strategy is for rates to be agreed upon as interim until some experience is gained and productivity assessments are possible, but this will definitely depend on circumstances and the parties involved in the agreement.

Close collaborative supervision is important to ensure that the contractor is achieving the prescription and leaving the stand in good conditions that are consistent with the silvicultural plan. As always, work collaboratively for improvement, and spend enough time on the block to deal with problems and misunderstandings while they are small.

5.5 SILVICULTURAL RECORD-KEEPING FOR INNOVATIVE FOREST PRACTICES

Silvicultural records play a critical role in linking silvicultural plans, current activities, and future management. If there are no consistent and reliable silvicultural records of what has been done in each stand and on the landscape, understanding the effects of past actions will be challenging. Therefore, it is critical to keep accurate, detailed, and easily accessible silvicultural records over the long term.

The shift towards more diverse silvicultural systems, including partial cutting in British Columbia, increases the importance of this record-keeping to provide long-term comprehension and continuity in silvicultural intent. Some silvicultural systems may leave stands stocked with a commercial overstory for a period during which that growing stock may be rapidly accruing value. The timing of interventions may be critical to success. Similarly, silvicultural systems may leave trees reserved from future harvest for non-timber objectives, but these leave-trees and reserved areas need to be documented and clearly indicated in silvicultural records so that they are not logged in the future.

As an example of the former situation, in a uniform shelterwood, the seed cut leaves the stand stocked with overstory, and the thinning leads to the regeneration of new trees in the shelter of the overstory. If the overstory is not removed in a timely manner, the regeneration will languish in the shade and may not respond well to its eventual release. The removal cut needs to occur after the need for shelter is satisfied and before the regeneration begins to lose vigour. Land managers need an annual or periodic reminder of silvicultural treatments to be implemented and commitments to be fulfilled, particularly since these commitments can span decades.

As another example, experience has shown that areas treated by brushing and pre-commercial thinning present the best opportunity for commercial thinning, but records of the investments decades ago have often not made it into the forest inventory. Robust and easy-to-access records of silvicultural treatments in the past are vital to inform current and future planning for commercial thinning.

Keeping track of the growing stock after a silvicultural intervention is an important part of maintaining the forest inventory. What has been retained and how it will grow into the future is a critical consideration in both stand- and forest-level management planning and in setting harvest levels.

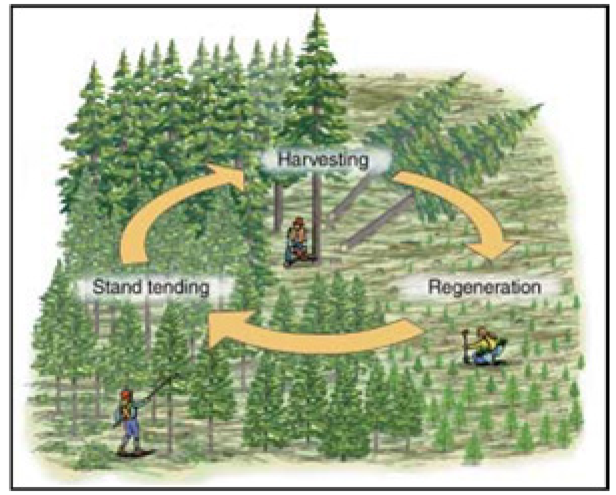
Finally, record-keeping is a critical component of adaptive management. It allows us to answer important questions: *What did we do here? Why did we do that? Did it succeed? What have we learned?* Regularly maintained, reliable, and easy-to-access silvicultural record-keeping systems allow us to learn from past forest management practices, and better understand the complex interplay between site characteristics, current stand conditions, and the actual effects of silvicultural treatments.

APPENDIX

Big Bar Lake near Clinton, B.C. Image source: Ken Day (used with permission).

APPENDIX 1:
SILVICULTURAL SYSTEMS DEFINITIONS FROM *SILVICULTURAL SYSTEMS HANDBOOK FOR BRITISH COLUMBIA (2003)*

REVIEW OF SILVICULTURAL SYSTEMS DEFINITIONS



What is a silvicultural system? Is it only relevant when we are doing something other than clearcutting? Why not keep it simple and speak in terms of clearcutting or selective logging? Why do some seed-tree systems and shelterwoods look the same?

