BRITISH COLUMBIA
BC Wildfire Service

2024 Fuel Management Practices Guide

Forest fuel management planning, treatment design and implementation methodologies

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About this Manual

Purpose

This document provides guidance around planning for and conducting fuel management activities in B.C. It provides examples and guidance for the application of forest and fuel management science-based principles within the B.C. policy and legislative framework. It provides a reference for practices and is intended to be technical in nature. This document aims to establish a straightforward and consistent approach to mitigating wildfire threat, through the application of fuel management techniques and principles. While there are other forms of wildfire risk abatement, such as practices within FireSmart, this document aims to tackle specifically the aspects of fuel management and the practices encompassing it.

Audience

The intent of this document is to help guide provincial resource agencies, forest practitioners, forest Industry, and other practitioners who engage in the planning and implementation of forest fuel management across B.C. This document is intended for use by professional practitioners planning fuel management treatments on Crown, Municipal, First Nations or privately-owned lands. These management practices are directed towards experienced professionals. They are not meant to be used by the public or individuals that do not have training and experience in both fire behaviour and forest management.

Roles and Responsibilities

The members of the Association of B.C. Forest Professionals are entrusted to ensure that practices applied to forest, forest lands, forest resources and forest ecosystems comply with legislative requirements, including the Wildfire Act, Forest Act and the Forest and Range Practises Act; and those assessments, plans and prescriptions for fire and fuel management will meet the intended objectives. Many aspects of fuel management fall under the scope of practice of professional forestry with the Forest Professionals BC (FPBC). In 2013 the FPBC released Interim Guidelines – Fire and Fuel Management to provide FPBC members with information and guidance to be considered when working in the area of fire and fuel management. It is not a technical document but provides professional considerations for members who work in the area. This guidance document is meant to fill the gap between the ABCFP Interim Guidelines and the technical aspects of fuel management that are common across B.C.

"Members of the Association of Forest Professionals play an integral role in the management of fire and fuels in B.C. forest ecosystems." The forest professional is responsible for carrying out the fire and fuels assignment and, if required, for providing recommendations to reduce the likelihood of fire and/or damages to values at risk.

As part of due diligence in fire and fuels management, forest professionals practicing in the area of fire and fuels management are expected to be aware, and have a solid understanding, of relevant jurisdictional requirements across jurisdictional levels. *"To properly manage fire and fuels, forest professionals are responsible for a broad area of practice including but not limited to 1) fire hazard and/or abatement assessments, 2) fire management planning, 3) prescribed fire plan or prescriptions, and 4) CWPPs". "Practising in the field of fire and fuels management requires a specific education and training in subjects such as, but not limited to fire ecology, fire effects, fire behaviour, fire regimes, conditions classes, fuel types, fuel moisture content, fire suppression, prescribed burning, fire behaviour modelling, and fire weather in addition to forestry subjects. …. Education provided at post-secondary school is insufficient and often additional expertise is obtained through experience fighting wildfires or working with a competent forest professional already practising in the field…."*.

Forest professionals play a key role in fuel management in B.C. - such as the development of Fuel Management Prescriptions. Forest professionals accredited by the FPBC who possess a sound understanding of both fire behaviour and resource management will be invaluable in planning for, and achieving, fuel management objectives. ("Planning and Implementing Fuel Mgmt. in B.C.'s Ecosystems")

[1] ABCFP. 2013. Interim guidelines – fire and fuel management. Association of B.C. forest Professionals Guidelines.

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Consultations with B.C. Wildfire Service and Ministry of Forests (MOF) Land Managers

Practitioners should contact their regional B.C. Wildfire Service (BCWS) Wildfire Prevention Officer (WPO) prior to and during the development of a wildfire risk reduction (WRR) plan or Fuel Management Prescription. This is also required prior to the submission of any application for wildfire risk reduction funding. The WPO works with BCWS zone and provincial ministry staff as well as internal and external government experts to provide guidance and technical support. Practitioners should also engage with the appropriate Land Managers (e.g. B.C. Parks area supervisors, local Natural Resource District) to ensure inclusion of local knowledge and linkages to existing or proposed plans.

How to Use This Guide

Due to its complexity, a variety of complimentary tools and literature must be drawn upon when practicing in the field of fuel management. References are cited through the guide and blue hyperlinks to relevant information or additional standards, direction, and background that support the development of this guide. The Fuel Management Practices Guide builds upon several documents:

1. ABCFP Interim Guidelines – Fire and Fuel Management
2. Tactical Fuel Management Planning Standard
3. Fuel Management Stocking Standards Guidance
4. PSTA Document
5. Wildland Urban Interface Risk Class Maps (WUI RC)
6. Fuel Typing in BC
7. Community Resiliency Investment (CRI)
8. Fuel Management Prescription Guidance

The document is organized into several sections ranging from planning for fuel treatments to implementation and monitoring. It does not include the threat assessment process for a Community Wildfire Protection Plan (CWPP), Community Wildfire Resiliency Plan (CWRP), or Tactical Plan as is described in the BCWS Threat Assessment Guide. Important information regarding fire behaviour principles, fuel hazard assessment processes, and fuel treatments prioritization are located within the BCWS Fire and Fuel Management webpage.

Limitations

This document is focused on planning and implementing fuel management treatments driven by the mitigation of risk to human life, values at risk, cultural, and natural resources. While ecosystem restoration may still be an objective of a hazard reduction treatment, ecosystem restoration guidance is not provided in this document. For more information on ecosystem restoration |treatments in BC, find it on the B.C. Government range management website.

Updates and Feedback

This guide is a living document that will be reviewed and revised as needed to reflect any policy changes, new legislation, user demand for additional content, or emerging science in fuel management. The latest version will be available on the Tools for Fuel Management B.C. Government webpage.

Questions and suggestions regarding the manual should be directed to: BCWSPrevention@gov.bc.ca.

Note on Terminology

There are key terms used throughout this document that have varying definitions and use depending on the jurisdiction. Please refer to the BCWS wildfire glossary as necessary. In the event that a term is not defined in the BCWS Wildfire Glossary, refer to the Canadian Interagency Forest Fire Centre glossary.

Part 1 Introduction

This part provides background information on the broad business context for fuel management in B.C. It provides background on fuel management planning, a broad term to identify areas to pursue fuel management opportunities. Examples of fuel management planning include tactical plans, CWRPs, CWPPs, fire management plans, etc. As defined in the CIFFC Wildland Fire Management Glossary, 2021 Fuel Management is the planned manipulation and/or reduction of living or dead forest fuels for forest management and other land use objectives (e.g. hazard reduction, silvicultural purposes, wildlife habitat improvement) by prescribed fire; mechanical, chemical, or biological means; and/or changing stand structure and species composition.

1.1 BACKGROUND

Wildfire is a natural and essential ecological process and has influenced nearly all forest and grassland environments in B.C.[2] These ecosystems have evolved with the presence of wildfire and have the capacity to respond to wildfire as an important, positive natural disturbance event. Since the early 1900s, wildfire suppression efforts have significantly reduced wildfire activity on the landscape with the intention of reducing negative impacts to values at risk, including timber.

British Columbia is experiencing increased incidents and intensity in the occurrence of wildfire. As the impacts of climate change grow, fire size and severity are likely to increase, and wildfire seasons will become longer. Given the economic, social, and environmental importance of B.C.'s land base, the need to mitigate negative impacts, and the escalating cost of suppression is critical.

The unintended consequence of long-term successful wildfire suppression is the impacts on ecosystem function, and the build-up of fuels, setting the stage for larger, more difficult to control wildfires. Fires are now occurring more frequently outside of their natural range of variation due to historically increased suppression efforts.

Balancing the potential benefits and risk of wildfire is complex and becoming increasingly challenging because of:

1. continued growth of the wildland urban interface (WUI) and the expansion of infrastructure related to energy development (and other industries) on the forested land-base,
2. unhealthy forest and range ecosystems, unhealthy habitats, unnaturally high fuel loads that built-up over long periods of time, forest practices which are setting the stage for larger, more difficult to control wildfires in the future,
3. longer and more extreme wildfire seasons related to climate change.

Figure 1. Comparative imagery from 1950 (top) and 2019 (bottom) illustrating conifer ingress in fire-suppressed grassland ecosystem.

Increasing wildfire activity also presents challenges for preserving natural values that are important to British Columbians and that are sensitive to the detrimental effects of wildfire. Wildfires impact multiple values, areas of responsibility, and levels of government in B.C. These can range from species at risk (SAR), timber supply, public health, tourism, and the overall provincial economy.

[2] Campos-Ruiz R., Parisien M.A., and Flannigan M.D. 2018. Temporal Patterns of Wildfire Activity in Areas of Contrasting Human Influence in the Canadian Boreal Forest. Forests. 9(4): 159.

1.1.1 Unprecedented Wildfire Seasons

2017, 2018, and 2021 are three of the worst wildfire seasons on record in B.C. In 2017, 2018, and 2021 there was over 1.22 million hectares, 1.35 million hectares, and nearly 869 thousand hectares burned respectively. Each wildfire season had a significant impact on the public, timber, ecosystems, habitat, and industry. The 2021 wildfire season had impacts on the Wildland Urban Interface, resulting in 181 evacuation orders and 304 alerts. Wildfires can disrupt infrastructure systems, including transportation, electricity supply, telecommunications, water treatment and sewage systems, homes, jobs, and livelihoods. During those wildfire seasons, impacts on utilities (such as electrical power infrastructure) affected wildfire response and wildfire recovery efforts. For example, power outages created challenges for evacuations and overall emergency co-ordination efforts. Communities, infrastructure owners and infrastructure operators all benefit from risk reduction measures applied to energy and utilities infrastructure.

Figure 2. BCWS uses a ranked scale to describe fire behaviour, each rank has its own associated wildfire suppression tactics. This is an example of a rank 6 wildfire, exhibiting an organized crown fire front and dominant smoke column.

The Office of the Auditor General of British Columbia issued a report in February 2018 titled *Managing Climate Change Risks*: An Independent Audit. It noted that the average temperature in the province has increased, leading to several potential impacts — including a higher risk of wildfires. The Auditor General also stated that “key climate-driven risk areas, like flooding and wildfire, require additional attention.”

In response to this as well as The Abbott Chapman Report, the Ministry of Environment and Climate Change Strategy has undertaken a strategic risk assessment for wildfires in B.C. It noted that, projected increases in temperature and decreases in summer precipitation, in conjunction with unnatural levels of fuel on the landscape, could be conducive to more severe wildfires occurring in the future.

Figure 3. Wildfire damaged provincial park signage.

1.1.2 Wildfire Risk Reduction Initiatives

Fuel mitigation in interface areas has been supported by the Province since it was officially recognized as a key mitigation measure in the Filmon Report which was a review of the record setting 2003 wildfire season.[3] Following this recommendation, the BCWS Prevention Program was initiated and continues to lead the wildfire risk reduction program and projects in partnership with: MOF, B.C. Parks, Union of B.C. Municipalities (UBCM), First Nations Emergency Services Society (FNESS), and Industry.

1.1.3 Community Resiliency Investment Program

There is an increased public expectation for all levels of government and the private sector to invest in wildfire risk mitigation projects to increase the resiliency of communities (economic, safety and recovery). Investment in risk mitigation activities has been highlighted as a gap in B.C. and elsewhere in Canada, in the 2016 Canadian Wildland Fire Strategy: A 10-year Review and Renewed Call to Action.

In 2018, the B.C. government introduced the Community Resiliency Investment program (CRI), which provides funding to mitigate wildfire risks to communities and critical infrastructure identified by the province.

The CRI program is comprised of the following funding streams:

1. The FireSmart Community Funding and Supports category provides funding for local governments and First Nations to address wildfire risks in and around their communities.

[3] Filmon G. 2004. Firestorm 2003 Provincial Review. Province of British Columbia. Victoria, British Columbia.

2. Fuel management projects on crown and municipality lands for community risk reduction
3. Critical infrastructure projects for wildfire risk reduction.
4. Cultural and Prescribed fire projects to reduce fuel loading around communities.

The B.C. government uses a risk-based approach to prioritize wildfire risk reduction activities, using publicly available tools such as the Provincial Strategic Threat Analysis and the Wildland Urban Interface Risk Class Maps. This type of approach requires up-to-date data to make decisions on risk mitigation efforts that will reduce the probability of wildfire events and their social, economic, and environmental costs.

