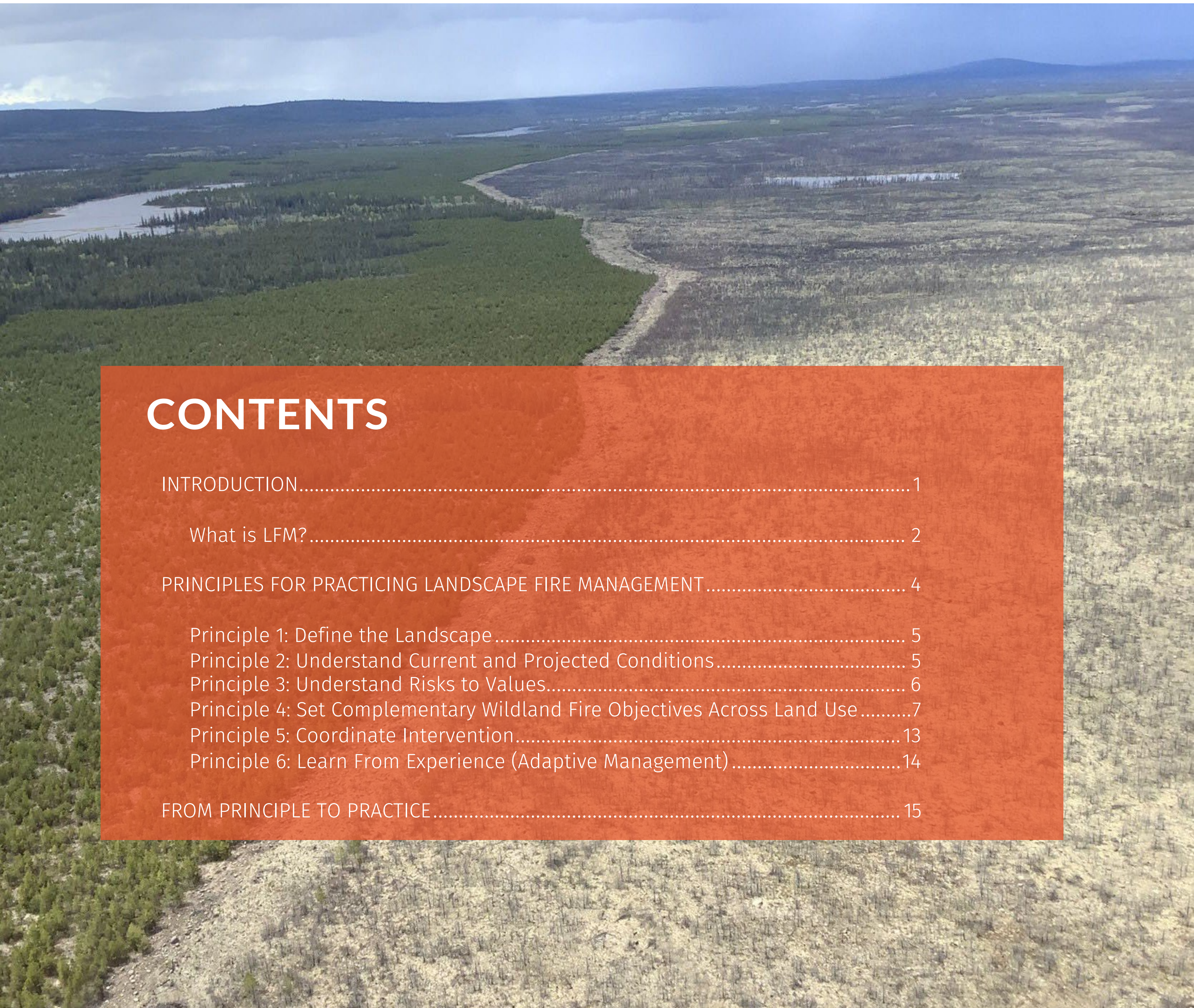
PRACTICING LANDSCAPE FIRE MANAGEMENT

Forest Practices Board

TECHNICAL BULLETIN



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INTRODUCTION

Wildfire can be ruinous, affecting individuals and society, from our personal health and well-being to the health of the economy and the ecosystems we depend on. Wildfire can also be renewing. Over millennia, many ecosystems adapted to fire. For some areas of BC, regular cycles of burns and re-burns created conditions that limited fire severity. However, the current status of our forests, and longer, more intense fire seasons due to climate change have contributed to conditions that lead to catastrophic consequences from wildfires.

To mitigate these risks, land managers have been working to reduce the negative impacts of wildfires on communities, particularly in the wildland urban interface (WUI). However, these efforts have largely overlooked the broader landscape.

Shifting forest and fire management policies, objectives, and practices is crucial for coexisting with fire on the landscape and restoring landscape resilience. Integrating Landscape Fire Management (LFM) into the land management framework in BC serves as the initial step.

LFM is an integrated system that facilitates both restoration and risk reduction. It involves a high level of coordination amongst land managers, where protected area management, utility corridor design and maintenance, roads, design, reforestation and stand tending are thoughtfully aligned. It calls for shared or complementary wildland fire objectives between adjacent land use zones, jurisdictions and resource users.

The BC Forest Practices Board's recent Special Report: *Forest and Fire Management in BC: Toward Landscape Resilience,* highlights the need for government to lead the integration of LFM into cycles of planning and provide a framework to guide land use and risk-reduction initiatives across all sectors.

WHO IS THIS BULLETIN FOR?

This bulletin is for land managers, including those in provincial, Indigenous and local governments, as well as those in industry. This includes forest professionals involved in forest landscape planning and protected area management. It also includes land managers in fire management, water management, mining, transportation, oil and gas, and energy and regulated companies in those sectors whose activities have a direct bearing on the health of BC's ecosystems.

Through its work on the special report, various principles emerged that are useful for putting LFM into practice. Each of these principles is described in this bulletin. The field of LFM is evolving, with an assortment of approaches to achieve it: some known, some novel, or yet developed. These principles are meant to be a reference point in an ongoing discussion. Practical examples of how the principles can be incorporated into planning and practice are provided for land managers and natural resource practitioners.

The purposeful integration of forest and fire management at this scale is a new yet necessary paradigm for land managers. We'll briefly discuss what LFM is, who does it, why it matters, and then present some principles useful for practicing LFM. The Board hopes that this bulletin can help to better integrate forest and fire management in BC.

What is LFM?

Landscape fire management is an ecosystem-based practice of managing fuels within forest and non-forest landscapes to achieve specific objectives such as restoring a mosaic of forests resilient through fire, reducing catastrophic wildfire, or improving wildlife habitat. Achieving landscape resilience will require cohesive effort across different scales of management, including the forest stand, watershed, and landscape scales. In part, this is achieved by coordinated activities to modify fire behaviour on a large scale, serving to contain or reduce wildfire spread in high-impact areas. Those actions are directed by a goal of increasing ecosystem health by bringing landscapes into balance with natural disturbance regimes while considering the effects of a changing climate.

Through engaging with over two dozen experts in fire and forest management during the development of our Special Report, *Forest and Fire Management in BC: Toward Landscape Resilience*, some useful principles for putting LFM into practice emerged:

1. Landscape Identification: adopt broad-scale boundaries that account for natural and human-made barriers to fire that extend well beyond the wildland urban interface;
2. Environmental Condition Awareness: understand fire regimes and what affects them within the landscape, including anticipated fire behaviour;
3. Consequence Assessment: identify the real and potential effects of fire on known values;
4. Complementary Objective Setting: set wildland fire objectives that are complementary across land use zones;
5. Deliberate Intervention: where appropriate, intervene with carefully coordinated management, and;
6. Adaptive Management: learn from experience, experts, elders and knowledge keepers.