In British Columbia, the careless use of silvicultural systems terminology creates considerable confusion and frustration among practitioners. Yet these systems are the foundation of sustainable forestry at the stand level. Systems are complex integrated programs that are designed to facilitate a process. Silvicultural systems facilitate the process of forest management for predictable sustainable flows of desired goods and services at the stand level. These systems integrate all aspects of forest management over a long time to accomplish this task.

This Appendix gives a brief overview of the range of silvicultural systems. The topic is complex and many good references already exist. Therefore, this section reviews the basic terms, and answers the most common questions regarding silvicultural systems definitions.

What Is a Silvicultural System?

Traditionally, silvicultural systems on most sites have been designed to maximize the production of timber crops. Non-timber objectives, such as avalanche control and wildlife production, have been less common. Recently, ecological considerations and resource objectives have increased. A silvicultural system generally has the following basic goals:

- Provides for the availability of many forest resources (not just timber) through spatial and temporal distribution.
- Produces planned harvests of forest products over the long term.
- Accommodates biological/ecological and economic concerns to ensure sustainability of resources.
- Provides for regeneration and planned seral-stage development.
- Effectively uses growing space and productivity to produce desired goods, services, and conditions.
- Meets the landscape- and stand-level goals and objectives of the landowner (including allowing for a variety of future management options).
- Considers and attempts to minimize risks from stand-damaging agents such as insects, disease, and windthrow.

Even-aged and Uneven-aged Stands

Even-aged stands generally have one 20-year age class. These stands generally have a well-developed canopy with a regular top at a uniform height.

Pure even-aged stands generally have a nearly bell-shaped diameter distribution. This means that most trees are in the average diameter class. However, diameter distributions should be viewed cautiously since diameter can be a poor criterion for age. The smallest trees in natural even-aged stands are generally spindly, with their vigour suppressed by the overstorey.

Uneven-aged stands have three or more well-represented and well-defined age classes, differing in height, age, and diameter. Often these classes can be broadly defined as regeneration (perhaps regeneration and sapling), pole, and sawtimber (perhaps small and large sawtimber). In the classic managed form, where diameters are a good approximation for age, distribution of diameters will approach the classic inverted-J form. The objective of such an approach is to promote sustained regular harvests, with short intervals, at the stand level.

Uneven-aged stands have an uneven and highly broken or irregular canopy (often with many gaps). This broken canopy allows for greater light penetration and encourages deeper crowns and greater vertical structure in a stand.

Integrating "Reserves" within a Silvicultural System

Reserves are intended to satisfy management objectives, requiring that the stand be maintained for a long period. Reserves are forested patches or individual trees retained during harvesting, or other forestry operations, to provide habitat, scenic, biodiversity, or other values, for at least one rotation. Reserves are areas that are to be maintained for a long time, such as more than 100 years—think old trees as in the *Biodiversity Guidebook*. Any incidental seed or shelter to the regenerating stand and site that reserve trees supply is secondary to their purpose as reserve trees. Seed or shelterwood trees are not reserves, since they are removed as soon as a new crop is established. Where trees are not retained for the long term, they are not reserves. Areas that are deferred from harvest only until the adjacent area is greened up are not reserves, simply areas of deferred harvest.

Use of reserves can be compatible with any silvicultural system, under appropriate stand and site conditions. When reserves are combined with a silvicultural system, they are incorporated into the name of the system as in *clearcut with reserves*.

To protect the structural integrity of reserve patches, there will generally not be any harvest entries. However, in limited cases, harvest entries may be required to address safety concerns or a management objective such as forest health. Treatments can be done on reserves for non-timber objectives. The treatment may involve cutting trees. Where a harvest entry occurs, predetermined stocking standards must be met.

There are three types of reserves. Type is based on the objective for the reserve. The two primary types are riparian and wildlife. The third type is a catchall for recording other objectives and simply labelled "other."

1. **Riparian** –as described in the *Riparian Management Area Guidebook*. Typically objectives are to minimize or prevent impacts of forest and range uses on stream channel dynamics, aquatic ecosystems, and water quality of all streams, lakes, and wetlands.
2. **Wildlife** – wildlife-tree management strategies can range from the retention of existing wildlife trees, as scattered individuals or in patches, to the creation of new wildlife trees. Many approaches can be applied within a single cutblock, although reserving patches is usually recommended as the priority approach. Wildlife-tree requirements apply to the use of all silvicultural systems.
3. **Other** – a catchall for reserves that provide for objectives other than the first two categories.