To minimize significant impacts on critical infrastructure and to prevent potential hazards becoming disasters, a coordinated and effective approach to wildfire risk reduction is needed. Such an approach must consider processes, systems, facilities, technologies, networks, assets, and services that are essential to the health, safety, security, or economic well-being of Canadians.

The B.C. government will be collaborating with owners and operators of critical infrastructure to share wildfire risk reduction strategies, prioritize risk mitigation activities, and develop appropriate roles and responsibilities for those efforts.

An effective fuel management program is a key element of B.C.'s prevention program. Benefits have already been realized in terms of increased suppression opportunity and mitigate negative impacts to communities in several locations including West Kelowna, Alexis Creek, Logan Lake, and Barnhartvale.

1.2 GOALS AND OBJECTIVES OF FUEL MANAGEMENT IN BRITISH COLUMBIA

Fuel management involves bringing together multiple components of both forest and fire management, over temporal ranges combined with a strong understanding of fire behaviour. Applying fuel management treatments on the land-base can be an effective land management tool. Fuel management is a key component of prevention activities to reduce and mitigate wildfire risk and can also coincide with other land management objectives. Ignition sources and fuels will always be present however, and fuel

Figure 4. A FireSmart neighbourhood in Fort McMurray after the 2016 wildfires.

treatments should be designed to minimize adverse effects of fires through reducing fire behaviour, as they will not stop a wildfire under extreme conditions.[4] Effective fuel management should reduce fire intensity and increase suppression opportunities, thereby improving opportunities to mitigate negative impacts to life, values at risk, cultural values and resources, and natural resources. In B.C., the goals for managing fuels on the landscape is to create wildfire resilient ecosystems and contribute to creating wildfire adapted communities by:

1. Reducing the potential for crown fire initiation, spotting, and a reduction in fire intensity so that it is safer and effective for fire fighters to suppress wildfire;
2. Reducing fire severity so that it is likely that larger areas of forest will survive, soil damage will be limited, and post-fire restoration activities will be minimized and;
3. Focusing on creating FireSmart communities and homes located in the WUI to mitigate the flammability of structures and the home ignition zone.

A big focus for fuel treatments should be on the ability to keep fires on the ground and out of the canopy, not to stop them. Surface fires burning under a canopy have less risk of spotting as the canopy act as a barrier and interferes with the development of an updraft[7].

From a fire management perspective, fuel is any biomass — in the soil, on the forest floor, elevated in the air— that has the potential to ignite and burn. There are infinite fuel configurations and combinations, depending on the kind, amount, size, shape, position, distribution, and arrangement of materials. Fuels come in a variety of vertical and horizontal arrangements, can be living or dead and are

[4] Reinhardt E.D., Keane R.E., Calkin D.E., and Cohen J.D. 2008. Objectives and considerations for wildland fuel treatment in forested ecosystems of the interior western United States. Forest Ecology and Management. 256.

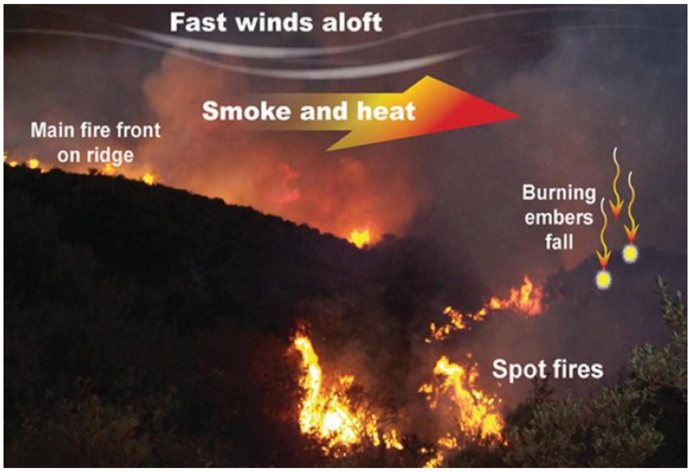

Figure 5. Visual process of spot fire development.

constantly changing over time. The structure and volume of fuel and the moisture content of that fuel determines the total available biomass that could be consumed during any given wildfire. These fuel characteristics are recognized as critical to fire behaviour in addition to weather and climate effects. Table one summarizes fuel layers and their relationships to fire types.

More information about fuel classification and fuel types can be found on the Natural Resources Canada [Canadian Wildland Fire Information System] website.

Fuel treatments require a range of approaches, which are driven by several factors that are highly variable across landscapes and ecosystems. These factors include but are not limited to; land use, fuel distribution, forests health, site specific objectives, constraints, local wind and weather patterns, topography, values at risk, and spatial patterns of values.[5]

Fuel Layer	Fire Types Supported
Ground Fuels: All combustible materials below the litter layer of the forest floor that normally support smouldering or glowing combustion associated with ground fires (e.g. duff, roots, buried punky wood, peat)	**Ground fires:** fires that burn, mostly by smoldering combustion, in ground fuels for hours, days or even years.
Surface Fuels: All combustible materials lying above the duff layer between the ground and ladder fuels that are responsible for propagating surface fires (e.g. litter, herbaceous vegetation, low and medium shrubs, tree seedlings, stumps, downed-dead round wood)	**Surface fires:** fires that burn, mostly by flaming combustion, in the surface fuel layer (excluding the crowns of the trees).
Ladder Fuels: Fuels that provide vertical continuity between the surface fuels and crown fuels in a forest stand, thus contributing to the ease of torching and crowning (e.g., tall shrubs, small-sized trees, bark flakes, tree lichens). ("Forestry glossary | Natural Resources Canada")	**Surface fires** (see previous) or **Crown Fires:** fires that burn through the crown fuel layer, usually in conjunction with the surface fire.
Crown Fuels: The standing and supported forest combustibles not in direct contact with the ground that are generally only consumed in crown fires (e.g., foliage, twigs, branches, cones) ("Basic Forest Fire Suppression Course - Online Lessons …")	**Crown fires** (see previous) may be: • Passive - torching trees discontinuously but spread driven by surface fire. • Active – wall of flame from ground surface to above crown fuel layer; and, • Independent – advancing through the crown fuel layer only.

Fire Intensity

Table 1: Summary of Fuel Layers (Definitions from CIFFC Forest Glossary https://ciffc.ca/sites/default/files/2022-03/CWFM_glossary_EN.pdf)

[5] Reinhardt E.D., Keane R.E., Calkin D.E., and Cohen J.D. 2008.
Objectives and considerations for wildland fuel treatment in forested ecosystems of the interiorwestern United States. Forest Ecology and Management. 256.

Part 2 Planning for Fuel Management on Crown Land

There is a growing recognition among land managers, scientists, and the public that it is neither economically possible nor ecologically desirable to eliminate all fires from the landscape. To achieve land use objectives and manage the challenges posed from wildfire's risk to people, the economy, and environment, integrated fire management planning must be considered to support decisions and overall resource management direction of the area.

To successfully address wildfire threat and fuel build up through fuel management practices, significant planning work is required to understand wildfire risk and vulnerability. Though fuel management is a key component of prevention activities in reducing and mitigating wildfire threat, there are other practices that communities should consider. Other practices that contribute to wildfire prevention are encompassed in the seven FireSmart disciplines: education, vegetation management, emergency planning, cross-training, interagency cooperation, legislation and planning, and development considerations.

The B.C. Public Service Agency utilizes the ISO 31000 standard for risk management. The framework for risk management in a wildfire context emphasizes the necessity for a risk-based process for fire management planning that integrates land management through the prioritization of values from a wildfire perspective, and locally identifying wildfire risk and mitigation opportunities. Planning for wildfire risk reduction activities should incorporate direction outlined in existing higher-level plans and products such as WUI risk class maps, and PSTA data.

The feasibility of a project should be assessed from the regional and local level prior to completing a Fuel Management Prescription. Priority treatment areas may already be identified in CWPPs, CWRPs, MOF Landscape Fire Management Plans (LFMPs), or Wildfire Risk Reduction Tactical Plans. The Provincial Strategic Threat Analysis (PSTA) and the WUI Risk Class Maps are tools to assist in locating priority areas for fuel management. These tools are a coarse filtered and are only available for Crown Land. Through stand level field assessments of the identified priority areas, fuel treatment area boundaries can then be established.

2.1 RISK ASSESSMENT IN THE CONTEXT OF FUEL MANAGEMENT

Risk is a concept used to give meaning to things, forces, or circumstances that pose danger to people and what they value.[6] Truly managing risk requires all parties to share knowledge/data to assist in a non-biased evaluation at multiple scales. Wildfire risk can be thought of as the possibility of a wildfire occurring and spreading across the landscape with increased fire intensity and rate of spread resulting in impacts to values. Once wildfire risk has been identified, mitigation planning is undertaken to lessen the risk to values on the landscape. Wildfire risk reduction activities can include:

1. FireSmart vegetation management – used to mitigate negative impacts to residences and public infrastructure,
2. Operational fuel management generally at larger scales on public land and/or domestic forests
3. Cultural and prescribed fire

Investments should be targeted to areas of highest threat and consequence, while balancing costs, probability of success, and expectations. The most effective approach is to implement fuel treatments in highest risk and consequence areas, in concert with other prevention activities such as education, enforcement, and adopting FireSmart principles. Current wildfire threats must be understood to identify areas where FireSmart and fuel management activities would be most effective.

The concept behind the wildfire risk values analysis is to provide both an understanding of the source of threat (fuel, weather, or ignition probability) as well as the implications for values either on, or contemplated for development on, the land base (consequence). The distribution and arrangement of fuels across the landscape, which are partly determined by resource management activities, is a major component of the wildfire threat analysis as this is the component which can be managed. Fuel treatments can require extensive resources and therefore must be carefully planned and prioritized. Across B.C. there are a wide variety of fuel and fire weather conditions which drive fire behaviour. Many of these areas could benefit from fuel management treatments.

[6] NRC (National Research Council). 1996. Understanding Risk – Informing Decisions in a Democratic Society. Committee on Risk Assessment Methodology, National Research Council. National Academy Press, Washington, D.C.

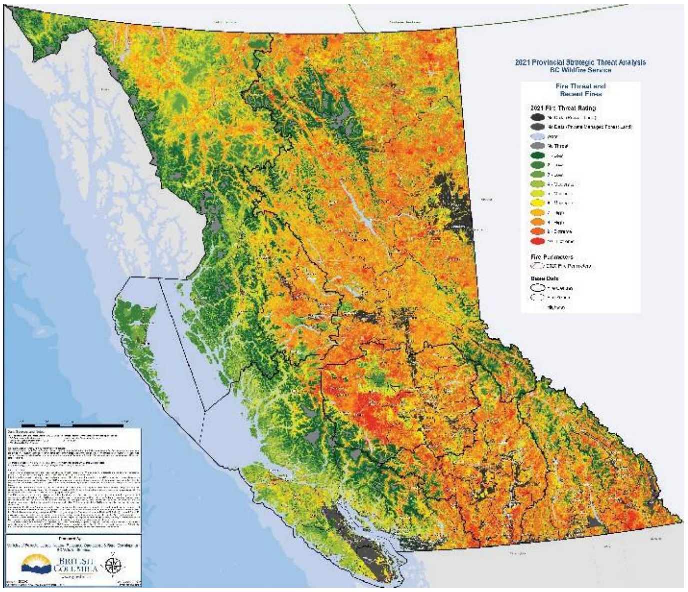

Figure 6. Provincial Strategic Threat Analysis map

The essence of risk-based assessment is the estimation of risk as the product of likelihood and consequence. Consequence is the loss in function of prioritized values within the area. Values are prioritized as within the Resource Sharing Wildfire Allocation Protocol used by BCWS, in descending order of priority: life and property, critical infrastructure, Indigenous values, high environmental and cultural values, and other resources. Multiplying likelihood times consequence together estimates risk for the area(s) that values occupy. Via this methodology risk can be estimated for overlapping values or values singly.