In some ways, these principles were practiced for millennia by Indigenous stewards in many parts of BC.[i] Today, these principles are sometimes applied around the edges of communities, but at a landscape scale, they're only practiced in a limited number of places in BC or Canada.

Why do we need to practice LFM?

BC's forest management practices, driven by goals of safety, economic growth, and environmental conservation, have inadvertently contributed to heightened wildfire risk. In parts of BC, fire exclusion has reduced wildfire frequency, allowing for forest in-growth and encroachment on grasslands. Forestry has favoured well-stocked, even-aged conifer plantations and suppression of deciduous species. This, along with extensive salvage harvesting and post-harvest fuel management, has influenced the age, pattern and distribution of forest fuels.

In much of BC, wildland fire[1] plays an important role in ecosystem functions, including maintaining ecological resilience. Many landscapes are in "fire deficit", meaning the return intervals of fire have been postponed and the cycle of periodic disturbance interrupted, particularly in frequent, low and mixed-severity fire regimes. These fire deficits, coupled with climate change, affect the scale of wildfires and can alter fire regimes, frequently resulting in catastrophic wildfires which are outside the adaptive capacity of forest ecosystems.

Catastrophic wildfire happens when moderate to high-severity fires result in high impacts on human health and environmental, economic, and social values. By the end of the century, the likelihood of catastrophic wildfires will increase globally by a factor of 1.31 to 1.57.[ii] The combination of increased weather conditions conducive to wildland fire, including extended fire seasons and extreme weather events, along with approximately 39 million hectares currently classified as high to extreme wildfire threat, elevates the risks for catastrophic wildfires in BC.

Resources for fire suppression and prevention are limited, so actions must be both well informed and wisely invested to protect societal values while recognizing the important role of fire in ecosystem function and ecological processes.

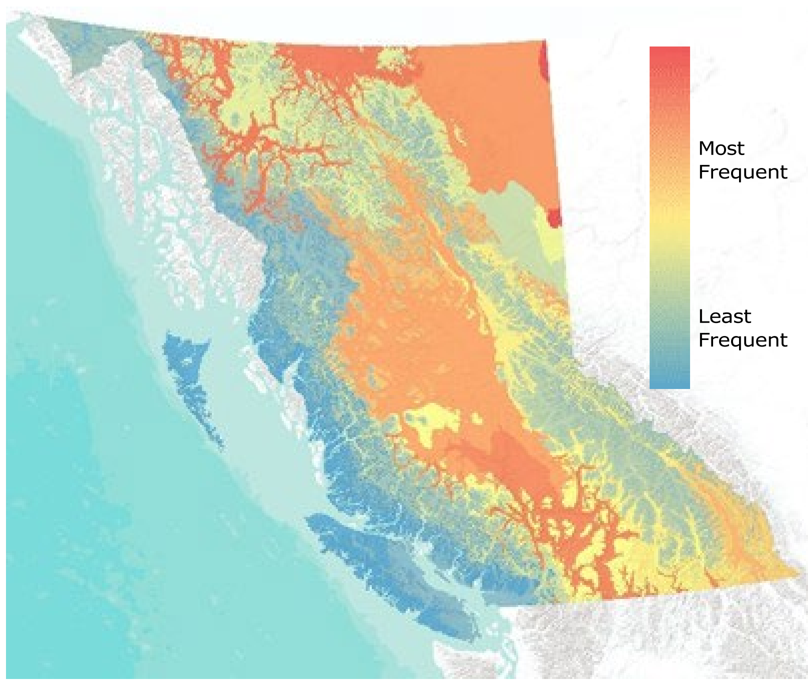


Figure 1. Fire frequency across fire regime types, developed by the Canadian Forest Service (Erni et al, 2020) and building off NDT/BEC linework, is a classification system to help regionally distinguish fire regimes.

[1] A wildland fire is any fire that is burning in and consume natural fuels: forest, brush, tundra, grass, etc. Includes wildfires and prescribed fires. Sourced from Canadian Interagency Forest Fire Centre (CIFFC). *Canadian Wildland Fire Glossary*. March 16, 2022. Retrieved from https://ciffc.ca/sites/default/fles/2022-03/CWFM_glossary_EN.pdf

Who must make LFM happen?

LFM is an integrated and interdisciplinary approach. It is led by governments and is informed by fire specialists and resource users. It is implemented both through Indigenous fire stewardship and at an industrial scale, integrated into the planning and business cycles of the forest industry, transportation, energy sector and protected area management.

Recent amendments[2] to the *Forest and Range Practices Act* (FRPA) require the provincial chief forester to consider the objective of preventing, mitigating and adapting to the impacts caused by significant disturbances to forests, including wildfire, when preparing a forest landscape plan (FLP). FLPs represent one policy framework to set fire objectives, but it isn't the only way. Government and all land managers need to carefully consider existing policy tools and initiatives for establishing fire objectives.

As described in the Board's Special Report, *Towards Resilience: Landscape Fire Management,* LFM requires vision and leadership. A government-led initiative would help ensure adequate support from tenure and taxation policies, as well as integrated landscape-level objectives.

SOME FIRE-DEPENDENT ECOLOGICAL PROCESSES

"Fire regulates the accumulation of above-ground dry biomass and can be a major determinant of nutrient cycling and energy flow.

Fire may stimulate sprouting, flowering and fruiting of shrubs and herbs and can trigger the release of seeds of serotinous tree species.

Fire releases mineral elements from living and dead organic substances, with some elements being volatilized.

Fire reduces plant cover shading and therefore increases the input of solar insolation which affects soil temperature and local microclimate.

Fire is an important regulator of insect populations and can terminate large outbreaks through the destruction of the host trees.

Post-fire levels of forage and browse plants may be higher than pre-fire levels and can represent an important food source for certain wildlife species."

Excerpt from Parminter, J. 1983. Fire History and Fire Ecology in the Prince Rupert Forest Region. Land Management Report 16, Ministry of Forests.

What does LFM look like?

To help illustrate LFM, imagine a landscape as a box: the edges are human-made or natural areas of low fuel that can help to contain or slow wildfires, and the insides are forests and the many values they provide. LFM initially focuses on modifying fire behaviour at the edges of the box by treating a small portion of the landscape to affect the size, location and impact of fire on communities, critical infrastructure, habitats and watersheds. By treating a small portion of the landscape, LFM facilitates wildfire containment, putting the right-size box around a wildfire by using a network of both human-made and natural fuel breaks like water, rock, ice and snow to limit the potential of wildfire spread and growth. By limiting potential fire behaviour, LFM can provide wildfire response decision-makers with a broader range of options to minimize adverse effects and maximize the beneficial effects of fire on the landscape.

Treating the "edges"[2] is not a cure-all. A longer-term goal of LFM is to treat the inside of the box. That includes an accepted, if not intentional, distribution of fire over time and space to achieve a mosaic of ecosystems that are resilient through fire. The patchiness of fire distribution results in the diverse successional conditions of the forest. Moreover, the combination of these successional stages and fuel conditions determines the diverse patterns of future fire behavior and severity. In essence, patterns shape processes, and processes shape patterns.