Each type of reserve can be further described as a patch or as dispersed. A patch is a group of trees important enough to be mapped at the scale being used. Dispersed is the appropriate description when trees are being reserved individually or in groups too small to be mapped. Any reserve that is not a patch is, by definition, dispersed.

Note: Reserve trees are greater than 12.5 cm dbh.

The Clearcut System

The clearcut system manages successive even-aged stands by cutting the entire stand of trees at planned intervals (the rotation) then regenerating and tending a new stand in place of the old.

The clearcut system is the most straightforward and easiest system to use, and has been applied around the world. While it has been successful for pure timber management, especially for valuable shade-intolerant species, concern over aesthetics, habitat impacts, and watershed impacts have prompted interest in alternate systems in many areas of British Columbia.

A "clearcut" means a silvicultural system that

a. Removes the entire stand of trees in a single harvesting operation from an area that is:
   i. More than 50% free of the influence of standing trees,
   ii. At least two tree-heights in width, and
b. Is designed to manage the area as an even-aged stand

This definition of clearcut focusses on the size and width of openings. Kimmins (1992) defines clearcutting as harvesting all trees in a single cut from an area of forest large enough so that the

"forest influence" is removed from most of the harvested area. Forest influence occurs along the edge or ecotone of an opening adjacent to a forest and is a gradient of mircoclimates in both directions from the edge of standing timber.

A "clearcut with reserves" means a variation of clearcutting in which trees are retained either dispersed or in small groups or patches, for purposes other than for regeneration.

Patch Cut System

The patch cut system involves removal of all the trees, from an area larger than two tree-lengths in width but still less than 50% outside of edge influence. Each patch cut is managed as a distinct even-aged unit, although they may be aggregated into a cutblock and harvested over time. If an area has several patch cuts, each opening is still managed as a distinct opening. Regeneration is obtained either by artificial or natural regeneration, or a combination of the two.

Many references will recognize this as a variant of the clearcut system. However, in British Columbia the Ministry of Forests recognizes these very small openings, which have characteristics that are different than an average clearcut, as a separate system.

The Basis for the Patch Cut Definition

Smith (1986) recognized the patch cut system as a type of clearcut silvicultural system promoting natural regeneration in small openings. Ashton and Kelty (2018) similarly recognize patches as intermediate between groups and clearcuts.

All definitions of patch cuts include the concept of small openings that will be managed as individual stand units, unlike the openings created in the group selection or group shelterwood systems.

▶ **See** "Additional Reading" (this section).

Retention System

The **retention system** sustains the major ecological conditions and processes characteristic of a forest by maintaining a level of stand structure, complexity, and diversity.

The retention system is a silvicultural system that is designed to:

a. retain individual trees or groups of trees to maintain structural diversity over the area of the cutblock for at least one rotation, and
b. leave more than half the total area of the cutblock within one tree-height from the base of a tree or group of trees, whether or not the tree or group of trees is inside the cutblock.

A harvested area is not a clearcut if the major ecological conditions and processes characteristic of a forested environment remain more or less intact (Keenan and Kimmins 1993). Forest influence extends from residual trees into a harvested area.

A retention silvicultural system is one where the resulting stand/area has retained trees (aggregated, edge, patch, or single) distributed throughout the cutblock, such that if a person were to conduct a random sample (of 20 samples or more) of the area actively harvested, they would find that greater than 50% of the cutblock is within one tree-height of retained trees (i.e., under the influence of retained trees).

The retention system is differentiated from the clearcut with reserves system by the distribution of leave-trees and the influence of edge effect. The retention system requires individual trees or groups of trees to be distributed over the block, with edge-effect influence covering at least 50% of the opening. The clearcut with reserves system is not bound by a 50% edge-influence requirement, nor the distribution over the block.

The retention system requires retained trees to be left in various locations across the whole cutblock, not concentrated in a few areas. The trees can be left singly, in groups of various sizes, or some combination of the two. There can also be a range in the amount and pattern of the retention. Retention objectives are unique to the individual area or landscape unit, and can include, but are not limited to, biodiversity, wildlife habitat, or aesthetic values. These objectives must be clearly expressed in the operational plan for the area.