The second level of risk-based fire management planning zeros in on those areas of high and low risk. High risk areas are then analyzed for the most cost-effective set of fuel management treatments, practice changes, FireSmart treatments, etc. that meet Firesmart management objectives for the area. Low risk areas can then be managed as managed wildfire with perhaps only FireSmart of specific values needed. The third level of fire management planning is the site level. It is at this level that Fuel Management Prescriptions, Burn Plans, and/or FireSmart practices are developed.

2.2 PROVINCIAL STRATEGIC THREAT ANALYSIS

The current approach in B.C. utilizes the Provincial Strategic Threat Analysis (PSTA) to identify the relative wildfire threat across the province, along with the Wildland Urban Interface Risk Class Maps to map out high risk areas within the WUI. Other localized approaches include Tactical Fuel Management Plans, CWRPs, and CWPPs. High values and high threat areas are prioritized for more intensive assessment, fuel management objectives are described, and fuel treatment plans are developed to modify the amount and distribution of fuels on the landscape.

In order to identify the area that will benefit the most from fuel treatments and to prioritize resources, the Province has produced and maintains a Provincial Strategic Threat Analysis (PSTA). This is a model that produces a spatial representation of the wildfire threat across the Province.

The relative level of wildfire hazard and threat throughout B.C. has been identified in the B.C. 2021 Provincial Strategic Threat Analysis Update. The PSTA is a high-level analysis and is a starting point to assess the relative wildfire threat to values at risk in B.C. The PSTA utilizes provincial fuel type mapping, historical fire occurrence data, topography, and historic weather station data; and interprets this data. The PSTA includes information and maps that describe fuel types, historical fire density, the potential for embers to land in an area (spotting impact), head fire intensity, and overall wildfire threat.

This analysis is available and used by natural resource management agencies, resource-based industry, First Nations, Local Governments, and stakeholders to help understand the risk from wildfire. It is also used to help inform fire and fuel management planning. This model helps to understand the potential source of threat (fuel conditions, weather, and potential ignition sources) as well as the values that would be at risk. This analysis is useful for evaluating the risk to existing as well as proposed development. Subsequent planning is required at a site level to confirm the threat and to identify opportunities for altering vegetation fuels in high-risk areas.

2.3 WILDLAND URBAN INTERFACE RISK CLASS MAPS

The wildland urban interface (WUI) is any area where combustible wildland fuels are found adjacent to homes, farm structures, or other outbuildings. This may occur at the interface, where development and wildland fuels (vegetation) meet at a well-defined boundary, or in the intermix, where development and wildland fuels intermingle with no clearly defined boundary. The CIFFC 2017 Wildland Fire management Glossary described the WUI as "The area where homes and other human development meets or are intermixed with wildland fire fuels."

In B.C. at the provincial scale, the WUI was first mapped as part of the 2004 PSTA[7] in response to recommendations from the Filmon Review; "to identify areas of the province where communities, infrastructure, and watersheds have the greatest potential to be impacted by large-scale fire".[8] In B.C., structure densities are used to define the boundary of the WUI for fire management planning purposes. A 2km buffer distance around structures greater than 6 per km2 is then applied to represent a reasonable distance a firebrand can travel from a wildfire and ignite a structure. Once defined, the WUI layer is combined with the wildfire threat layer to identify areas of higher risk.

The intention of the Wildland Urban Interface Risk Class Maps is to provide a strategic-level analysis of many different factors that contribute to wildfire threats, but it is not intended to represent absolute, site-specific values. The Wildland Urban Interface Risk Class Maps were created at a provincial scale focused on greater than 25 structures per km2. It is necessary to verify wildfire-threat at the local level. This can be completed by a qualified professional using the documents provided under the Wildfire Threat Assessment Material heading on the Tools for Fuel Management webpage. If found that the information was not accurate from the risk class maps and a higher risk class rating can be validated for the site, then that site can still potentially be able to qualify for funding under the CRI program.

Any limitations of the PSTA, WUI and Wildland Urban Interface Risk Class Maps are related but not limited to the accuracy of the Vegetation Resources Inventory (VRI); the 17 fuel types identified under the Canadian Forest Fire Behaviour Prediction (FBP) System; historical fire data; and assumptions associated with the development of the head fire intensity and spotting impact data layers.

The Wildland Urban Interface Risk Class Maps do not assess wildfire threats on private land parcels since these are best determined through a site-level assessment such as FireSmart. Wildland Urban Interface Risk Class Maps were designed to assess the forested land base. The FireSmart assessment takes into consideration individual structural components (e.g. roofing and siding), fences, exotic plants, and vegetation 10 metres and beyond from the structure — key areas linked to the spread of a wildfire into a community. The Wildland Urban Interface (WUI) component of the Wildland Urban Interface Risk Class Maps do not take this information into consideration.

2.4 B.C. PROVINCIAL FUEL TYPE LAYER

The Provincial FBP Fuel Type Layer data provides information on forest fuel types for all of B.C. and is used for several purposes and associated fire behaviour prediction models. The identification of fuel types is fundamental for any type of fire behaviour prediction modelling or analysis. It is the basis for fire behaviour modelling and forecasting at multiple scales and in different contexts in B.C., including at the wildfire incident level and for larger analysis projects. The B.C. Provincial Fuel Type Layer is a key input into the spotting impact and head fire intensity layers which add up to a total of 70% of the weighted inputs

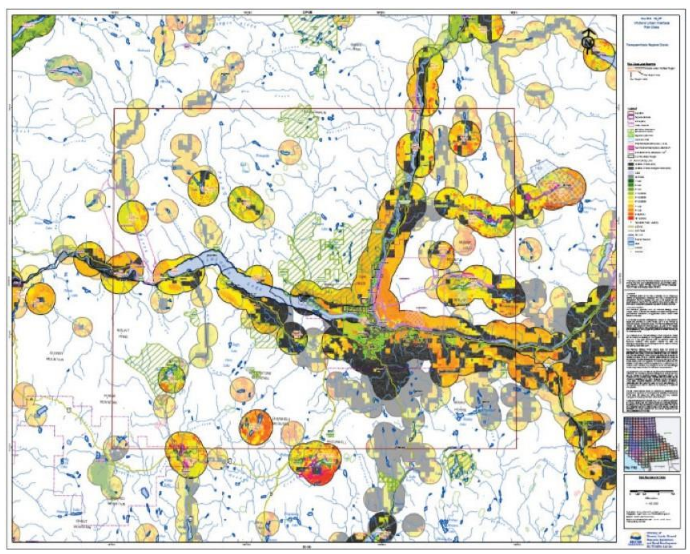

Figure 7. 2021 WUI Risk Class Map for Thompson-Nicola Regional District.

[7] Beck J., and Simpson B. 2007. Wildfire Threat Analysis and Development of a Fuel Management Strategy for British Columbia. Ministry of Forest And range. Province of BC.

[8] Filmon G. 2004. Firestorm 2003 Provincial Review. Province of British Columbia. Victoria, British Columbia.

into the PSTA. Changes to both data attributes and fuel typing assignments will have a direct impact on the final product. Understanding fuel types and their relationships to predicted fire behaviour is paramount to any fuel management plan.

Due to the diversity of forest and non-forest ecosystems across BC, describing fuels for fire behaviour prediction is a complex task. ("British Columbia Wildfire Fuel Typing and Fuel Type Layer Overview") The fuel layer data is based primarily on forest inventory data from the provincial VRI Layer polygons (minimum 1 hectare) and their respective land cover attributes.[9] The provincial surface area (~95 million hectares) is represented by approximately four million VRI polygons, which are then classified into FBP fuel types (plus 'non-fuel' or 'water'); the classification is based on an extensive set

of decision rules reflecting attributes such as tree species, density, bio-geoclimatic zone and other non-forest cover attributes. The fuel layer is updated annually in accordance with updates to the forest inventory data. More detailed information and background on the B.C. Provincial Fuel Type Layer can be found here;
B.C. Provincial Fuel Type Layer Overview (Updated 2021).

2.5 FIRE MANAGEMENT PLANNING

Fuel management is often a component of fire management planning within B.C. The BCWS has been annually updating fire management plans for over 10 years. To date, those fire management plans are a primary plan ensuring that accurate, timely information on all values at risk are available to the incident management team to allow for informed decision making that results in reduced harm to values and the safety of firefighters. That information includes mapped locations of values and any land management direction from higher level plans. These plans are continually being improved through the addition of information regarding priority values, fire effects, suppression considerations and appropriate tactics, and firefighter safety.

Ideally Fire Management Plans should inform fuel management activities across the landscape to assist in fuel treatment placement and prioritization. Plans are designed to provide guidance to land managers responsible for fuel management near the area(s) of interest. These plans include specific forest management objectives and strategies such as:

- reforestation planning,
- targeted harvesting of high hazard fuel types;
- modified stocking standards; road and corridor right of way widening;
- linking natural fuel break features with treated stands;
- ecological restoration;
- prescribed burning;
- and post-harvest fuel hazard abatement

2.6 PROVINCIAL LEVEL PLANNING – B.C. PARKS OVERVIEW

B.C. Parks protects and maintains important natural and cultural values, with a mission to "protect representative and special natural places within the province's Protected Areas System for world-class conservation, outdoor recreation, education and scientific study".[10] The Park Act, Ecological Reserve Act and the Environment and Land Use Act and their associated regulations govern all actions within the Protected Areas System.

B.C.'s Protected Areas System has several designations including provincial parks, conservancies, recreation areas and ecological reserves.[11] At a coarse filter, these designations determine a protected area's overarching legislation, general purpose, and management considerations. At a fine-filter, strategic management planning documents (i.e. Park Management Plans, Purpose Statements) provide descriptions on the values, uses, purpose and allowable activities within a protected area. Some protected areas also have Fire Management Plans which detail specific fire management strategies based on values at risk, ecology, fire environment, and climate change considerations. Both filters provide insights to the management priorities and potential fuel management opportunities within a protected area.

In addition to B.C. Parks' legislation, B.C. Parks' Conservation Policy and Impact Assessment Policy and Guidance direct all activities within parks and protected areas, including fuel management and prescribed burning.

[9] The Ministry of Forests, Lands and Natural Resource Operations' Forest Analysis and Inventory Branch provides more details about the Vegetation Resources Inventory Layer process on the VRI Data Management website: http://www.for.gov.bc.ca/hts/vridata/

[10] B.C. Parks. (n.d.). B.C. Parks Mission and Mandate. B.C. Parks – Province of British Columbia. http://bcparks.ca/about/mandate.html

[11] Use of "parks and protected area" in this document refers to all designations within B.C. Parks' Protected Areas System.

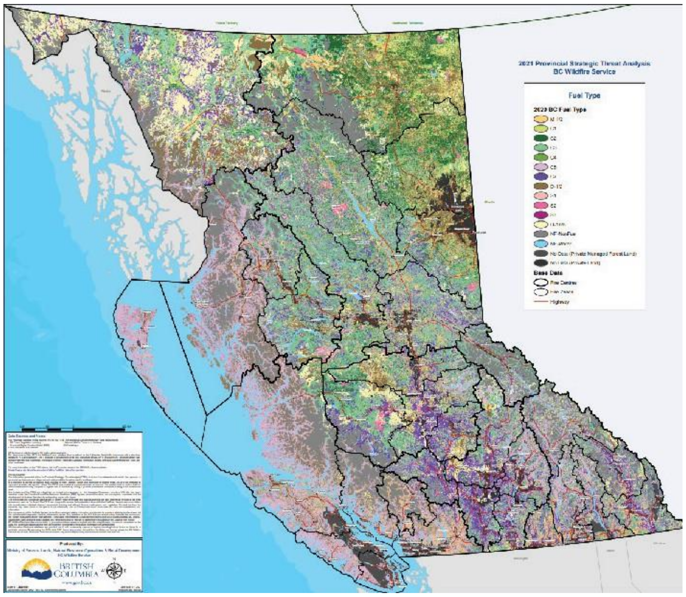

Figure 8. British Columbia Provincial Fuel Type Layer Overview Map

The Conservation Policy provides both strategic and subject-specific management direction within parks and protected areas, while the Impact Assessment Policy and Guidance directs the review of proposed activities in parks and protected areas to determine risk, impacts to key values and mitigation strategies and informs statutory decision-making. The B.C. Parks Prevention Prescription template and associated guidance have been developed to reflect B.C. Parks legislation and policy, support the Impact Assessment process and must be used for fuel management within B.C. Parks.