Mimicking the patterns of vegetation that develop in response to fire regimes can be one approach to achieving this goal. Fire regimes are driven by differences in climate, physiography (slope, aspect, elevation), and vegetation (fuel types) leading to variations in the frequency, size and severity of fire. Low, mixed, and high-severity fire regimes can produce stabilizing feedbacks that help moderate future burn severity.[iii] Activities such as prescribed burning and silviculture that mimic natural patterns of disturbance can lead to vegetation structure, composition and distribution that help to maintain resilient ecosystems. Some land managers we interviewed, including those in the US Pacific Northwest and with Parks Canada, aim to have at least 30-40 percent of a landscape under some form of fuel management to achieve resiliency.

NATURAL DISTURBANCE TYPE (NDT) MANAGEMENT AND FIRE

The NDT system was introduced in the 1990s and provides a framework for a natural-disturbance-based management paradigm for BC.[iv] It was introduced as an amalgamation of many disturbance agents without differentiating the effects, interactions or synergisms between those agents.[v] This has led to a simplified understanding of disturbance frequency and severity of fire as either stand-maintaining (NDT4) or stand-replacing disturbances (NDT3, NDT2, NDT1). However, fire ecologists distinguish fire effects across a spectrum of frequencies (frequent, infrequent, rare) and severity (low, mixed or high severity), differentiating fire regimes.[vi] Fire regimes and fire history are an important reference point in LFM and can provide stand and landscape-level ecological indices for planning and practice.

[2] As of July 2023, the amendments are not yet in force.

PRINCIPLES FOR PRACTICING LANDSCAPE FIRE MANAGEMENT

The Board engaged over two-dozen experts in forest and fire ecology, including Indigenous stewards, scientists in government and academia, industry practitioners, and sector leaders. Common themes emerged as principles of LFM. These principles can be integrated into practice for land managers across all land uses, whether actively changing vegetation or planning for the exclusion or inclusion of fire to mitigate risks and/or promote resilient landscapes. They can be used for conservation initiatives or forest operational planning, whether from a forest landscape planning table or a future iteration of a similar process. They cohesively link a strategic plan to activities on the ground in an iterative and incremental way.

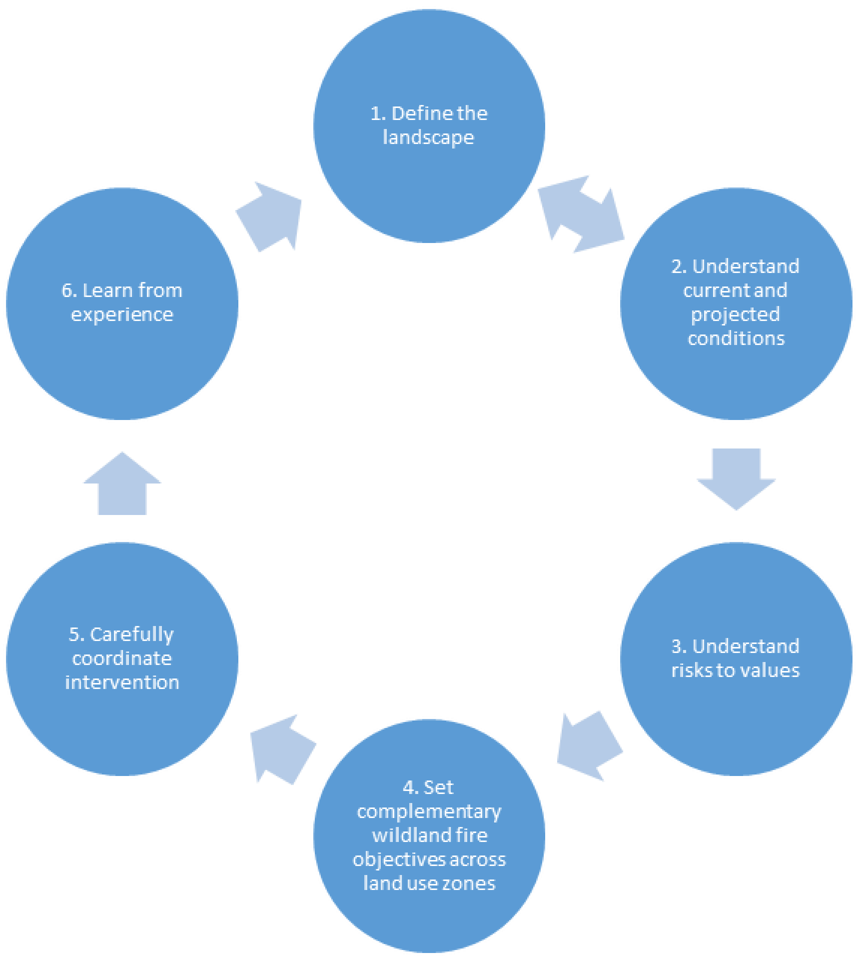


Figure 2. Six principles for practicing landscape fire management.

Principle 1: Define the Landscape

Administrative boundaries rarely align with natural patterns of fire and fuel on the landscape. Since fire doesn't adhere to administrative boundaries, it's important to consider where and how fire can spread and grow within a planning unit.

Planning in the United States has been based on the concept of a "fireshed" as a geographic "box" to manage wildfire risk, within which fire can be managed to mimic natural disturbance, minimize adverse effects, and enhance beneficial fire effects.[3] Boundaries of firesheds should be relevant to fire containment or fire control features, such as waterbodies, roads/hydro lines, or transitional fuel features (e.g., ridgetops).

The size of firesheds reflect landscape conditions, and can be up to tens of thousands of hectares. The size and shape of the planning unit likely corresponds to those useful for forest landscape planning, such as subdivisions within existing landscape units used throughout the province.

Defining the planning unit (e.g., landscape or fireshed or a 'potential operational delineation' or PODs as they are called in the US[4]) should be done with a knowledge of the location of values at risk and landscape conditions, including potential fire behaviour. These boundaries of firesheds might change as more is learned about the current and projected environmental conditions.

Principle 2: Understand Current and Projected Conditions

To help mitigate the risk of catastrophic wildfire and realize the benefits of wildland fire, it is crucial to know where fires are likely to start and how they are likely to spread. LFM involves risk management. In natural resource research, risk is a measure of the probability that something will happen and the seriousness of the consequences (e.g., likelihood x impact).[vii] The landscape condition describes the hazard, based on fuel types, past fire patterns, likelihoods of ignition sources, and predicted fire behaviour. It also describes the current fire regime, its departure from historical fire regimes, and a projection of future fire regimes. A description of the landscape condition also includes information on recent disturbance by insects or wildfire and patterns of land use, including harvest history and access.

The BC Wildfire Service (BCWS) publishes both the Head Fire Intensity[5] (HFI) and the Provincial Strategic Threat Analysis[6] (PSTA) threat rating which provide a good baseline to measure the current landscape condition. The HFI is periodically updated with forest cover and predicts a fireline intensity based on the type of fuel present, the slope and aspect of the land, and expected weather conditions. The PSTA uses HFI and other information to assess the threat of wildfire to certain known values. These publicly accessible maps and spatial data serve as the foundation for wildland fire planning in BC.

Assessing landscape fire metrics and fire risk modeling can pose difficulties in regions with low burning probability, like the boreal forest. While probabilistic modeling may not be the most effective approach for capturing the risk of rare events,[viii] researchers are exploring promising alternatives, such as fire exposure metrics.[ix]

Figure 3. Mixed severity fire effects and a secondary fuel break in the Cariboo.