Regeneration can be accomplished by either natural or artificial methods. A description of the residual stand in the harvested area is required.

Forests are dynamic, and temporal change is a feature of functioning ecosystems. The element of time is a crucial consideration in planning ecosystem maintenance. The structure retained by the retention system will promote a more rapid return of ecosystem functions into the stand. Group retention has the additional advantage of providing refugia for many organisms. These areas can act as lifeboats, that allow organisms to repopulate adjacent areas once conditions become suitable again. With the retention system, the emphasis is on selecting what will be retained.

> *Unlike most silvicultural systems, which are named for the primary method of promoting regeneration, the name of the retention system reflects the importance placed on the structural elements of the pre-harvest stand that are retained after the area is harvested.*

Variable retention is an approach to forest planning and forest harvesting in which structural elements of the existing forest are retained throughout a harvested area through the next rotation, to achieve specific management objectives. The approach utilizes a wide spectrum of retention with varying amounts, types, and spatial patterns of living and dead trees. Variable retention uses all silvicultural systems, from single-tree selection to clearcutting, including the retention silvicultural system, to achieve variable retention over a landscape.

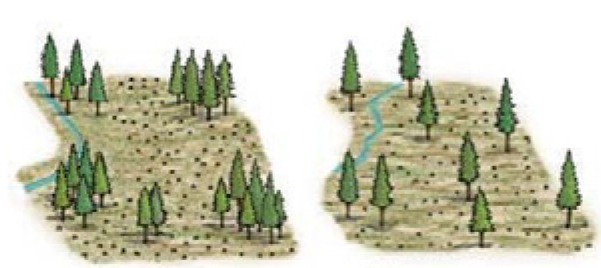
Palik and D'Amato (2024) provide further information, including 19 implementation case studies from around the world.

Seed-Tree System

In a seed-tree system the entire cutting unit is managed as it is with clearcut systems except that, for a designated time period, harvesting excludes those trees selected for the purpose of supplying seed. Trees are generally left just to supply seed for the next crop; therefore, the best phenotypes should be selected to try to encourage desirable genetic traits to meet specified management objectives.

In a classic seed-tree system, natural regeneration is used, although the seed trees may not be relied upon entirely and some planting may occur beneath seed trees, often at reduced stocking levels. It is useful to conduct a stocking survey after 3 years and use fill planting to fill in any gaps in stocking. Usually, the seed trees are removed in a "removal cut" once regeneration is established, although in practice this is not always the case.

Seed-Tree System Variations



a. Uniform Seed-Tree System
   Seed trees are left more or less uniformly distributed throughout the block.
b. Group Seed-Tree System
   Group seed trees are left in small groups. These groups may be irregular or in strips. Seedfall distance and windthrow risk play a major role for their distribution on the block.
c. Combination
   The uniform and group seed-tree systems can be used in combination. When this is done the terminology is combined, as in *"uniform and group seed-tree system."*
d. Seed-Tree System with Reserves
   Reserves can be used with any system.

▶ **See** **"Reserves" in this section.**

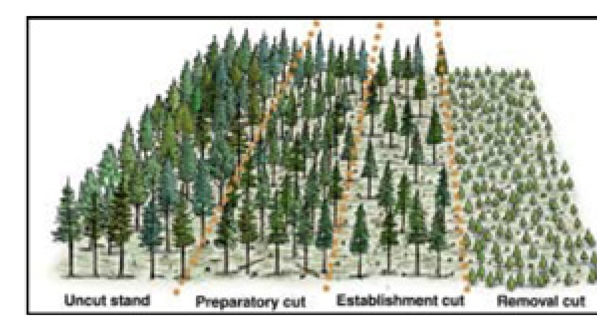
Shelterwood System

In a shelterwood system the old stand is removed in a series of cuttings to promote the establishment of a new even-aged stand under the shelter of the old one.

The primary intent of this system is to provide seed and shelter the developing regeneration. Generally, shelterwood systems aim at natural regeneration, although some planting may occur to diversify the species mix, bolster stocking, and introduce improved seed. The central theme to shelterwoods is that the overstorey leave-trees are left on site to protect the regenerating understorey until the understorey no longer requires the protection. At some point the overstorey starts to inhibit development of the understorey trees through crown expansion and shading. This depends on the density of overstorey trees and the species being managed. The shelterwood trees are removed after the new trees no longer need their protection, so that the new tree can develop uninhibited.