As the land manager, B.C. Parks has the responsibility to manage for key ecological, cultural and recreation values in the protection of representative and special natural places. Throughout the planning and project lifecycle, fuel management within B.C. Parks must be considered with these B.C. Parks objectives at the forefront. B.C. Parks must be part of the collaborative fuel management planning team within parks and protected areas to identify management considerations and values, and how these should be incorporated into projects to support B.C. Parks' mandate.

2.6.1 B.C. Parks Fuel Management Requirements

Fuel management within parks and protected areas needs to be carefully planned within the framework of B.C. Parks' legislation, regulation, and policy, as well as ecological, cultural, and recreation values. Within a park or protected area, site-specific information must be considered to reflect the Conservation Policy, support the Impact Assessment process, and inform appropriate fuel management treatments that meet both B.C. Parks management objectives and fuel management objectives.

B.C. Parks management objectives, land uses, and activities vary across parks and protected areas, and within a specific protected area are guided by designation types, agreements and/or land use plans for the area, and strategic management planning documents. The B.C. Parks Zoning Framework can be applied spatially during a protected area management planning process to identify appropriate land uses and activities across a protected area. Different zones can be applied across the protected area to reflect intended land use, current land use and required management or development. There are six possible zones with varying objectives, ranging from Intensive Recreation Zones, where impacts and land management may be more intensive, to Wilderness Conservation Zones, where impacts are low and land management is avoided. A protected area's zones will help determine where fuel management may be supported.

Strategic management planning documents also detail management principles within a protected area, which will help broadly identify potential opportunities for fuel management. While these documents may not necessarily speak to fire or fuel management, they may specify management commitments, priorities and/or values that will guide fuel management planning. Management commitments may include partnership agreements or references to other planning processes, such as Land Use Planning documents or adjacent land managers (i.e., Parks Canada). Management priorities can include protection of representative ecoregions, watershed integrity and recreation opportunities. Identified values can include special geological features, rare or endangered species habitat and viewing opportunities or visual aesthetics.

Where supported by strategic management planning documents (i.e. zoning designations, management priorities and identified values within those documents), fuel management must also consider and mitigate impacts to the suite of values within parks and protected areas. Strategies to achieve these mitigations will vary depending on the protected area and must be discussed in collaborative planning with B.C. Parks staff.

Appendix H B.C. Parks Fuel Management Case-Study, reviews the West-Arm Provincial Park Fuel Management project, from project conception to operational implementation, highlighting the fuel management processes unique to B.C. Provincial Parks.

Part 3 Fuel Treatment Design

Fuel management objectives can only be met with successful fuel treatment design. Fuel treatments must be designed specific to the site and be anchored, accessible, and defendable. This is attained through considering the site-specific features including terrain, fuel attributes, and proximity to values. Part 3 of this guide breaks down the principles and objectives of fuel management, how to design fuel treatments to meet these objectives at different scales, and how to manage for overlapping objectives.

Fuel Treatment Areas

Fuel treatments may include any combination of a reduction or removal of surface, ladder, and/or crown fuels through any method including managed natural wildfire, harvesting, ecosystem restoration, etc.

The term fuel break often has varying interpretations. In keeping with the BC Wildfire Regulation (2023), a fuel break is defined as either:

a. A barrier or change in fuel type or condition, or
b. A strip of land that has been modified or cleared.

Throughout this text the term fuel treatment area is used to describe any feature on the landscape that is treated to mitigate wildfire risk. In this context, a fuel treatment area is one type of fuel break.

The following challenges must be considered and managed for at preliminary design stages to avoid undesirable, consequences:

1. the limited ability of a fuel treatment area to influence fire behaviour in extreme conditions,
2. the false sense of security a fuel treatment area can give,
3. the increased public access which may increase incidences of human-caused ignitions;
4. the need for, and potential lack of, maintenance

Land managers and forest professionals must be aware of these challenges when designing fuel treatments and manage for them where practicable.

3.1 FUEL MANAGEMENT PRINCIPLES

The fundamental objective of fuel management is to reduce potential wildfire intensity within the areas treated and reduce the probability of fire occurrence and spread beyond treated areas.

Effective fuel management design entails following several guiding principles:[12]

1. **Rationalized fuel management objectives at different scales:** the fundamental objective of fuel management is to reduce the risk of wildfire to communities and values through facilitating safe suppression opportunities. Fuel treatments are generally located within the Wildland Urban Interface but may also be applied across the landscape for an isolated structure, to provide a secondary buffer to reduce fire behaviour approaching a community, or for landscape level biodiversity management (emulating or restoring historical natural disturbance patterns).
2. **Reducing Potential Fire Behaviour:** Prescribing specific and measurable targets for fuel load and continuity reduction to effectively reduce potential fire behaviour. Regardless of the stand being treated, prioritization of fuel modification should be in the following order, with reducing crown bulk density being the last attribute to be modified to meet potential fire behaviour objectives:
    a. Reducing surface fuel load.
    b. Increasing crown base height.
    c. Reducing crown bulk density.
3. **Fuel Treatment Location:** Fuel management objectives drive the placement of treatments on the landscape. Designing fuel management treatments requires consideration of site-specific features such as terrain, fuel, and proximity to values when prescribing treatments. Locate fuel treatments where there is maximized opportunity to anchor to non-fuel

[12] Jain T.B., Battaglia M.A., Han H.S., Graham R.T., Keyes C.R., Fried J.S., Sandquist J.E. (2012) A comprehensive guide to fuel management practices for dry mixed conifer forests in the northwestern United States, Gen. Tech. Rep. RMRS-GTR-292. USDA, Forest Service, Rocky Mountain Research Station, Fort Collins.

Figure 9. Comparative imagery of a dry interior Douglas fir stand pre- (left) and post- (right) fuel treatment.

or low flammability areas such as water bodies, wetlands and roads and provides adequate breaks in continuous fuels (e.g., wildlife tree patches, riparian reserves etc.). Ensure treatments are accessible for implementation and suppression. Most importantly, ensure treatments provide defensible space, considering fuel and terrain attributes.

4. **Alignment with Higher Level Plans and other Resource Management Objectives:** Align with other legal, resource management and non-statutory objectives including First Nation consultation requirements.
5. **Fuel Treatment Longevity and Maintenance Planning:** A solid understanding of desired future conditions for a treatment area is critical for long term success and must be considered in design and documented in a prescription. Additionally, understanding of the length of time the treatment will be effective in achieving the fire behaviour targets and outcomes is necessary to facilitate maintenance treatments. Maintenance planning should include fuel attribute levels that trigger the need for maintenance to occur. Frequency of monitoring should also be outlined.
6. **Economic Viability:** Reducing risk to communities, values, and critical infrastructure through facilitating safe and successful suppression in the event of a wildfire is the primary objective of fuel management and should not be compromised to maximize cost effectiveness. However, consideration of the most economically feasible approach to fuel management, while still meeting targeted potential fire behaviour is important. Community and first responder safety are imperative to the success of fuel management. Residual fibre utilization or opportunities for treatments to occur as a commercial timber harvest are examples of enhancing fuel management economic viability.

Fuel management activities can influence the amount, composition, and arrangement of fuels, which means they can modify the intensity and severity of a wildfire. Fuel is present in many different arrangements, species, shapes, and sizes each of these attributes affecting fire behaviour. The size and spatial arrangement of fuel treatments across the land base are also fundamental to their overall effectiveness during wildfires. Fuel treatments affect fire behaviour by reducing and redistributing surface fuel loads, increasing height to live crown, and increasing crown separation. Wildfire risk reduction utilizes these management activities, which are achieved primarily through the creation and maintenance of fire resilient forests as described above.

Table 2 outlines the main fuel management principles/strategies and potential effects and concerns each can have.

3.2 FUEL MANAGEMENT OBJECTIVES AND RATIONALE

Fuel management objectives can be specified in Community Wildfire Resiliency Plans, Community Wildfire Protection Plans, Tactical Overview Plans, and Fuel Management Prescriptions. Objectives are scale specific, at both the local (WUI) and landscape scales. Local fuel management objectives may seek to reduce fire behaviour, (likelihood of crown fire, fire intensity, or rate of spread) and may also achieve several of these objectives simultaneously[15]. Landscape scale fuel management objectives typically seek to define an acceptable or desirable role for wildfire across broad landscapes. Objectives may include a desire to reduce fire size, reduce fire behaviour (e.g. reduce fire intensity over the landscape) or encourage the use/application of prescribed fire for various ecological

[14] Agee J.K., and Skinner C.N. 2005. Basic Principles of fuel reduction treatments. Forest Ecology and Management. 211, 83-96.

[15] Hoffman C.M., Collins B., and Battaglia M. 2018. Wildland Fuel Treatments. S.L. Manzello.

purposes. 20 Landscape scale objectives are achieved through the combined implementation of local (i.e. stand level) fuel management objectives with continuous landscape level planning to ensure project connectivity. Whether at the landscape or local scale, plans typically seek to reduce the impact of wildfire on values and to enhance wildfire suppression effectiveness and success as an overriding objective. The following list provides examples of landscape level fuel management objectives or secondary objectives to fuel management within the WUI that is specific to wildfire risk reduction:

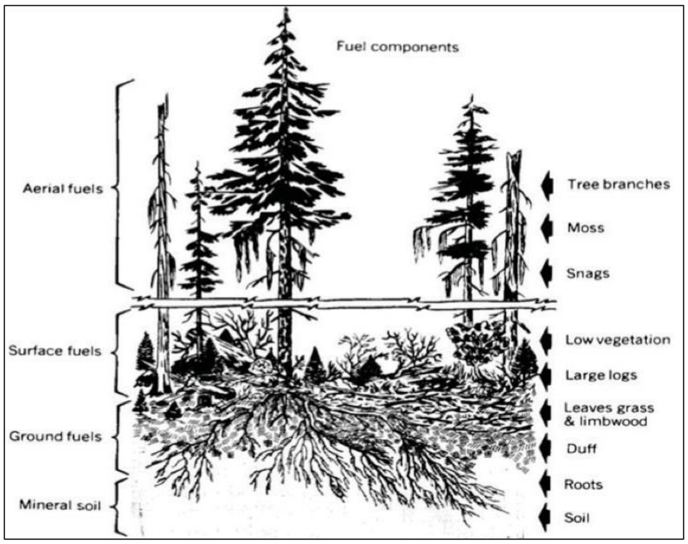

Figure 10. Fuel components[13]

- Reducing negative impacts on ecosystems and the environment,
- Restoring the natural fire cycle, and associated ecological benefits,
- Enhancing other values on the land base: range, recreation, cultural heritage

The objectives listed above can often be met in conjunction with facilitating safe suppression opportunities around communities.

In the WUI, the scale of fuel treatments is typically more localized. The objective for fuel management within the WUI is community risk reduction, therefore reduced fire behaviour targets are prioritized to facilitate greater suppression opportunities. The following list provides examples of primary fuel management objectives within the WUI related to wildfire suppression:

- Improving fire-retardant drop success of reaching wildfire on the ground
- Allowing rapid and safe deployment and evacuation of firefighting resources
- Providing anchor points to conduct planned ignitions
- Providing safer work areas for suppression crews

Fuel treatment objectives will drive the rationale for treatment area placement, treatment strategies, and treatment method. When specifying objectives for a fuel treatment, first define the rationale for why the fuel treatment is necessary. Examples of rationale include:

- threat and/or risk level;
- reducing risk to a specific value(s);
- improving suppression opportunities;
- improving access and egress;
- or it was pre-identified in an existing approved plan.

An example statement defining the primary objective of a fuel management project is as follows, “treatment unit one was identified as priority #2 in the XXX Tactical Plan and provides suppression opportunities and improves egress safety along the community’s main access road”.

Principle	Effects	Concerns
Reduce surface fuels	Reduces potential flame length, less potential for torching, lower fire intensity.	Surface disturbance is less with fire than mechanical.
Increase the height to the live crown	Requires longer flame length to engage the crowns and reduces the potential for crown fire initiation.	Opens understory; may allow for increased surface wind.
Decrease crown bulk density	Makes tree to tree crown fire less probable. Reduces crown fire potential. (“Grasshopper Restoration Project Fuels Report”)	Opens understory; may allow for increased surface wind and dry out surface fuels.
Keep larger, more fire resilient conifer and deciduous trees	Reduces tree mortality when wildfire does occur, increases ignition resistance, and reduces long-term vegetation fuel hazard	Less economical.