[3] These are also sometimes referred to as Potential Wildland Fire Operational Delineators (PODs).
[4] For more information on PODS, see: https://www.fs.usda.gov/research/rmrs/projects/pods
[5] https://catalogue.data.gov.bc.ca/dataset/bc-wildfire-psta-head-fire-intensity
[6] https://catalogue.data.gov.bc.ca/dataset/bc-wildfire-psta-fire-threat-rating

LFM should consider how hazards change over time, projecting environmental conditions across future scenarios. There are major gaps in this field in BC, but this shouldn't stop LFM planning. Fire weather and fuel types are necessary to model future hazards. Fuel types can be modelled over time to reflect forest succession and related changes in fire behaviour. This could be advanced through growth and yield models to change forest cover (the current fuel type base in BC). Climate change modelling has been linked to both temperature and precipitation change, so it is possible to estimate trends in future fire weather. Wildfire is part of a feedback loop that can have beneficial or detrimental effects on ecosystem productivity. A site that sustains forests now may not after a burn or reburn. For this reason, modelling future hazards should be iterative and ongoing, accounting for updates in disturbance, burn severity and forest composition.

Fire behaviour is determined by a number of factors including topography, vegetation patterns, fuel types,[7] fuel load and arrangement and fire weather (such as dominant windspeed and direction). Some areas are intrinsically at a higher or lower hazard for burning than others due to landscape positioning and fuel types. Modelling current conditions and various fire weather scenarios helps to illustrate how landscape conditions affect fire behaviour.

Canada's Forest Fire Behaviour Prediction System (FBP)[x] classifies 16 fuel types across BC. Despite some limitations with how the system treats modified fuel-treated stand structure.[xi] These fuel types are often used as inputs for fire behaviour models, predicting fire behaviour in untreated natural stands. A fuel type layer is derived from the Vegetation Resource Inventory: it is updated annually and is available on BC Data Catalogue. Some of the most common fuel types in BC include:

- C3 *Mature Jack or Lodgepole Pine:* The most common fuel type in BC, characterized as fully stocked (1000-2000 sph) pine stands, matured to the stage of complete crown closure.
- C7 *Ponderosa Pine and Douglas-fir:* Open and uneven-aged stands of ponderosa pine and Douglas-fir. Woody fuel accumulations are light and scattered with shallow to non-existent duff layers.
- M1 or 2 *Boreal Mixedwood:* Stands with mixed coniferous (black spruce, white spruce, subalpine fire) and deciduous (trembling aspen, white birch) species. Seasonality greatly affects fire spread rates, with the summer/leaf-out phase (M2) exhibiting more slowly spread rates than spring phases (M1).
- D1 or 2 *Leafed or Leafless Aspen:* Pure semi-mature trembling aspen stands with seasonal variations of leafless (D1) and leaf-out phases (D2). Well-developed shrub understory typically present with dead and down roundwood fuels as a minor component of the fuel complex.
- O-1 *Grass*: Continuous grass cover, with occasional trees that do not affect fire behaviour.

MODELLING TOOLS USEFUL FOR FOREST AND WILDLAND FIRE MANAGEMENT

BC's fuel-type layer serves as the foundation for various fire behaviour modelling software. Some models currently used in BC include:

- FuelCalcBC: a tool to help set pruning targets by inputting field data. This tool allows users to determine the desired lift or height based on the tree's canopy base, the density of the canopy bulk density, and the presence of surface fuel.
- Crown Fire Initiation and Spread Model (CFIS): provides outputs for (1) the probability of crown fire initiation or occurrence, (2) the classification of crown fire type (active or passive) and its rate of spread, and (3) the minimum spotting distance needed to enhance the overall rate of spread for a fire.
- Critical surface intensity calculator: inputs fuel type, crown base height (CBH) and the foliar moisture content (FMC) according to date, location and elevation to help predict whether a fire will be surface or a crown fire.
- Spatial Management System (SMS): approximations of danger ratings and fire behaviour at a province-wide daily and hourly scale.[xii]
- Prometheus: a scenario-based and fine-scale program for operational use and planning.[xiii]
- Probabilistic Fire Analysis System (PFAS): predicts the probability and direction of fire growth using climatology.[xiv]
- Burn Probability, Prediction and Planning (Burn P3): uses simulations of fires based on local fire history.[xv]
- Canadian Fire Effects Model (CanFIRE): uses Fire Weather Index and FBP system rate of spread inputs, along with estimated fuel load values to estimate the critical surface fire intensity (CSI) to initiate crowning.

Principle 3: Understand Risks to Values

To assess the consequences of catastrophic fire, it is key to set priorities for values and understand where those values are in relation to landscape conditions. BC has a lot of experience in planning how to resource fire suppression relative to values at risk from wildfire. Public safety always takes priority, typically followed by critical infrastructure and high environmental values (such as drinking water sources). However, many other values are at stake, including values identified by Indigenous peoples or the many values identified under the *Forest and Range Practices Act* (FRPA), such as biodiversity or timber.

Despite our sophisticated fire suppression regime, in difficult fire seasons, BCWS must balance risk to values against available resources. Using LFM, we can prioritize and reduce risks to other values, such as cultural heritage, watershed health, wildlife habitat, and timber resources.

BCWS has been guided by the Resource Sharing Wildfire Allocation Protocol (RSWAP) to determine protection priorities throughout the province. This protocol defines four priority levels based on high-value resources and assets at risk. In descending order of priority, the four levels are: 1) life and property; 2) critical infrastructure; 3) high environmental and cultural values; and 4) other resources. These priorities set a good standard to apply a risk assessment for LFM.

[7] The FBP system relies on fuel types derived mostly from eastern forests: few of these fuel types describe representative forests in BC. Therefore, the interpretation of fuel types needs an understanding of the physical characteristics of the specific stand type and which fuel type best represents that stand type within the Canadian system.

While RSWAP priorities around communities will always be necessary, land managers will find exceptions to RSWAP. For example, while timber is ranked as one of the lower priorities, an area of merchantable green timber that sustains a mill and community economy may have an equal consequence as critical infrastructure. Similarly, a traditional use area or rare old growth ecosystem may have an irreplaceable value, elevating the need to define wildland fire objectives. Practitioners should look at RSWAP as guidance, but it is not a recipe in assigning priorities to regionally important values that need protection from wildfire.

The PSTA is a threat analysis that uses structure density as a proxy for public safety. While this is an important input, the threat to other societal values also should be assessed. By quantifying the probability and consequence of fire through risk assessment, we can consistently understand and rank the values at risk. There is no single comprehensive wildland fire risk framework in Canada, but there is a long history of wildland fire research that offers essential expertise.[xvi]

A transparent approach, such as the threat assessments developed by the BCWS,[xvii] can assess values relative to wildfire hazard—an essential step in creating trans-jurisdictional LFM objectives. When designing objectives, the identification of values by different groups can sometimes lead to implicit expectations for how a value is managed or protected. This can cause polarization when faced with trade-offs. In some cases, these trade-offs may need additional analysis, such as Structured Decision Making,[xviii] to ensure consistent documentation of the best alternative.

PLANNING INITIATIVES THAT USE RISK ASSESSMENT AND COMPLEMENT LFM

Natural Resource Districts currently collaborate with the BC Wildfire Service to develop **Fire Management Plans**. These plans are updated annually and help allocate resources for wildfire suppression, helping to ensure that responses to wildland fire have considered options that align with objectives, such as protection of critical infrastructure. This internal government planning mostly focuses on suppression efforts as opposed to risk reduction.

Community Wildfire Resiliency Plans (formerly Community Wildfire Protection Plans) identify wildfire hazards and consequences at a community scale. They guide wildfire mitigation funding and are developed by First Nation and municipal governments within the wildland urban interface. These plans are closely associated with the Ministry of Forest's **Community Resilience Investment program**, which includes funding for **FireSmart BC** and **Crown Land Wildfire Risk Reduction**. BC currently has around 670 Community Wildfire Resiliency Plans.