Variations of Shelterwoods

a. Uniform Shelterwood
   Leave-trees are left for shelter, more or less uniformly distributed throughout the block.
b. Group Shelterwood
   Groups are opened in the stand such that the surrounding edges of uncut timber shelter the new regeneration. The group size will be increased by one or more cuts until the entire block has had the overstorey removed. This gradual removal of the original overstorey occurs relatively quickly in successive harvesting entries within a normal regeneration period for an even-aged stand (10–25 years). The final groups to be harvested may require artificial regeneration.
c. Strip Shelterwood
   Initial harvesting occurs in the stand as uniformly spaced linear strips. In future harvesting entries, strips are added beside the initial strips, progressively into the prevailing wind, until the entire block is harvested within a normal even-aged regeneration period (10–25 years). Harvesting in each strip may occur gradually and include a preparatory, regeneration, and removal cut, following in sequence. Strips may be oriented to use the side shade from adjacent timber, maximize sunlight penetration, or allow for visual screening from the uncut stand matrix.



d. Irregular Shelterwood
Irregular shelterwoods differ from others based on timing of harvesting entries. There are longer periods between the initial establishment cut and the removal cut than for a traditional shelterwood (removal period generally exceeds 20% of the projected rotation).

Uniform, group, and strip shelterwoods can all be used in an irregular variant (e.g., *irregular group shelterwood*). This system may be the same as a *shelterwood with reserves* if the overstorey is retained for the entire rotation. The difference is that with an *irregular shelterwood* the removal cut is delayed for a very long time. The intent is to continue to shelter the young stand regeneration for much longer than the normal regeneration period. *"Irregular"* refers to the resulting variation in tree heights in the new stand, which provides an age-class structure that is neither even- nor uneven-aged. This variant is difficult to administer and approaches single-tree and group selection.

e. Natural Shelterwood
The *natural shelterwood,* often referred to as overstorey removal or release cutting, is a form of shelterwood where the overstorey is removed to create open growing conditions for a fully stocked suppressed understorey. This form of shelterwood has only a removal cut as a harvesting entry.

f. Nurse-tree Shelterwood
This form of shelterwood is similar to a natural shelterwood except that the overstorey trees are of a different species from those in the understorey. The establishment cut would leave the overstorey nurse-trees, while the removal cut removes the overstorey nurse-trees.

This shelterwood approach follows natural successional patterns in stands such as those that include aspen and spruce, larch and redcedar (or hemlock), pine and spruce (and subalpine fir), alder and redcedar, and cottonwood and Sitka spruce (or redcedar). Often these stands are originally established after large disturbances that open the entire stand. Both species may establish at approximately the same time. The understorey species may build its presence more slowly under the established overstorey.

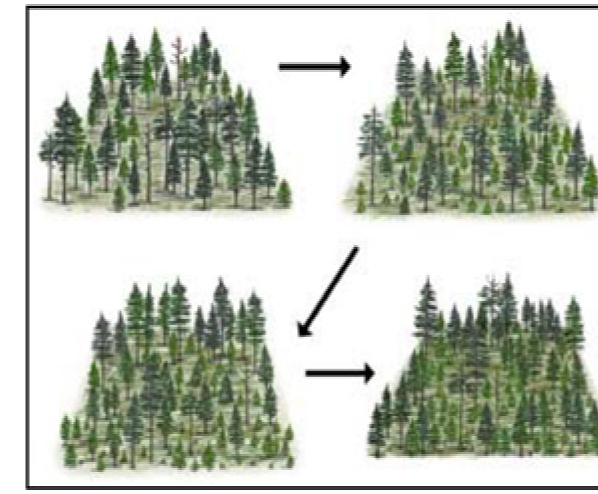
Nurse-tree shelterwoods may be started in cleared areas by planting. For example, at the Malcom Knapp UBC Research Forest, alder and western redcedar have been planted together for this purpose. Nurse-tree shelterwoods have been established through underplanting where the pioneer species is already established as a continuous canopy. In such cases, gaps in the canopy may be created by cutting or girdling to increase early survival and growth in the understorey. When long-lived species are managed as the pioneer overstorey, careful retention of a pioneer component through the rotation will ensure a regeneration potential for that component, helping to sustain the system, if that is desired.