Table 2. Fuel management principles and their associated effects on fire behaviour.[14]

[13] Pyne S.J., Andrews P.L., and Laven R.D. 1996. Introduction to wildland fire, second edition. John Wiley & Sons, New York. 769 pp.

In this example, the objective is "Public Safety". When defining the primary objective, expand by adding details such as "To improve public and responder safety on the community's main access road by reducing the potential for crown fire initiation, fire intensity, and crown fire spread within the adjacent stand. .."

All objectives should be informed by the data collected during the office-review, consultation, and field assessment. Be clear on the objective of the treatment from a fire behaviour, fire effects, and fire suppression perspective, as well as land management goals. Design your fuel treatment to achieve the desired fire behaviour outcome. Details on historic fire regimes, behaviour, and weather trends should support your objective and fuel treatment targets. Design your fuel treatment to achieve the desired fire behaviour outcome.

3.2.1 Reducing Potential Fire Behaviour

Often, especially in the WUI, the intent of establishing a fuel treatment area is to provide an opportunity for suppression that is part of a multi-barrier approach to reduce the risk to values (e.g., structures). A fuel treatment in and of itself is unlikely to stop a wildfire under most conditions. The effectiveness of a fuel treatment is dependent of two key factors:

1. Reducing fire behaviour potential to a specified fire behaviour outcome, and
2. the application of appropriate suppression tactics in a timely manner with sufficient resources

In B.C. the desired fire behaviour targets should be based on the ability for suppression activities to occur, or critical surface fire intensity (whichever is the lowest). Direct attack fire suppression efforts can only be maintained until a maximum fire intensity of 4,000kW/m, which has a flame height of ~3.5m. The goal is to have all fuel managed areas well below 4,000kW/m, more appropriately below 2,000kW/m, as this will allow for direct fire suppression for crews. The critical surface fire intensity can be determined using a combination of inputs including surface and crown fuel loading, to help determine the possibility of crowning under certain fire weather conditions. The use of the 90th percentile weather conditions for example to drive the target height will link weather driven changes to the critical surface flame length, as well as help plan for treatment objectives. Wildfires that occur in the higher percentile weather are represented by the large-scale fires that occur under high winds, low fuel moisture with higher spread rates, and intensities where large-scale losses occur. Using the information supplied on the Tools for Fuel Management webpage there are directions on how to calculate this.

Crown Fires

Crown fires are a natural disturbance process in some forest types in B.C., facilitating ecosystem functions and providing opportunities for habitat and species regeneration. However, most of B.C.s ecosystems are adapted to lower intensity, more frequent fire regimes. Ideally, fuel management practices at both the stand and landscape level should mimic historical, natural disturbance regimes.

Crown fires present extreme wildfire behaviour that limits suppression opportunities and have potential for severe impacts on values and communities. Crown fires have higher rates of spread, larger flame length, and a greater ability to create spot fires compared to surface fires. Therefore, transitioning crown fires to surface fire and subsequently reducing fire behaviour is often the target of fuel treatment objectives.

a. Reduce the potential for sustained ignition and crown fire initiation by reducing surface fuel loading to achieve potential surface fire intensity levels below the critical surface fire intensity to a maximum of 2,000kW/m.
b. Reduce the potential for crown fire ignition by increasing the height to live crown, rendering a higher critical surface fire intensity threshold
c. In forest types where applicable, reduce crown closure and canopy bulk density as necessary to reduce crown fire spread rate, potential, and spotting and to encourage crown to surface fire transition.

3.2.2 Fuel Treatments and Wildfire Suppression

In the WUI and in some instances, on the landscape, the fundamental objective of fuel management is to facilitate safe suppression opportunities and reduce negative impacts to communities and critical infrastructure. This objective is obtained through decreasing potential fire behaviour, specifically fire intensity, crown fire initiation, crown fire spread, and spotting.

Crown fires present extreme wildfire behaviour, have the potential to severely impact values and communities, and are difficult to suppress. Moderate fire behaviour associated with surface fires enhances suppression opportunities, success, and crew safety.

Fuel management treatments that result in stands that do not facilitate fire intensity levels above 2,000kW/m allow for greater suppression capability through:

1. Improving fire-retardant drop success at reaching fire on the ground
2. Allowing rapid and safe deployment and evacuation of firefighting resources
3. Providing anchor points to conduct planned ignitions
4. Providing safer work areas for suppression crews

Table 3 expands on Figure 11, describing potential fire behaviour characteristics and associated wildfire suppression tactics that can be successfully and safely implemented.

3.2.3 Overlapping Resource Management Objectives

The placement of fuel treatment areas will consider complimentary resource management objectives. At the planning stage, stakeholders and agencies work together and consider the full range of values. Where possible, fuel treatments are to complement desired future condition (e.g., where wildlife burns are planned, core grasslands are intended to be maintained, licensees have planned harvesting activities, ungulate winter ranges, etc.). This

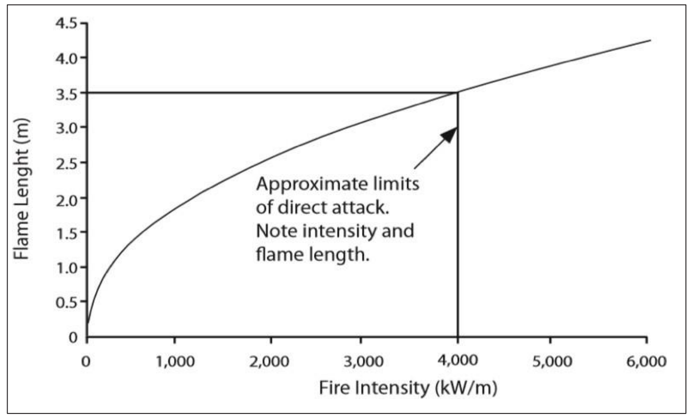

Figure 11. chart showing the flame length and fire intensity at which suppression opportunities are limited.

Example of HFI related to wildfire characteristics and suppression options (green pine)					
Fire Intensity Class	**Head Fire Intensity (kW/m)**	**Surface head fire**		**Type of fire and wildfire suppression difficulty**	**Fire Weather Index (FWI)**
		Flame Length (m)	**Flame Height (m)**		
1	< 10	< 0.2	< 0.1	Fire brands that cause an ignition to occur are self-extinguishing (e.g., fire fails to spread). Going fires remain of the smouldering ground or subsurface variety, provided there is a forest floor layer of significant depth and general level of dryness. Extensive mop-up is generally required.	0 – 3
2	10 – 500	0.2 – 1.4	0.1 – 1.0	Creeping or gentle surface fire. Direct manual attack at the fire's head or flanks by firefighters with hand tools and water is possible. Constructed fireguard should hold.	4 – 13
3	500 – 2000	1.4 – 2.6	1.0 – 1.9	Low vigor to moderately or high vigorous surface fire. Hand constructed fire guards likely to be challenged. Heavy equipment such as bull dozers, pumpers, retardant aircraft, skimmers, and helicopters with buckets generally successful in controlling fire.	14 – 23
4	2000 – 4000	2.6 – 3.5	1.9 – 2.5	Very vigorous or extremely intense surface fire (torching common). Control efforts at fire's head may fail	24 – 28
5	> 4000	> 3.5	> 2.5	Intermittent crown fire to active crown fire development (>10,000kW/m). Very difficult to control. Suppression action must be restricted to fire flanks. Indirect attack with aerial ignitions e.g., helitorch or Plastic Sphere Dispenser (PSD) may be effective	> 29
Adapted from poster "Fire Behaviour in Jack Pine Stands – as it relates to the Canadian Forest Fire Weather Index (FWI) System – M. E. Alexander W. J. DeGroot 1988 Northern Forestry Centre, Edmonton AB.					

Table 3. Fire behaviour characteristics and associated suppression options

approach helps to achieve multiple objectives and minimize impacts and costs. When larger areas are targeted for fuel treatments, the more effective they will be at modifying fire behaviour. This includes creating gaps and openings to further reduce the potential for crown fire.

All stands within a fuel treatment area need to be assessed for their ability to reduce fire behaviour in the event of a wildfire. This includes stands of various age class structure, including both Old Growth Management Areas and stands immediately post-harvest, as all stands contain fuel that will influence fire behaviour. It's important to understand stand structure and its associated fuel loading within a fuel treatment in order to be best prepared for a wildfire.

Figure 12. surface fuel management with prescribed fire.

3.3 CULTURAL AND PRESCRIBED FIRE PLANNING

B.C. has a long history of using cultural and prescribed fire to meet land management objectives including public safety, cultural use, forest and rangeland management, habitat enhancement, and environmental stewardship. In the face of a changing climate, cultural and prescribed fire is an important tool in addressing the increased risks of wildfire faced by indigenous and non-indigenous communities where reducing the risk to life from wildfire is ultimately paramount.

Cultural and prescribed fire is one tool for integrated land management and to mitigate wildfire risks in an area. It is more effective when used alongside complementary risk reduction measures such as thinning, pruning, mechanical removal of vegetation, etc. It is often necessary to use a combination of these methods to meet land management objectives safely and effectively. An integrated and collaborative approach across all landowners and jurisdictions and using a variety of strategies is the best way to minimize wildfire risk and achieve ecological and cultural objectives.

Prescribed fire burn plans are operational plans that link to stand and/or landscape level prescriptions which identify resource objectives for an area including the desired fire effects. Objectives of individual burns will be clearly stated, preferably as measurable objectives. Clearly stated objectives facilitate the formation of suitable burn prescriptions, fire implementation tactics and allow evaluation of burn success for adaptive management purposes.

Objectives of individual burns are guided by, and service landscape level strategic objectives. Burn projects are ideally linked to higher level plans whereby required referrals, consultation, and other input and endorsements have occurred at the appropriate phase.

Often a cultural and prescribed fire project can meet multiple management objectives because different resource values may share similarities or have significant overlap regarding their preferred outcomes of a treatment. Therefore, it may be advantageous to plan for cultural and prescribed fire using a collaborative approach.

Engagement and partnerships are critical components to the success of cultural and prescribed fire. Proactive partnerships and participation with provincial and federal governments First Nations, local governments and stakeholders will ensure cooperation and communication and will benefit both parties. Engagement also serves to increase awareness of the benefits of cultural and prescribed fire while acknowledging its limitations and the challenges associated with its implementation.

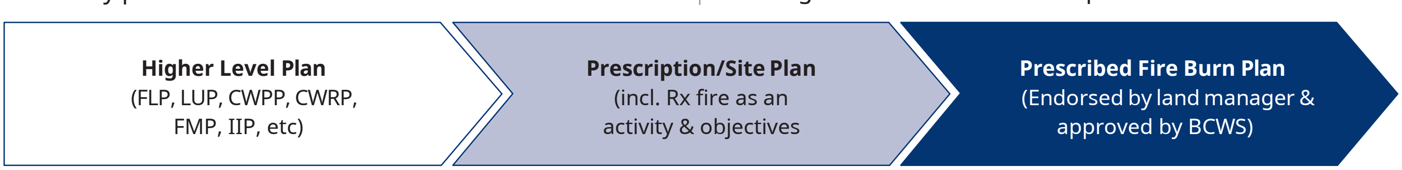

Figure 13. Planning phases of prescribed fire.

Cultural and prescribed fire projects require appropriate planning. Due to the complex nature of these projects, planning for them may take 6 months to 1 year in duration and can be considerably longer as scale and complexity increases. In terms of general planning, factors that must be considered when planning a cultural and prescribed fire include the expanding wildland urban interface (where urban development borders on grasslands and forested areas), critical infrastructure, and land management objectives related to wildlife habitat and watersheds.

Agencies that carry out prescribed burning must comply with all relevant legislation, policy and planning requirements. In B.C., related legislation and guidelines address where and when prescribed fire can occur based on land management and ownership, jurisdictional considerations, environmental protection, Indigenous rights and traditions, air quality, public safety and other topics. Prescribed fires are referred to as "resource management open fires" in the Wildfire Act and the Wildfire Regulation. A burn plan sets the parameters for weather and site conditions for the prescribed burn to be implemented safely while meeting the predetermined land management objectives. It also pre-identifies potential values at risk and measures to reduce risk to those values.