Principle 4: Set Complementary Wildland Fire Objectives Across Land Use Zones

Setting land use objectives across land use zones that complement wildfire management is crucial for shaping the desired outcomes and defining the acceptable role of fire across a landscape. While a forest or grassland area may have multiple overlapping objectives, they can also coincide with or complement wildland fire objectives. Wildland fire objectives will vary depending on the landscape conditions for fire behaviour and the relative location of values. This section provides criteria to consider when developing wildland fire objectives and gives examples of strategies and targets that can be used to attain them.

Wildland Fire Objectives

Wildland fire objectives will differ depending on ecology, land use, what the value is or its relative position, and geography. Some areas, such as those near communities, may emphasize wildfire containment: putting the right-sized boxes around wildfire. Other areas may emphasize fire-resistant or resilient ecosystems: areas that will burn but maintain or recover ecological functions. Despite these variations in objectives, some common criteria can be applied:

- Be informed by the level of risk. Risk assessments that incorporate all values can help determine the likelihood of wildfire and the potential consequences if a wildfire were to occur. Risk categories allow priority setting to strategically treat areas to reduce value losses, facilitate wildfire containment and improve resilience.
- Design objectives to be spatially specific. Desired conditions and fire-behaviour outcomes are assigned to specific areas. Fire-behaviour outcomes consider fire regimes, including the historic frequency and severity of fire, and the current departure from fire return intervals, while also contemplating climate adaptations.
- Have targets that are measurable and achievable. Consider ecology, the cost of implementation, and access to the areas in question.

Across different land use zones in the planning unit, wildland fire objectives and strategies to achieve them should be clear and accessible to help ensure implementation is coordinated.

Strategies

Wildland fire objectives are achieved through a gradient of passive to active strategies. Where there is no imminent threat to values, a wildfire can be passively managed to minimize costs and damages while realizing the ecological benefits of fire. Active strategies involve either converting, reducing or isolating fuels in select areas.

Managing wildfire

Letting areas burn can make landscapes more resilient to wildfire. "Modified response" is commonly used by fire managers when risk is limited, and where ecological objectives can be met through burning. A modified response also considers operational resources, allowing wildfires to burn under controlled conditions, or apply strategies that prioritize firefighter and public safety. This may involve the use of tactics such as fireguards, controlled back-burns, and strategic use of firefighting resources to slow the spread of a fire. This approach recognizes that wildfires are a natural and necessary part of many ecosystems, and that efforts to suppress all fires can have negative ecological consequences in the long run.

Structured and transparent decisions to allow modified response are important. LFM should include a comprehensive plan for managed wildfire for each area of the planning unit. This plan documents appropriate burning windows, outlines resource management objectives, and provides clear guidance on when a managed wildfire requires suppression.

Active strategies

Most active strategies are applied over a limited area, analogous to the edges of the box, to help reduce wildfire risk, and require programmed maintenance in response to vegetative growth. They include:

Convert fuel to less flammable types: Fuel conversion is changing one fuel type to another, for example, converting a mixed conifer deciduous (M1/M2) fuel type to a deciduous fuel type (D1/D2). The goal is to reduce fuel flammability by changing to a species with higher moisture content or lower amounts of volatile oils. Strategies include designing lower-flammable retention, encouraging/planting fire-resilient species, or the targeted removal of fire-intolerant species.
Reduce fuel quantity: This includes reducing surface fuel and ladder fuels (increasing crown base heights) and the overall reduction of crown bulk density.
Isolate fuel: Break fuel continuity through conversion or fuel-reduction techniques. Fuel breaks may be natural or human-made.

Where there is an objective to conserve ecological values, such as biodiversity or wildlife, then a goal should be to sustain the natural processes that created those ecosystems.[xix] Fuel levels and burning conditions in these conservation areas should resemble historic fire regimes and anticipate future fire regimes, while identifying and managing for climate refugia.[8] Strategies may include fuel reduction or conversion where landscape fire deficits pose a risk to ecological values.

Figure 4. Prescribed fire in Jasper National Park, July 2022.

Parks Canada recognized that departures from historical fire cycles have led to altered fire regimes, with catastrophic consequences. Using a fire deficit model, managers in places such as Banff National Park, Jasper and Yoho National Park are carefully encouraging fire back to the landscape based on an historic range of variability (HRV). Using historic fire regimes across varying ecoregions as a reference for fire type, size and frequency of return, managers calculate the expected annual area burned and assess annual targets.[xx] This system, called the Area Burned Condition Class, closely follows the Fire Return Interval Departure (FRID) analysis systems used in the US. There, the time- since-last-fire is used to quantify departures from reference conditions to identify areas where fire regimes are outside of the HRV.[xxi] Management units are then divided into categories (low/mod/high) to describe departure rates and help prioritize intervention.

[8] Climate refugia are locations on the landscape that are expected to have stable local climates, even as the climate changes in the surrounding area. These refugia can provide habitat and sources of new individuals for species as the surrounding environment changes and experiences disturbances.

Where timber production is the objective, the strategy may be to isolate stands or larger forest areas with fuel breaks, non-fuels, and topography. Younger stands that have closed crowns (30 years to approximately 60 to 80 years) can be a significant fuel source with high horizontal and vertical fuel continuity. For fully stocked and managed stands, pole sapling stages have ladder fuels and stem exclusion stages have significant surface fuel buildup, which can make way for natural in-growth in dry forest ecosystems. Where conversion or fuel reduction strategies (such as commercial thinning) are too expensive, the fuel isolation strategy may be best.

For areas with a low-volume fuel objective, such as tactical fuel breaks, the aim is to slow wildfires and shift their severity (e.g., from a high-intensity crown fire down to surface fire condition that are directly or indirectly actionable).

Examples of Strategies and Targets to Achieve Them

This section describes strategies to help achieve LFM objectives. These strategies may only apply to a small portion of the landscape. Each strategy is carried out deliberately, complementing adjacent objectives, and coordinated between land managers across land use or sectors.

These are not standards, but information-only examples to show the links between fire management and forest practice. Consultation with qualified experts, such as fire management specialists, is necessary to make sure that practices achieve a desired fire-behaviour outcome and are consistent with LFM objectives.

Table 1. Common attributes and target units by which to measure active strategies for converting, reducing, or isolating landscape fuels.

STRATEGY	MEASURABLE ATRIBUTE	TARGET UNITS
Create fuel breaks	• Clearing widths • Periodicity of maintenance	• Metres and length • Years (annual to 10-15-year return)
Establish fire-tolerant stands	• Tree species and density	• Stems per ha • Inter-tree spacing (m) • % low-flammability species
Design low-flammable retention	• Tree species and patch size • Distance edge	• Hectares, shape index
Manage surface fuel loading	• Diameter class by species • Periodicity of maintenance	• Kilograms per square metre (kg/m²) or tonnes per hectare (tonnes/ha)[9] • CWD pieces/ha • Years
Reduce Crown fuel load	• Tree species and crown position • Canopy Bulk density	• Basal area (m²/ha) • Stems per ha • Kg/m³ • Inter-crown spacing • Crown closure
Increase crown base height	• Height to live crown	• Crown base height (m)
Report on condition class	• Condition classes of forest	• % of landscape/fireshed in low-risk condition class

Fuel Breaks

Fuel breaks can isolate fuels, either containing fire within an area, or insulating a value from the threat of wildfire. Fuel breaks are part of LFM strategies but are not considered a stand-alone strategy.[xxi] Fuel break designs often link to existing natural barriers, such as lakes and wetlands, rock outcrops or alpine, or human-made barriers, such as agricultural clearings or right-of- ways.[10] These create a network of low fuel that is anchored, accessible and defendable.