g. Combinations
The following combinations of shelterwoods may commonly be applied:
- Group and strip – different combinations of group and strip are commonly used in Europe and elsewhere.
- Uniform and group – may be used when sheltering leave-trees are clumpy in distribution.
- Irregular with uniform, group, strip, or nurse-tree – as described previously.

h. Shelterwood System with Reserves
Reserves can be used with any variant of the shelterwood system (e.g., *strip shelterwood with reserves*). These may be a form of irregular shelterwood.

▶ **See** **"Reserves" in this section.**

Selection System



Selection systems remove mature timber either as single scattered individuals or in small groups at relatively short intervals, repeated indefinitely, where an uneven-aged stand is maintained. Regeneration should occur throughout the life of the stand with pulses following harvest entries.

These systems depend on recruitment of trees into successive age classes over time and the predictable yield from merchantable age classes. Yield will be obtained by thinning clumps, by harvesting individual trees, or by harvesting whole groups of the oldest age class to create small openings scattered throughout the stand.

The selection system can be complex. Three variations of selection systems are used.

Variations of the Selection System

a. Single-tree Selection
Single-tree selection removes individual trees and small clumps of trees of all size classes, more or less uniformly throughout the stand, to achieve or maintain a balanced, regulated, uneven-aged stand structure. It is easier to apply such a system to a stand that is naturally close to the uneven-aged condition. However, an even-aged stand can be converted to an uneven-aged stand for management under a single-tree selection system, although numerous establishment cuttings must be made to bring the stand into a structure where the system can truly be applied.

Once the uneven-aged structure approximates the balanced condition, the single-tree selection system generally manages a complex mixture of small even-aged clumps that are thinned over time. In theory these clumps should be able to yield at least one mature tree of the specified maximum diameter; however, in practice these clumps are often larger.

New regeneration develops in small, scattered gaps. Since regeneration is always being recruited and larger mature trees are scattered individuals or very small groups, these stands appear quite open, with many gaps. Since regeneration is always being recruited and immature age classes are intermixed in a balanced uneven-aged structure, the total stand basal area may be somewhat less than that of a fully stocked, mature, even-aged stand on a similar site.

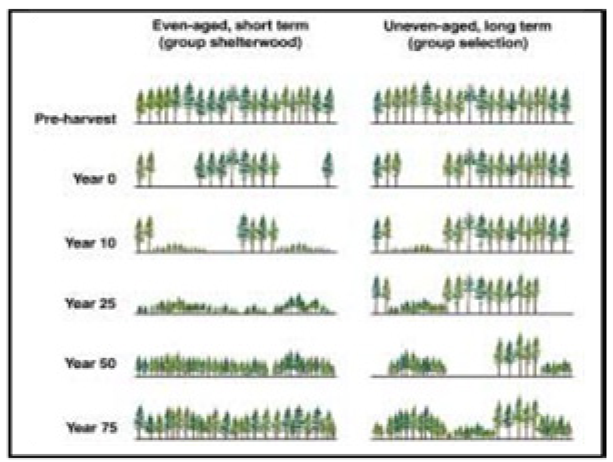
Issue: *Single-tree harvesting is not necessarily single-tree selection.*

Single-tree selection is a term that has been misunderstood and therefore abused in British Columbia. It has been incorrectly applied to many stands where single trees were only harvested for salvage, highgrading, or general thinning. This has created considerable confusion around the term.

Single-tree selection manages a stand using regular, predictable sustained harvesting entries in perpetuity by managing towards a balanced (or close to balanced) uneven-aged structure, as described previously.

Single-tree selection is much more complex than removing a few large trees from a stand. While highgrading should not be tolerated, one would legitimately harvest a portion of the large trees at each entry while thinning throughout the stand to create growing space for retained trees and allow a pulse of regeneration.

A 0.25-ha first-entry opening in a group selection system in the Engelmann Spruce–Subalpine Fir (ESSF) zone.