Many areas that are burned require periodic follow-up burns to maintain grasslands or reduce fuel loading. Within a stand and/or landscape level prescription, include a maintenance plan based on the length of time the treatment will be effective in achieving the fire behavior targets and outcomes. This section will include treatment objectives and triggers such as increased fuel load (kg/m2) or a reduction in inter tree spacing. Treatments should be monitored and re- treated at the most economical time frame. For example, it may be more economical to use prescribed fire to maintain forest encroachment while the regen is small enough to kill with understory fire. See the BCWS Fuel Management Survey Data Collection Standard for more details on monitoring and post treatment reporting.

When preparing a burn plan, vegetation type, terrain, weather conditions, fire behaviour and the venting index are considered. The venting index is an indication of how quickly smoke can be expected to dissipate and provides guidance to people wishing to conduct open burns. Although prescribed fires are not prohibited by the Environmental Management Act or Open Burning Smoke Control Regulation (OBSCR), smoke management must be addressed within the burn plan along with any applicable local government or First Nation burning bylaws. More information on planning for and implementing cultural and prescribed fire can be found here https://prescribedfire.ca/.

3.4 FUEL TREATMENT LOCATION

Determining where to place fuel treatments on the landscape, their size, and when maintenance is required, have all proven difficult questions to answer for people working in diverse landscapes. To modify fire behaviour across broad landscapes, fuel treatments need to be strategically located in anticipation of fire movement. An important element of fuel management is recognizing the relative complexity and cost of both fuel treatments and fire control. Studies have shown that "random placement of treatments is substantially less effective than an informed arrangement of treatments".[16]

Factors to consider when determining fuel treatment placement include:

1. Targeting high risk areas for fire spread
2. Topographical influences on fire behaviour
3. Proximity to value being managed for (community, critical infrastructure, etc.)
4. Strategic placement between community and dominant fire spread direction
5. Overlapping resource management objectives
6. Opportunity to anchor to non-fuel or low flammability areas
7. Accessibility for treatment implementation and first responders
8. Land ownership boundaries

3.4.1 Planning for Spotting

The potential lofting of embers (i.e., "spotting") over and across a fuel treatment area must be considered during fuel management planning. Depending on the fuel type and fire weather, spotting over or within a fuel treatment has the potential to create spot fires beyond the fuel treatment area that can expand in size and threaten values at risk, or land directly on or near structures and ignite

[16] Finney M.A., Seli R.C., McHugh C.W., Ager A.A., Bahro B., and Agee J.K. 2007. Simulation of long-term landscape-level fuel treatment effects on large wildfires. International Journal of Wildland Fire 16: 712–727.

them. Effective fuel treatment design can reduce short range spotting and prevent the spread of wildfire but not eliminate it. Fuel treatments along evacuation corridors can be designed to reduce fire intensity to ensure that the corridors are useable during an emergency. Proactive application of FireSmart techniques and fuel treatments adjacent to critical infrastructure can also reduce the risk of loss due to wildfire.

To address spotting, fuels between the fuel break and the values at risk should be evaluated and treated to create

Figure 14 Example of a low severity surface fire in a Ponderosa pine stand.

conditions where extinguishment of spot fires is possible, and FireSmart Standards should be applied to structures and associated vegetation and other fuel to reduce the risk of structures igniting. A multi-barrier approach that reduces the risk to values can include establishing multiple fuel breaks, addressing fuels between the fuel break and structures (interface fuel treatments), and applying FireSmart standards to structures and the surrounding vegetation.[17] Fuel breaks require periodic maintenance to retain their effectiveness. Maintenance is essential for these areas as it is usually cheaper and much easier to maintain than to fuel treat a new project area.

3.4.2 Anchoring

Linking or anchoring fuel treatments areas to existing fire resilient features will create stands that have conditions that will lower fire behaviour in the event of a wildfire (based on desired fire behaviour outcomes) and create a continuous fuel break over an area. "Treating in strategic locations can help break up both continuous horizontal and vertical layers of fuels." ("A Land Manager's Guide for Creating Fire-Resistant Forests ...") For example, utilizing existing fire-resilient areas that have a lower crown-fire potential or areas that could achieve fire resiliency with a relatively low investment.[18]

A summary of some of fire resilient features are listed below:[19]

1. Non-fuel:
   i. natural: Glaciers, ridgetops, lakes, rivers.
   ii. man-made: Roads, landings, gravel pits, mines, talus, bladed structures, densely populated urban areas.
2. Low Flammability Areas: Swamps, wetlands, deciduous, brush fields, avalanche chutes, alpine, or irrigated fields / orchards.
3. Areas with low crown fire potential:
   i. Fuel treatment and recent wildfire areas.
   ii. Low surface fuel load / high crown base height (power line and gas line right of ways)
   iii. Open stands where crown closure has been reduced to influence crown fire initiation and spread
   iv. Low flammability fuel types (e.g. D-2 deciduous or C7 high crown base height)

Cutblocks between 0 and 20 years since harvest may act to effectively reduce fire behaviour potential; however, this assumption requires ground truthing.[20] The amount and dispersal patterns of slash left on cutblocks is highly variable and as such should be evaluated in the field to assess fuel loads and stocking to determine if these areas will function as effective breaks or if they represent an additional hazard due to their potential to contribute to fire behaviour. The potential fire behaviour within the fuel break is also directly related to adjacent fuel types and fire weather and should be considered in the planning. Historically, many of these areas were broadcast burned or mechanically site prepped and could be considered to function as an effective fuel break for several years. More recently cutblocks with residual slash have the potential to increase wildfire rates of spread and contribute to more volatile fire behaviour due to the amount of existing dead wood on the ground in combination with harvesting residue.

[17] Finney M.A. 2001. Design of regular landscape fuel treatment patterns for modifying fire growth and behavior. Forest Sciences. 47: 219–228.

[18] Fitzgerald S.A., and Bennett M. 2017. A Land Manager's Guide for Creating Fire-Resistant Forests. OSU Extension Catalog. EM 9087.

[19] Fechner G.H., and Barrows J.S. 1976. Aspen Stands as Wildfire Fuel Breaks. Aspen Bibliography.

[20] Nicholls D., and Ethier T. 2018. Post-Natural Disturbance Forest Retention Guide – 2017 Wildfires. Ministry of Forests, Lands, Natural Resource Operations and Rural Development.

Figure 15 shows how broadcast burning a cutblock can influence fire spread and intensity years after the activity.

Fuel breaks are not usually identified in areas with low wildfire threat, areas lacking significant values, areas where wildfire is ecologically desirable, or areas with a high degree of fire resiliency. Areas with a high degree of fire resiliency provide fuel discontinuity and natural barriers to fire spread. Areas with high fire resiliency have many existing features that create wildfire suppression options.
In general, small, isolated treatments are of limited value for improving wildfire suppression capability. The areas closest to values at risk or within the WUI should be the highest priority for treatment.

3.4.3 Wind Patterns & Dominant Fire Spread Direction

Predominant wind patterns are a fundamental consideration when determining the placement of fuel breaks. Wind speed, wind direction, and fine fuel moisture condition influences wildfire trajectory and rate of spread. In BC, wind patterns are generally from the south / southwest, however, wind vectoring due to topography, diurnal winds, and other factors can modify this pattern. Wind Roses can be an effective tool to aid in determining the predominant wind direction. BCWS has also developed Initial Spread Index Roses for each weather station in its inventory. [The Initial Spread Index (ISI) roses](#) are completed for each active weather station in the B.C. Wildfire Service weather station network but doesn't include stations with less than 5 years of data or Environment Canada stations. Each rose shows the frequency of counts by wind direction

Figure 15: Influence of broadcast burning site preparation on fire behaviour

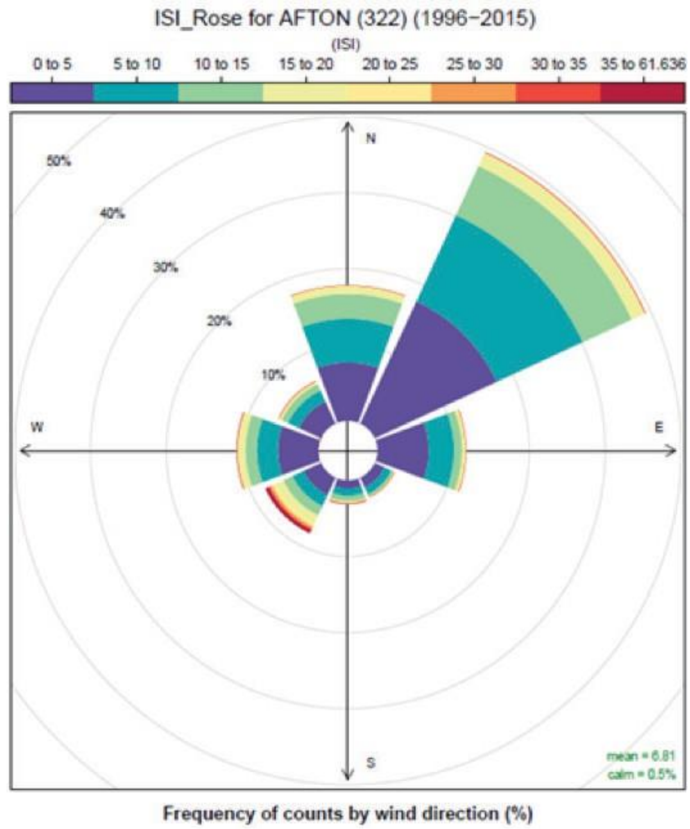

Figure 16: Initial Spread Index Rose for Afton (Kamloops)

with the frequency of the ISI values during that time-period. The upper limits of the ISI are based on the highest recorded ISI for the station, in this case, the upper limit is 35 – 61.636 with 103 being the highest recorded ISI for this station.

The ISI Roses are an important tool for fuel break planning, especially when coupled with historical wildfire perimeters that show historic fire growth patterns, and local knowledge. Local knowledge and ground truthing are important in areas with unique terrain features or in areas where cold fronts area a concern. Wind roses will show average prevailing winds over long periods of time and are unlikely to highlight strong bursts of wind associated with cold fronts. Cold front winds typically shift from the south/southwest to north/northwest as the front passes, and additional fuel breaks could be considered upwind of anticipated cold front winds. All weather stations in the planning area should be assessed and 90th plus percentile weather used as a baseline for determining desired outcomes.

3.5 STRATEGIC SIZE OF FUEL TREATMENT AREAS

Fuel treatments need to be strategically located and of adequate size in anticipation of fire movement. Generally, wider fuel treatments are more effective at moderating fire behavior and providing a window of time for first responders to arrive. Fuel treatment width should be determined on a site-by-site bases as there are many variables that will need to be considered such as adjacent fuel type, topography, response time in the event of a wildfire, anchoring opportunities, etc. Principles driving fuel treatment widths are:

1. A minimum 100m width in most terrain and a minimum of 200m on steeper slopes as recommended by BC FireSmart
2. Two tree lengths
3. The economic maximum skid distance
4. Greater than the maximum spotting distance

Effectiveness for creating conditions conducive to fire resilient stands;

5. Properly designed and constructed fuel breaks eliminate or reduce "wicks". Wildfire often escapes control because of fuel bridges that carry the wildfire across control lines.
6. Fuel breaks can be more effective if they include road access to allow first responder vehicle accessibility.
7. Linear/straight fuel breaks without sharp changes in direction are preferred; however, the use of a combination of fire resilient features, cutblocks, and fuel treatment units etc., to build a fuel break system should be considered. If the later can be accomplished

3.6 SCALED FUEL TREATMENT DESIGN

Fuel treatment design principles are scale-specific – strategies, planning approach, management objectives, practices, and fire behaviour thresholds for fuel management at the WUI-scale and Landscape-scale differ. However, there are strong dependencies between these two scales, as sometimes fires that end up threatening communities start outside of the WUI, that must be strategically considered when planning fuel treatment designs in either the WUI or on the landscape.