Fuel breaks range in width and level of vegetation removal, from cleared primary breaks, to shaded fuel breaks with wider inter-crown spacing, reduced surface and ladder fuels. Access roads

Figure 5. Fuel break linked to transmission line right-of-way

[9] 0.5 kg/m² is equivalent to 5 tonnes/ha.

[10] Hydro transmission right-of-way can be problematic for fuel breaks. Air and ground operations are affected by the high-voltage lines, and maintenance is at BC Hydro's discretion. In the Cariboo, hydro transmission lines are sometimes backed up with a 300-metre primary fuel break to create defensible space on the upwind side of the right-of-way.

are necessary for the design and maintenance of tactical fuel breaks and should be considered in forest planning. Tactical fuel breaks can be used to impede the spread of fire and support operations such as back burning.

Targets for fuel breaks strategies vary and include narrow, right- of-way size (less than 75 metres) to large clearing widths for primary breaks (e.g., 390 metres).[xxii] Some licensees, such as the Burns Lake Community Forest[xxiii] or Alex Fraser Research Forest, are strategically managing shaded fuel breaks along forest service roads.

EXAMPLE

Prescription for a shaded fuel break in the Interior Douglas-fir zone:[xxiv]

Thinning from below to retain an open stand of the largest Douglas-fir trees, with a basal area target of 16-20 m^2/ha or 300 to 500 stems/ha; reducing surface fine fuel (<12.5cm) to 1 kg/m^2 or less by piling and burning or by removal to roadside; maintaining a low-fuel condition through time.

Establish fire-tolerant stands

Fire management stocking standards set out a desired stand structure to help meet LFM objectives. Stocking decisions determine the future (20-30 year) horizontal and vertical continuity of fuel, fuel type and periodicity of fuel maintenance. BC foresters are beginning to incorporate fire management stocking standards around the WUI. Careful consideration at the stand establishment stage is also required in areas that are at high risk of wildfire, or part of fuel discontinuity corridors. Fire management stocking is a trade-off that carefully balances hazard and consequence, with lower risks in exchange for lower quantities or qualities of timber.

Species selection and stand density greatly influence fire behaviour. Rooting habits dictate moisture content, with deep- rooted species increasing fire resistance. Species with higher foliar moisture content, such as deciduous trees, are generally less flammable. Other stand attributes, such as sparser foliage, thick bark or low resinous compounds will increase fire resistance and resilience.

Stand density also influences fire behaviour. A tree's self-pruning ability will determine crown to base heights, with shade-intolerant species generally more likely to self-prune. Crown closure affects future surface vegetation, tree vigour and mortality rates, ground fuel moisture and wind speeds. These factors, along with patterns of spacing (clumps and gaps or uniform spacing), are variables that significantly affect the rate of fire spread.

Fire management stocking strategies need to consider site objectives, ecology and balance economics. Low-density stocking will eventually lead to closed crowns, or may not lift because of a lack of shade. Depending on the site, low-density stocking may also encourage more flammable understory biomass, such as hemlock ingrowth, increased windthrow or drier surface fuels from lower shade. Weighing the site objectives, ecology and economics may therefore favour other risk-reduction strategies, like pre-commercial thinning, instead of low- density regeneration.

There is no single recipe for fire management stocking, as each site needs to account for the desired configuration of fuel types in the broader landscape, the ecological suitability of species, potential fire behaviour, and fire management objectives. Prescriptions for fire management stocking are often developed by modelling fire behaviour relative to fire management objectives. Consultation with qualified expertise, for example, fire behaviour specialists, is essential in developing strategies. The BC Chief Forester's *Fire Management Stocking Standards Guidance Document* (2016) provides an overview of considerations when developing standards, along with helpful examples.

EXAMPLE

Prescription for fire management, even-aged stocking standards in the ICH:[xxv]

For zonal site series (ICHdw1, 101), use preferred species Interior Douglas-fir (Fd), Western Larch (Lw), yellow pine (Py) or Western white pine (Pw). Acceptable species include Trembling aspen (At) and paper birch (Ep). Target 400 well-spaced stems per hectare, with a maximum conifer stems per hectare at free growing, not exceeding 800.

Surface fuel loading

The goal of surface fuel loading strategies is to reduce ignition potential and limit fire spread. Fine fuels (less than 7.6 cm),[xxvi] including slash from post-harvest, dry more quickly, ignite more easily, and burn with greater Head Fire Intensity. To limit fire spread, a strategy is to break up fuel types' horizontal and vertical continuity.

People undertaking any high-risk activities, including forest licensees, have legal obligations to assess, and where necessary, abate fire hazards to a regulatory standard. Abating surface fuels often means re-distributing fuels or removing fuels.

Historically, post-harvest broadcast burning was used to reduce surface fuels, but that program ended by the 1990s. Prescribed fire and cultural burning continues as an important discipline with a growing demand. These days, reducing surface fuel more often involves piling and/or pile and burning, either mechanically or by hand. To help meet best practices for surface fuel removal using pile and burning, the BCWS has published guidance, the *Wildfire Risk Reduction Pile Construction and Burning Guidance* (2023). This guidance covers pile construction, burn planning, smoke management, and ignition techniques.[11] Surface fuel reduction is guided either by standards published by the BCWS, from a written rationale from a forest professional operating within their scope of practice, or a certified burn boss.

Whether in a cutblock or a forest stand treated to reduce wildfire risk, surface fuel load must be measured or estimated. In BC, it is common to measure by tonnes per hectare (t/ha) or kilogram per square metre (kg/m²). An accurate way of measuring fuels is by using the line intersect method, as described in the FRDA Handbook 01[xxvi], although other methods, like photoload sampling protocols used in the US,[xxvii] offer practical and credible alternatives.

Current surface fuel loading targets in the BCWS Hazard Assessment and Abatement Guide[xxviii] vary depending on the distance from values, fuel type, and topography. That standard, developed for assessing hazards from industrial activities such as logging, provides targets using BC's Fire Risk Map[12], which focuses on relative distance to communities. Meeting those targets can be challenging. Recent research in North-Central BC suggests that post-harvest low fuel targets, such as under 1-5 t/ha, are difficult to achieve when using mechanical treatments alone.[xxix] In treated stands, research in the US found the most effective ways to reduce surface fuel was a combined approach using mechanical treatments and prescribed fire.[xxx] Either way, the closer to the community, the steeper the slope, the warmer the aspect all amount to higher hazards and lower targets for surface fuel.

The *BCWS Fuel Management Prescription Guidance*[xxxi] is another useful reference for setting surface fuel targets. Developed for stand-level prescriptions for wildfire risk reduction objectives, it promotes developing targets to consider fire behaviour under the 90th percentile fire weather conditions. The guide emphasizes reduction of fine fuels (less or equal to 7 centimetres) to achieve a critical surface fire intensity of less than 2000 kW/m. This leaves room for maintaining some larger diameter dead woody surface fuels (greater than 20-centimetre diameter),[13] which may provide greater coarse woody debris (CWD) conditions for soil productivity, wildlife needs, and soil protection.[xxxii]

Setting a surface fuel target therefore depends on the wildland fire objective for a particular area in a landscape or fireshed. If a low fuel hazard is the objective, then aim to maintain a critical surface fire threshold below 2000 Kw/m, such that resources can be effective in suppression actions on the ground. When the HFI is higher than 4000 Kw/m or a fire intensity class 4, it becomes unsafe for firefighters to work on the ground, and the chances of extinguishing the fire are low.[xxxiii]

LFM extends the same objectives for managing surface fuels beyond the WUI, targeting lower surface fuel in strategically positioned areas across the landscape, whether within a cutblock or a treated stand. For example, creating a fuel discontinuity corridor anchored to non-fuel areas such as a wetland would require targets for lower surface fuel loads.