First-entry strips in a four-pass strip selection system in the Interior Cedar Hemlock (ICH) zone. Future strips will progress down the ridge (to the right) into the wind.

b. Group Selection
Group selection systems also promote uneven-aged stands with groups of even-aged trees well distributed throughout the cutting unit. Unlike single-tree selection, however, these small even-aged groups are large enough that they can be laid out and tracked within the stand (LEFT). The small gaps or openings are created at intervals to develop a mosaic of at least three or more age classes throughout the stand (MIDDLE, LEFT). The harvesting entries are light enough so that an uneven-aged structure develops, unlike a group shelterwood.

Groups may be uniformly staggered narrow linear strips (usually 15–50 m wide). Future harvesting strips are added at regular intervals beside the initial strips, progressively into the prevailing wind (BOTTOM, LEFT). Such an approach minimizes windthrow risk.

Harvesting intensity and timing between entries are planned to create an uneven-aged stand with linear groups of age classes, thus meeting the definition of selection. This differs from its shelterwood counterpart by harvesting the entire area much more slowly over time through harvest entries that remove much less volume.

c. Selection System with Reserves
Reserves can be used with any variant of the selection system (e.g., *group selection with reserves*).

The Coppice System

The coppice system is defined as an even-aged silvicultural system for which the main regeneration method is vegetative sprouting of either suckers (from the existing root systems of cut trees) or shoots (from cut stumps). In British Columbia, this system is limited to broadleaved (hardwood) species management. Due to the shade-intolerant nature of most of British Columbia's broadleaf commercial tree species, the coppice system is generally conducted in stands larger than a patch.

Variations of the Coppice System

a. Coppice with Reserves
Reserves can be used with the coppice system.

b. Coppice with Standards
Standards are trees retained at the time of harvest for the purpose of improved growth and later removal. Standards are generally of a different species, regenerated by seed, and will have a higher value than the coppice species when they are harvested. Spruce and aspen, or redcedar and cottonwood, are two examples of potential mixtures.

Autecology is the study of the interaction of a species with its environment, including concepts such as tolerance, sensitivity, and limiting factors.

Brushing is done shortly after regeneration (+/- 10 years) to adjust the species composition of the young stand. May be in conjunction with spacing.

Cultural or prescribed fire is an intervention intended to reduce vegetation and surface fuels, releasing growing space and supporting traditionally important plants.

Dispersed refers to scattered individual trees or small clumps of several trees.

Forest is a complex ecological system and natural resource in which trees are the dominant life-form. In an administrative sense, this definition may be taken one step further to also mean a tenure unit, comprising part of one or more landscapes.

Forest influence is the total area of the intervention that is within one tree-length from the base of a tree or group of trees, whether the tree or group of trees is inside or outside the cutblock.

Group opening is an opening with a maximum width of two mature tree-heights across the open area (Ashton and Kelty 2018); groups are large enough to be mappable operationally.

Group retention refers to intact portions of the preharvest stand up to and including two mature tree-lengths in width.

Hazards are intrinsic stand or site characteristics that increase the vulnerability of a specific stand in a specific location to threats from biotic or abiotic damaging agents.

Higher-level planning is a collective term for all the various planning activities that set expectations for land management at the provincial, regional, and landscape levels. These planning activities result in goals and objectives to which silvicultural planning must respond.

Intervention is any management activity within the stand that changes the stand development trajectory. Interventions are planned to influence the stand development towards the desired future condition.

Land manager refers to those with legal authority to set plans for and direct broader-scale land management.

Landscape is a planning area delineated based on a number of biophysical features. Typically, they cover a watershed or series of watersheds incorporating multiple individual stands.

Patch opening is an opening with a width greater than two mature tree-heights across the open area (Ashton and Kelty 2018), but a harvested patch has more than 50% of the area within a tree-length of an edge (Keenan and Kimmins 1993).

Patch retention refers to intact portions of the preharvest stand more than two tree-lengths in width.

Regeneration cut is the process and actions of establishing young trees on an area after a disturbance, such as removal of overstory trees. Regeneration is an important element of a stand.

Removal cut is an intervention designed to release regeneration (of trees and/or other target vegetation) from the overhead shade of the retained overstory by opening or removing overstory.

Reserves are required by regulation (e.g., wildlife tree reserves, riparian management areas) or practice standards (e.g., dispersed reserves or large veteran trees). Legal reserves are generally intended to be long term.