In the WUI, fuel treatments are designed with a primary objective of minimize negative impacts to communities through the reduction of potential fire behaviour. However, on the landscape scale, fuel management may look to: align with broader management objectives, be resource value based, and/or provide a broader buffer area around communities.

3.6.1 Fuel Treatment Design in the WUI

Fuel management activities in the WUI, near larger communities with higher wildfire threat are generally the highest priority unless there is a strong rationale to support otherwise. Specific considerations for identifying high priority areas include level of threat, values at risk, treatment objectives, treatment type, treatment timing, treatment complexity, and constraints (terrain, smoke management, costs, funding available, etc.).

Identifying the areas of highest wildfire threat within the WUI is key to designing logical fuel treatment areas that are functional from a fire behaviour and wildfire suppression perspective. If the area has been identified as a priority for fuel treatment, the boundaries of the treatment will be located based on terrain, prevailing winds, fuel types, expected fire behaviour, and fuel treatment objectives.

Fuel treatment areas in the WUI are designed to modify fire behaviour, create wildfire suppression options, and improve suppression outcomes. These areas can be used as a location to burn off fuels and prevent the main fire front from reaching communities, critical infrastructure, or other values. The high threat stands between the fuel treatment area and values at risk should be assessed and planned for to reduce the amount of fuel available and the potential fire intensity that could threaten the value.

Completed and proposed fuel management treatments and timber harvesting within WUI areas should be integrated where they coincide with strategic fuel break locations.

3.6.2 Landscape Level Fuel Treatment Design

To modify fire behaviour across broad landscapes, fuel modification treatments need to be strategically located in anticipation of fire movement, including anchoring projects into non-burnable landscape features (lakes, rivers, roads, etc.). Proactively altering the amount, composition, and arrangement of fuels can reduce the intensity and severity of a future wildfire. This influence is more effective or pronounced when larger areas are identified for fuel management treatments.

Landscape level fuel treatments have varying objectives – influencing their design. Landscape level fuel treatments for community risk reduction are often located upwind and at a significant distance from a community in a strategic location, to create additional suppression options to limit or slow fire spread of a major wildfire before it can reach the community.[22] these types of fuel treatments are particularly relevant in situations when valley corridors channel wildfire season winds directly towards major communities. Additional these treatments may reduce losses to environmental, cultural, and resource values (e.g., caribou habitat, heritage site, timber, etc.).

Landscape level fuel treatments not directly related to community risk reduction are designed to create suppression opportunities to reduce the losses to environmental, cultural, and resource values. Additionally, landscape level fuel treatments strategically look to:

1. maintain fire resilient landscapes,
2. restore landscape-level fire regimes, and
3. support ecosystem adaptation to climate change.

Fuel management at the landscape level incorporates a configuration of patches and corridors to moderate fire spread and intensity. In moderating fire spread and intensity at the landscape scale wildfires can be contained and managed effectively to reduce negative impacts and where appropriate, achieve beneficial fire effects.

Maintaining and restoring fire regimes at the landscape level will sustain and enhance ecosystem processes that are integral to ecosystem health and produce desired ecosystem services and values as well as reduce future carbon emissions relative to the alternative of larger, more severe unmanaged wildfires. This is achieved primarily using cultural and prescribed burning consistent with projected fire regimes and by integrating land management objectives into wildfire response strategies to achieve desired rather than adverse fire effects.

Developing these fuel treatments feasibly requires the use of existing fire resilient areas, combining treatments with commercial timber harvesting, and seeking out opportunities to partner with existing funding programs with complimentary objectives (e.g., Ecosystem Restoration, Land Based Investment, Forest Enhancement Society, etc.). There is more information on landscape planning within the Tactical Fuel Management Planning document.

3.6.2.1 Fire as a Natural Disturbance

A fire regime is represented by the location, frequency, intensity, and seasonality of fires. Fire regimes shape large-scale patterns in biodiversity, carbon, and vegetation across B.C. When regimes shift over time due to climate change or human influence (fire suppression), shifts in species distribution and landscape diversity and productivity can also be expected. Understanding fire regimes and fires influence as a disturbance on the landscape is crucial to developing successful fuel management strategies. Re-establishing and restoring pre-colonial, natural fire regimes is a typical objective of fuel management.[23] There can be cascading negative impacts if natural fire regimes are not replicated in fuel management through over- or under-treatment including:

- Introduction and establishment of invasive species
- Increasing stand susceptibility to disease and pests
- Decreasing surface fuel moisture content

B.C. has diverse ecosystems with unique histories of wildfire, human settlement and development, and current and historical suppression impacts. When planning for fuel treatments, there is a requirement to look to the past to see the role wildfire has played in shaping the ecosystems of B.C.. Highly variable fuel, weather, and topographical conditions exist across B.C., which produce multiple fire regime scenarios. For example, in Southern B.C., there are open grassland ecosystems, with Ponderosa pine graduating towards various densities of Douglas-fir stand, where fire often burned. In high elevation areas and coastal forests, wildfires burned infrequently but with higher intensities when they did. Multiple variants exist between these two examples in the mixed conifer and deciduous forests as well.

Ecosystems in B.C. are maintained and managed by natural disturbances such as wildfire. In B.C. natural disturbances are classified into 5 Natural Disturbance Types (NDT). NDTs are classified by the return interval of the disturbance and if the disturbance is stand maintaining or stand initiating. Stand maintaining fires occur on a 5-to-40-year return interval while stand initiating fires occur on much longer return interval of up to 200 years.

When evaluating fuel conditions, it is imperative that the NDT system that the stand falls under is understood

[22] Mooney M.C. 2010. Fuel break Effectiveness in Canada's Boreal Forests: A synthesis of current knowledge. FP Innovations.
[23] Sommers, W. T., Coloff, S. G., and Conard, S. G. 2011. Synthesis of Knowledge: Fire History and Climate Change. JFSP Synthesis Reports. 19

BC Wildfire Service

NDT	Summary	Fire Parameters
NDT1	Ecosystems with rare stand-initiating events.	The mean return interval for these disturbances is generally 250 years for the CWH and ICH, and 350 years for the ESSF and MH biogeoclimatic zones.
NDT2	Ecosystems with infrequent stand-initiating events.	Wildfires were often of moderate size (20 to 1000 ha), with unburned areas resulting from sheltering terrain features, higher site moisture or chance. Many larger fires occurred after periods of extended drought, but the landscape was dominated by extensive areas of mature forest surrounding patches of younger forest. The mean return interval for these disturbances is about 200 years for the CDF, CWH, ICH, SBS, ESSF and SWB biogeoclimatic zones.
NDT3	Ecosystems with frequent stand-initiating events.	Historically, these forest ecosystems experienced frequent wildfires that ranged in size from small spot fires to conflagrations covering tens of thousands of hectares. Mean return interval for disturbances is about 100 years for the wind-dominated CWH and the fire-dominated SBPS and BWBS with deciduous species prominent. For the SBS and BWBS with coniferous species prominent, the mean fire return interval is about 125 years. The ESSF, ICH and MS units in this NDT experience a mean disturbance return interval of about 150 years.
NDT4	Ecosystems with frequent stand-maintaining fires.	This NDT includes grassland, shrubland, and forested communities that normally experience frequent low-intensity fires. On grasslands, these fires limit encroachment by most woody trees and shrubs. Late seral and climax grasslands and shrublands are typically restricted to droughty sites that occur at low elevations or on steep south-facing slopes or fire-prone areas. Surface fire return intervals for the PP and IDF biogeoclimatic zones historically ranged from 4 to 50 years; stand-initiating crown fires were rare in the PP and occurred at intervals ranging from at least 150 to 250 years or more in the IDF.
NDT5	Alpine Tundra and Subalpine Parkland ecosystems.	The ecosystems in this natural disturbance type occur above or immediately below the alpine treeline, and are characterized by short, harsh growing seasons. The vegetation is strongly patterned by variations in local topography. Fire can have a dramatic effect in this disturbance type, weakening or killing plants and causing long-term shifts in the position of the tree line. The harsh climate and short growing season restrict the rate of plant growth that can take place following a stand-initiating disturbance.

Table 4. B.C. Natural Disturbance Type classification system [24].

and influences treatment specifications. The following table summarizes the NDTs that make up B.C. and their associated fire parameters.

In BC, it is the dry forests of the NDT 4 that burned frequently with low intensity fires where forest structure and composition has now been modified though 60 to 100 years of wildire suppression that are a focus of fuel treatments planning and mitigation. With this, we continue to learn through science the complexity of these ecosystems.

Mixed severity fire regimes are when a landscape is subjected to both high and low severity fires. "Mixed-severity fire regimes result in complex landscapes comprised of stands that last burned at a range of fire severities, as well as stands that have not burned for long periods"[26]

Fuel treatments that are focused on specific challenges regarding the WUI or other high values at risk may be appropriate in all forest types but broadly, not every forest type in B.C. should be a priority for treatments. Many of the coastal forests, high elevation Engelmann spruce subalpine fir, or interior cedar hemlock ecosystems have rarely experienced a wildfire and may not have a fuel problem.[27]

3.7 PLANNING AND DESIGN FOR MULTIPLE VALUES AT THE STAND LEVEL

The placement of fuel treatment areas will consider complimentary resource management objectives. At the planning stage, stakeholders and agencies work together and consider the full range of values. Where possible, fuel treatments are to complement desired future condition (e.g., where wildlife burns are planned, core grasslands are intended to be maintained, licensees have planned

[24] H.M., Gergel S.E., and Daniels L.D. 2013. Mixed-severity fire regimes: How well are they represented by existing fire-regime classification systems? Canadian Journal of Forest Research. 43(7): 658-668.

[26] Marcoux H.M., Gergel S.E., and Daniels L.D. 2013. Mixed-severity fire regimes: How well are they represented by existing fireregime classification systems? Canadian Journal of Forest Research. 43(7): 658-668.

[27] Peterson D.W., Dodson E.K., and Harrod R.J. 2015. Post-fire logging reduces surface woody fuels up to four decades following wildfire. Forest Ecology and Management. 338: 84-91.

harvesting activities, ungulate winter ranges, etc.). This approach helps to achieve multiple objectives and minimize impacts and costs. When larger areas are targeted for fuel treatments, the more effective they will be at modifying fire behaviour. This includes creating gaps and openings to further reduce the potential for crown fire.

All stands within a fuel treatment area need to be assessed for their ability to reduce fire behaviour in the event of a wildfire. This includes stands of various age class structure, including both Old Growth Management Areas and stands immediately post harvest, as all stands contain fuel that will influence fire behaviour. It's important to understand stand structure and its associated fuel loading within a fuel treatment in order to be best prepared for a wildfire.

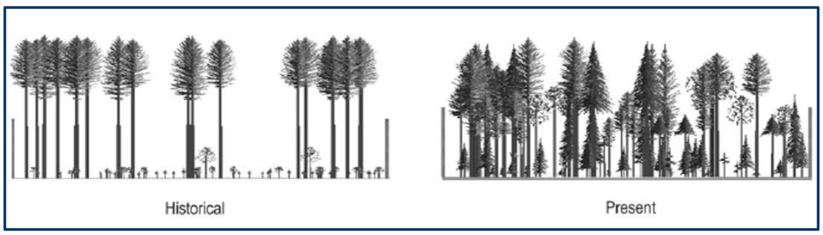

Figure 17. NDT4 representation of changes in vertical arrangement and horizontal continuity in forest stand structure. Today's forests tend to have more fuel strata, higher densities of fire-sensitive species and suppressed trees, and greater continuity between surface and crown fuels [25]

British Columbia forests cover approximately 55 million hectares of the 95 million hectares of land, which are comprised of approximately 80% coniferous trees.[28] Approximately 40% of these forests are over 140 years old. Every year ~200,000 hectares of forest is harvested in B.C. Timber harvesting is one of the most important economic drivers, and to preserve that for future generations it is vital to put an emphasis on the sustainability of BC's forests.

With the dependence of forestry, logging is going to take place within and outside the WUI. Forestry operations give forest professionals the opportunity to consider the temporal and spatial distribution of harvesting and can be designed to increase fire resiliency using several techniques. Linking existing fire resilient features with timber harvesting and/or fuel treatments that create fire resilient stand structure and conditions following harvest or treatments, as well as being selective with the species planted and coinciding with the Fire Management Stocking Standards Guidance Document. The next few sections provide suggestions on how to manage for wildfire risk reduction and other objectives.