EXAMPLE

Prescription for surface fuel reduction in the IDF:

Loadings for an area with low risk tolerance might call for a 1 t/ha target for surface fuel loading of fine woody debris <=7.0 cm, and ≤ 4 well-dispersed large CWD (>20 cm diameter and 10 m length) per hectare to minimize the HFI intensity to less than 2000 Kw/m.

[11] https://www2.gov.bc.ca/assets/gov/public-safety-and-emergency-services/wildfre-status/prevention/fre-fuel-management/fuels-management/wrrpileconstructionandburningguidance_fnal_2023_june_06.pdf
[12] https://www2.gov.bc.ca/gov/content/safety/wildfre-status/prevention/for-industry-commercial-operators/hazard-assessment-abatement/haz-assess-abate-fre-risk?keyword=hazard&keyword=and&keyword=abatement&keyword=map
[13] Consistent with the Chief Forester's Guidance on Coarse Woody Debris Management and the Chief Forester's Guidance on CWD Management Wildfire Mitigation Treatments.

Crown fuel load and base heights

Two well-established strategies for increasing fire resistance include reducing crown fuel loads and increasing crown base heights.[xxxiv]

When the main canopy provides enough continuous fuel for a fire to spread from crown to crown, thinning the overstory may be necessary to lower the risk of an "active" crown fire. The goal is to lower the "canopy bulk density" (CBD) to a level that minimizes the crown fire risk, while not exposing the stand to increased winds or reducing shade so much that it causes surface fuels to dry out and regeneration to increase. Some research[xxxv] suggests that the threshold necessary to support active crowning is 0.1 kg/m³; therefore, targets are often much lower,[xxxvi] such as between 0.04-0.08 kg/m³ or less on steeper slopes. While difficult to measure, crown bulk density (kg/m³) is mostly a function of tree density and diameter. For example, a Douglas-fir stand of 32-centimetre diameter at breast height trees at 400 stems per hectare has a CBD of about 0.1 Kg/m³. The abatement of slash from a thinning treatment is critical to not increase surface fuel loads.

Increasing the height to live crown involves removing ladder fuels. This decreases the chance of fire spreading from the ground to the crowns, preventing a crown fire. Removing ladder fuels can be done through thinning from below by cutting down small and intermediate trees, or by pruning the lower branches on trees that are retained. Crown base heights should be much taller than the estimated height of the flames to prevent torching and to reduce the chances of a crown fire. Prescribing the right base heights should account for fire behaviour factors, such as surface fuel loads, fuel type, stand density and topography. These factors may lead to a wide range of acceptable base heights. For example, a stand at Knife Creek at the UBC Alex Fraser Research Forest was shown to maintain a low fire rank with a minimum crown base height of 2 metres, where surface fuels were less than 4 kg/m² and stand density was under 2000 stems per hectare.[xxxiv] Other research suggests that, for dry forests, a base height should be 6 metres or more.[xxxvii]

EXAMPLE

Prescription crown fuel loads:

A mature jack pine stand with little understory near Fort Providence, Northwest Territories[14] was thinned to 500 stems per hectare and a CBD of 0.07 kg/m³, with thinnings mechanically removed from site.[xxxviii] Experimental prescribed crown fires in adjacent untreated stands were wind driven (10-15 km/hr) into the thinned site. Upon entering the treated area, the crown fire dropped to the ground and the rate of spread slowed from 20-40m/min to 1 m/min.

Design low flammable retention

High levels of volatile compounds in fuels, such as cedar, yew, and true firs, promote high-intensity fire and rapid spread. Moisture content in fuels also affects fire spread and intensity. Stand structure and fuel properties, including wood density, heat content and thermal conductivity, should be considered when deciding whether to retain or remove trees. Some species, such as Douglas-fir, ponderosa pine, and larch may have adapted to be more resistant to fire. Lodgepole and jack pines, hemlocks and true firs have thin bark and are less fire resistant, so retaining these species may not be the best choice for maintaining forest cover and limiting fire severity.[xxxix] Retaining the largest diameter species will increase the stand's resistance and help to restore the historic structure, increase shade, and retain moisture in moisture-deficient sites.[xl]

For more information, see the Forest Science, Planning and Practices Branch's *Silvicultural Regimes for Fuel Management in the Wildland Urban Interface or Adjacent to High Landscape Values – Guidance.*[15]

Condition classes

Targets can also be set at a landscape scale. Some areas, such as BC's Northeast, have a refined approach for measuring natural disturbance effects, such as wildfire, to help set targets for the distribution of forest ages, patch size, stocking and stand structure.[xli]

For some planning units, there will be a goal to minimize the area outside the natural fire regimes. Emulating or restoring a fire regime means influencing fuels and using prescribed fire to meet reference indices for fire frequency and severity within a given area. Condition classes measure the degree of departure from a historic fire regime and have been developed and mapped in areas such as southeast BC.[vi] Research there shows that, in some areas, fire exclusion has meant that up to 10 natural fire cycles have been missed.[xlii] Increases in condition class create risk to landscape resilience, as fire frequencies are departed from historical frequencies by multiple return intervals. Condition classes can therefore be developed by fire regime and can be used to inform landscape targets.

EXAMPLE

Prescription for condition classes include those set by Parks Canada.

Parks Canada uses Area Burned Condition Classes,[xliii] setting targets based on a reference fire regime area or fire cycle. For example, the Management Plans for Yoho, Banff and Kootenay parks set a goal of achieving 50 percent of the area within those parks to be within the reference fire cycle.[xliv]

[14] Find more at Fort Providence Wildfire Experimental site: https://storymaps.arcgis.com/stories/9ed742e986894f1888cd53fe5507bd49
[15] Available at https://www.for.gov.bc.ca/ftp/hfp/external/!publish/LBIS_web/Guidance/FFT%20guidance%20-Silvicultural%20Regimes%20for%20Fuel%20Management%20in%20the%20WildLand%20Urban%20Interface_V2.3.pdf as of July 2023.

Principle 5: Coordinate Intervention

LFM should be integrated with the forest industry, using skills and expertise of fire management specialists and forest professionals to implement it across all zones of land use within the province. Landscape objectives with clear fire behaviour outcomes may therefore require road locations and a cutblock's shape, size, retention and regeneration to consider fire regimes, fuel types, values at risk, post treatment fuel loading, and fire behaviour potential.

Table 2. Examples of integrating LFM strategies into forest planning and practices.

STRATEGY	INTEGRATION INTO PLANNING AND PRACTICES
Create primary / secondary / shaded fuel breaks	• Road planning, building, and maintenance
Manage surface fuel loading	• Prescribed or cultural burn • Post-harvest pile • Post-harvest mastication / chipping • Post-harvest pile and burn • Stand treatment hand cleaning
Reduce crown fuel load	• Target harvesting • Modified stocking • Spacing / thinning (commercial or pre-commercial)
Increase crown base height	• Targeted harvesting • Pruning

While necessary, fuel treatments offer transient benefits. Forests are constantly changing, and without intervention, vegetation growth eventually leads to an increase in fuel levels. The frequency of fuel reduction practices increases with ecosystem productivity.[xlv] Therefore, maintaining a low fuel level requires ongoing management efforts: programmatic practice instead of individual projects.