Resilience is the capacity of an ecosystem to recover to essentially the same community composition and ecosystem structure and function after being impacted or modified by a disturbance. For example, a resilient forest can recover to an approximation of its pre-disturbance state, following a wildfire that was severe enough to significantly alter its structure, composition, or function. Resistance is often considered to be one aspect of ecosystem resilience.

Resistance refers to the capacity for an ecosystem to resist the impacts of disturbances without undergoing significant change. For example, wildfire can burn through a resistant forest without significantly altering its structure, composition, or function. The structure and composition of a low-density forest dominated by fire-tolerant trees is perpetuated by frequent, low- to moderate-severity fire as it repeatedly consumes fuels and regeneration in a patchy way.

Restoration includes activities that assist the recovery of ecosystem integrity when they have been degraded, damaged, or destroyed and that enhance the capacity of an ecosystem to adapt to change. Ecological restoration focusses on re-establishing ecosystem functions by modifying or managing the composition, structure, spatial arrangement, and processes necessary to make ecosystems ecologically functional and resilient to disturbances expected under current and future conditions.

Retained stand matrix relates to the rest of the forested stand where gaps will not be created.

Retention is left for specific objectives, most often conservation of biodiversity, and can be left for varying lengths of time, but is often long term.

Retention system is a silvicultural system that is designed to retain individual trees or groups of trees to maintain structural diversity and forest influence over the majority of the harvested area for at least one rotation. Generally, retention is intended to be long term, with no intention of future removal.

Risks are a combination of the likelihood of an impact and consequences of that impact.

Silvics is the body of knowledge that describes how trees will grow in their environment, including their competition with their community. It is the foundation of silvicultural practice.

Silvicultural plan is a site-level plan prepared by a qualified forest professional that is a prescribed silvicultural intervention to influence the development of a stand on a pathway from current pre-treatment condition towards a desired future condition.

Silvicultural system is a plan for the care, development, maintenance, and/or replacement of a forest stand over time via stand interventions to promote specific stand structural characteristics, ecological conditions, and features consistent with desired objectives and values for the site. Time periods for silvicultural systems are longer, typically ranging from multiple decades to one or more centuries. These time spans are sometimes expressed as “over the life of the stand.”

GLOSSARY

Site is an area described or defined by its biotic, climatic, and soil conditions in relation to its capacity to produce vegetation. It tends to describe the smallest scale for forest management planning, below a stand.

Spacing (or pre-commercial thinning) is done shortly after regeneration (+/-15 yr) to favour the growth of desirable individuals, as an investment in the quality and growth of the stand (Ashton and Kelty 2018).

Stand is the basic management unit for the application of silvicultural decisions, defined by differences in forest age, composition, or productivity.

Standards unit is one or more parts of a cutblock for which a standard of achievement has been established through the silvicultural plan.

Stand development pathway is the course of stand development towards the desired future condition, as influenced by interventions over time.

Stand interventions are the intentional manipulations of ecosystem structure, composition, or dynamics within a stand by forest managers to move the stand towards an end goal.

Stand neighborhood includes a stand, several stands, and/or denuded areas within and surrounding the area under the silvicultural plan, and includes adjacent forested and non-forested ecosystems that may be influenced by silvicultural and management interventions.

Thinning (or commercial thinning) is the removal of individual trees from a stand to maintain or improve the health of remaining trees by providing more space and resources to grow (e.g., sunlight, water, and nutrients). The choice of trees to be retained and the resulting stand density or structure will be based on the management objectives for the stand (Ashton and Kelty 2018). Commercial thinning yields a commercial product from the thinning.

Variable density thinning is a commercial entry that varies the intensity of removal across the stand, to create gaps, thinned areas, and unthinned areas. The purpose is to accelerate the development of complexity and heterogeneity, including the regeneration of new cohorts in gaps (Palik and D'Amato 2024).

Variable retention uses all silvicultural systems, from single-tree selection to clearcutting, including the retention silvicultural system, to achieve variable retention over a landscape.

Variable retention harvest is an intervention that emphasizes the permanent retention of mature canopy trees—as well as other important structural legacies—at the time of regeneration harvest. It is an approach to forest planning and forest harvesting in which structural elements of the existing forest are retained throughout a harvested area until at least the next rotation to achieve specific management objectives. Varying amounts, types, and spatial patterns of living and dead trees are retained.

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