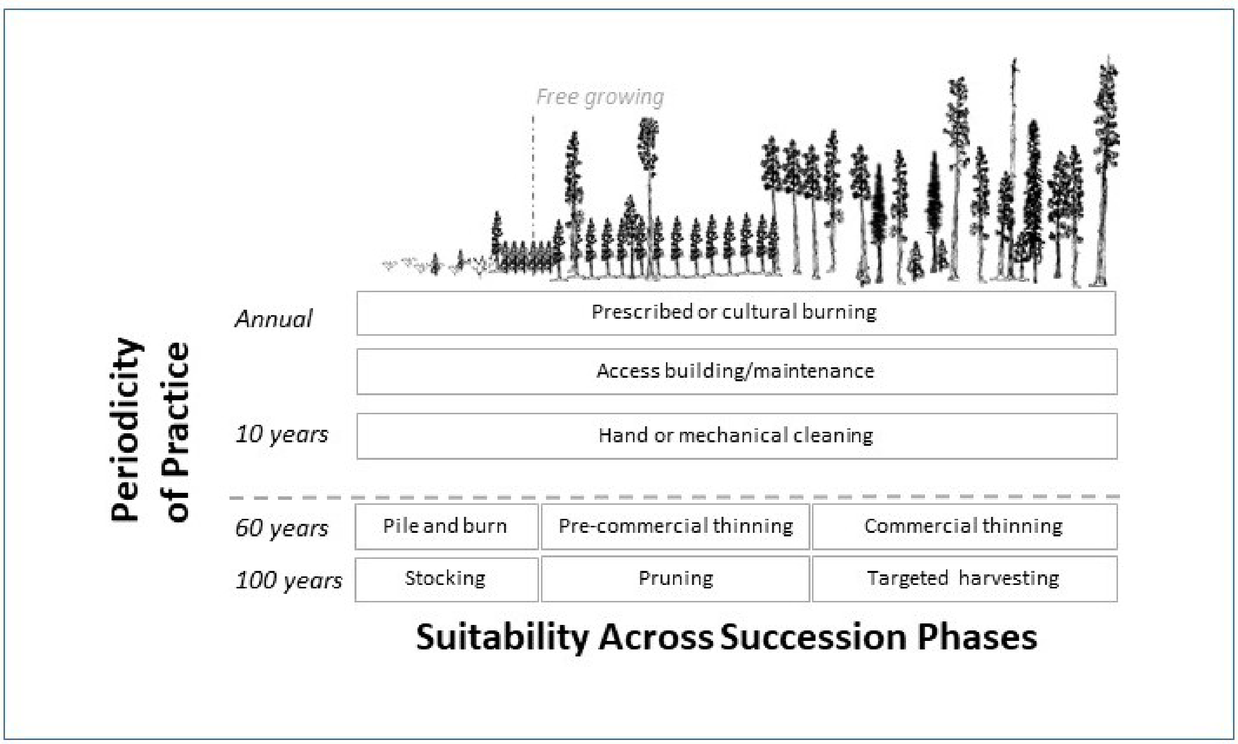


Figure 6. Example of risk reduction strategies to meet landscape fire management objectives. Activities below the dotted line might only occur once per rotation or harvest entry, with exceptions for multiple-pass silviculture.

Principle 6: Learn From Experience (Adaptive Management)

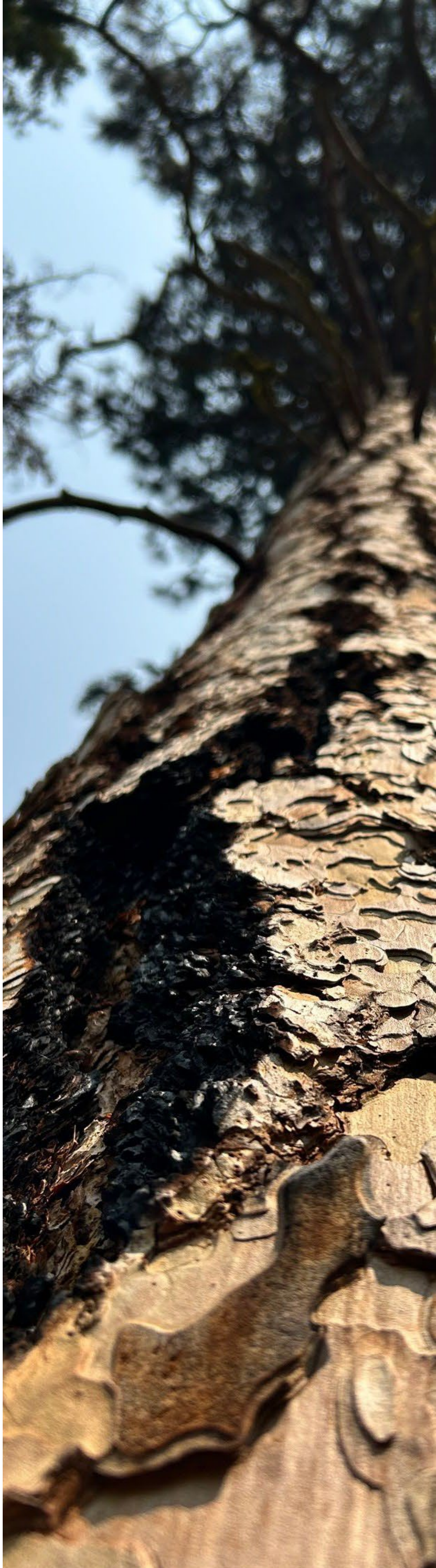
Since LFM is a new concept with limited implementation and scientific literature to support the practice, it is critical that effectiveness monitoring be a part of the program. Documenting where and when treatments are carried out is necessary to inform monitoring. Effectiveness monitoring should be conducted on any landscape-scale treatments that have subsequently had wildfire. The primary focus of the monitoring should be access if the treatment met fire behaviour objectives. There is much to learn to refine the practice of LFM, particularly where we test the concept of shaded fuel breaks as an effective fire mitigation strategy. The effects of silviculture treatments on fire have been studied in controlled research experiments on sites across the US under the Fire and Fire Surrogate study,[xlvi] and various post-fire reviews of risk reduction treatments.[xlvii] While there has been limited work to study the efficacy of fuel treatments in Canada, with most focusing on the boreal forest,[xlviii] the work is beginning in BC.[xlix] These learnings can calibrate our target fuel management standards with predicted rates of spread and intensity, and to relate these to suppression difficulty and fire severity within a given ecosystem.

LFM is an iterative and ongoing process that is periodically updated to recognize changing infrastructure, forest harvesting, natural disturbance, and vegetation growth that all affect patterns of fuel over time. For example, after a wildfire occurs in an area, there is a period of time where the risk of another wildfire decreases. This is because the previous fire has disrupted the landscape fuels, creating a patchwork effect. As a result, newer fires are less likely to spread beyond the edges of the previously burned areas.[l] Likewise, wildfire hazard changes as managed forests change from young to mature forests. These random and predictable events across a landscape require a dynamic feedback loop where forest management is responsive to changes in risk levels.

FROM PRINCIPLE TO PRACTICE

Fire and forest management will need to be better integrated over the next decade in order to achieve goals of ecosystem health and landscape resilience. While it is a rapidly evolving scope of practice, the Board believes that LFM is a powerful collaborative system to achieve those goals while promoting both restoration and risk reduction.

A next step is for land managers across industries or jurisdictions to contemplate how their work can be affected by LFM and what role they play towards implementing LFM. The Board has published this bulletin to inform dialogue and be a practical reference to assist land managers and natural resource practitioners in integrating fire and forest management across BC.



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