3.7.1 Visual Resource Management

The Government of B.C. is entrusted with managing visual impacts on crown land. B.C.'s visual resource management program conducts a range of activities to ensure the scenic quality expectations of the public and the tourism industry are met.

Forested hillsides are the features usually identified for scenic management. These steep landscapes support a range of natural resource values, some of them crucial to two key B.C. industries — tourism and forestry.

Visual quality objectives (VQO) guide forest management activities on a landscape.

When it is determined that a wildfire threat or risk to values is stemming from forested areas within an VQO, fuel management work may need be carried out these areas. To attempt to maintain the visual quality objectives, the following principles should be considered:

1. Removal of surface fuel less than 7 cm in diameter to achieve potential surface fire intensity levels below 2,000kW/m).
2. Increase the height to live crown through a reduction in ladder fuels (crown base height) to reduce potential for crown fire initiation.
3. Maintain Coarse Woody Debris (CWD) to a level suitable to maintain biodiversity but not to create a wildfire hazard.
4. Maintain crown closure if the factors for the initiation of crown fire (surface fire intensity, crown base height and foliar moisture content) have been reduced to the extent necessary

[25] Peterson D.L., Johnson M.C., Agee J.K., Reinhardt E.D. 2003. Fuels Planning: managing forest structure to reduce fire hazard. Conference Paper Second International wildland fire ecology and fire management congress and firth symposium on fire and forest meteorology, At Orlando FL.
[28] The state of British Columbia's Forests – 3rd edition. 2010. Library and Archives of Canada Cataloguing in Publication.

3.7.2 Old Growth Management

Millions of hectares of forest in B.C. are deemed old growth forests. These forests contain trees that are more than 140 and 250 years old in the interior and the coast, respectively. These forests house intrinsic and economic value from biodiversity and critical habitat to timber and recreation.

Figure 18. Forwarder removing timber from a partial cut stand.
The removal of codominant stems reduces canopy bulk density.

Old growth stands present in many different forms throughout the province, however in most instances when a fuel treatment is necessary, fuel management objectives can be met while still maintaining and enhancing their old growth values. To attempt to maintain old growth structure and biodiversity attributes the following principles should be considered:

1. Removal of surface fuel less than 7 cm in diameter to achieve potential surface fire intensity levels below 2,000kW/m
2. Increase the height to live crown through a reduction in ladder fuels (crown base height) to reduce potential for crown fire initiation.
3. Maintain Coarse Woody Debris (CWD) to a level suitable to maintain biodiversity but not to create a wildfire hazard.
4. Maintain crown closure. Fire behaviour objectives in old growth forests can be met while maintaining their integrity and large, old trees.

3.7.3 Ungulate Winter Range

An Ungulate Winter Range (UWR) is defined as an area that contains habitat that is necessary to meet the winter habitat requirements of an ungulate species. There are instances within the WUI and on the landscape where fuel management treatments overlap with UWR. Where these overlaps occur treatments can be performed to maintain the forest structure and biodiversity necessary for winter cover for ungulates while also reducing the wildfire threat and risk. The following treatments should be considered during these instances:

1. Some of the objectives of a UWR may conflict with wildfire mitigation treatments is terms of understory retention. The understory can be left in a patchy distribution within a wildfire mitigation treatment area if it is separated from the remaining trees in terms of vertical and horizontal separation. This done to mitigate the chances of a crown fire initiating from these clumps.
2. Removal of surface fuel less than 7 cm in diameter to achieve potential surface fire intensity levels below 2,000kW/m.
3. Maintain or increase the height to live crown through a reduction in ladder fuels (crown base height) to reduce potential for crown fire initiation
4. Maintain Coarse Woody Debris (CWD) to a level suitable to maintain biodiversity but not to create a wildfire hazard.
5. Decrease crown closure if the UWR retention strategy allows for openings in the canopy and if it necessary to mitigate wildfire risk/threat. Maintain crown closure if the factors for the initiation of crown fire (surface fire intensity, crown base height and foliar moisture content) have been reduced to the extent necessary

Figure 19. Example of timber harvesting techniques in Mountain Caribou Habitat

Part 4 Prescribing Fuel Management Treatments

Part 4 builds upon fuel management design, introducing the document in which fuel management treatments are prescribed, the importance of data collection, how to define future stand conditions, and specifying treatment targets. Recognizing that fuel management objectives and scale (wui vs landscape) drive desired future conditions and treatment targets.

4.1 FUEL MANAGEMENT PRESCRIPTION

A Fuel Management Prescription (FMP) is the legal document that outlines the current site conditions of a fuel management area and describes the fuel management treatments required to meet potential fire behaviour objectives. Prescriptions must clearly demonstrate their reduction of fire behaviour through detailing fuel management treatment targets for[29]:

1. Reducing surface fuels
2. Increasing the height to live crown
3. Decreasing crown bulk density
4. Modifying stand stocking and species conversion

FMPs must provide data that confirms the targets above result in measurable reduction of potential fire behaviour and be appropriate to the site-specific ecology. Site ecology and considerations tied to meeting the potential fire behaviour objectives are detailed in the FMP. It is also imperative that the FMP outline how the fire behaviour objectives will be met, and treatments implemented, in compliance with all applicable legislation and regulation (E.g., Land Act, Migratory Bird Convention Act, and Forest and Range Practices Act and associated Forest Planning and Practices Regulation). Although prescriptions are site specific, they must be developed in consideration with how they strategically fit into the landscape and higher-level plans. Prescription development follows and incorporates a suite of guidance documents, policy, and tools that are outlined in the BCWS Fuel Management Prescription Guidance document.

Prescriptions are developed, signed, and sealed by forest professionals working well within their scope of practice. As stated in the ABCFP released Interim Guidelines – Fire and Fuel Management, practicing within the field of fire and fuel management requires specific education, training and experience related to a variety of subjects including: fire ecology, fire effects, fire behaviour, fire regimes, fuel types, fire suppression, and fire weather. These subjects are in addition to proficiency in the subject of forestry. Fire ecology, effects, behaviour, regime, type, suppression, and weather experts can be accessed through the BC Wildfire Service or external practitioners When developing fuel management prescriptions professionals should be in contact with local BC Wildfire Service staff to ensure prescriptions are meeting all fire behaviour objectives.

Prescriptions should include specific targets for fuel treatments that are selected with consideration of land management, fire behaviour, and other overlapping land objectives. Fire behaviour modelling based on Canadian fuel types should be used to model current and target fuel conditions. This should demonstrate a change in fire behaviour potential from crown fire to surface fire for weather conditions for up to at least 90th percentile fire weather conditions or similar fire weather indices for a specified area.

Fire behaviour models may also be used to demonstrate reductions in crown fire initiation and fire intensity post-treatment. This will help to determine whether fuel treatments are able to demonstrate that they lower the overall wildfire threat represented by the fuel loading. Quality data collection is fundamental for accurate fuel loading scenarios and associated fire behaviour outputs. Understanding fuel loading, fuel classes, fuel moisture, fire weather and their relationships to fire behaviour is required. All fire behaviour modelling should include documentation with full disclosure on assumptions and inputs used in the modelling process. This will allow for full understanding of the outputs.

The following list of modelling software is expended upon in Appendix I Fire Behaviour Modeling Software:

- Fuel CalcBC
- CFIS
- BurnP3
- Prometheus

[29] Safford H.D., Schmidt D.A., and Carlson C.H. 2009. Effects of fuel treatments on fire severity in an area of wildland-urban interface, Angora Fire, Lake Tahoe Basin California. Forest Ecology and Management. 258: 773-787.

4.2 DATA COLLECTION FOR FUEL MANAGEMENT PRESCRIPTIONS

Fuel management prescriptions must detail the existing and desired characteristics of the forest stand and fuels within the treatment area. This information ensures the prescription outlines measurable treatment specifications that meet the prescription objectives. Data should be collected in accordance with the principles outlined in the BCWS Fuel Management Survey Data Collection Standards document.

Article 4, Treatment Decision Survey and Article 5, Prescription Development Survey of the BCWS Fuel Management Survey Data Collection Standards outline data that should be collected specific to deciding whether to an area should be incorporated for treatment in a fuel management prescription and for fuel management prescription development respectively. Article 3, Standards Applicable to All Surveys of the BCWS Fuel Management Survey Data Collection Standards outlines general standards that should be practiced during an fuel management surveying.

Collecting field data to support fuel management prescription development requires survey skills to ensure data is collected to an acceptable standard and intensity that is appropriate for determining fuel treatment thresholds and defining future conditions. More specifically; *"Surveys must be undertaken according to scientifically sound and statistically acceptable methodologies in order to quantify such attributes as stem density, fuel loading, vegetation inventory, habitat types as well as other site values."*[30]

The intent is to ensure that the entire fuel treatment area will reduce the overall fire behaviour potential. Science based thresholds for target fuel conditions post-treatment provide a measure of project success. The method of data collection and its units of measurement should be compatible with those used by the Province and should facilitate post treatment re-measurements.

When quantifying fuel loading, regardless of the system used, it should consider surface fuels, ladder fuels, and crown fuels as well as their vertical and horizontal continuity. These measurements must be repeatable to allow for post treatment evaluations and long-term monitoring.

Figure 20. Fuel loading data collection transect

4.3 DEFINING DESIRED FUTURE CONDITIONS FOR EFFECTIVE FUEL TREATMENTS

Developing an effective Fuel Management Prescription requires a sound understanding of both forestry and wildfire. The objective of the treatment needs to be clear from a fire behaviour, fire effects, and stand management (tree silvics, silviculture, and vegetation development including succession) perspective. Accounting for some but not all relevant factors may result in a treatment that is not effective in meeting its desired objective. Defining desired future conditions is a site-specific activity due to the infinite ways in which fuels can be present in an area, and how they are related to the environment around them; therefore, pre-prescribing thresholds is impractical. For example, determining what type of fuel structure is required to meet a specified treatment and how the fire behaviour objective will vary by surrounding fuels, slope, aspect, elevation, as well as wind speed, humidity, and temperature. The USFS Fire Effects Information System is an excellent source for fire related information by species.

Ensure that desired future conditions are clearly illustrated and designed in the fuel management prescription to guarantee the most effective fuel treatment.

A study on fuel treatment effectiveness literature over the past decades suggest that while individual treatment effectiveness varies widely (related to vegetation and treatment type) the overall effect of fuel treatment on

[30] ABCFP. 2013. Interim guidelines – fire and fuel management. Association of B.C. forest Professionals Guidelines.

Figure 21: Pre (left) and Post (right) fuel treatment in a Douglas fir stand.

fire is large and significant as measured by a reduction in canopy volume scorch, surface fire intensity, and rate of spread.[31] Most effective were treatments in conifer forests that were thinned leaving larger diameter trees in the stand with subsequent prescribed fire applied to reduce surface fuels. In addition, the study also supports the premise that surface fuel reduction is the primary driver in fuel treatment effectiveness.

Understanding what makes a fuel treatment effective is just as important as understanding what types of treatments will not be effective. B.C. Wildfire Service is invested in studying fuel treatment efficacy. Preliminary observations during site visits of fuel treatments in B.C. that have interacted with fire included the following:

1. Treatments were often not located in logical locations,
2. Treatment areas were often too small to have much effect, although under certain weather conditions, there are no treatments that are going to be effective.

Some key learnings from this case study include:

- Thinning mature or near mature stands appears to be cost effective and feasible at a scale that can make a difference in certain stand dynamics,
- Silviculture treatments can be extremely effective in reducing potential fire behaviour. Including both site preparation and management of stand structure through planting and density control (disc trenching, broadcast burning, etc.), and
- Having large scale treatments tying into non-burnable features.

4.4 SPECIFYING TREATMENT TARGETS

Regardless of the scale of the fuel management project, all treatments aim to disrupt wildfire processes through reducing the quantity and continuity of forest fuels in the surface, ladder and crown fuel layers. Specifically surface fuel load, crown base height, and crown bulk density must be modified. No matter the stand being treated, prioritization of stand attributes for modification should be in the following order, with reducing crown bulk density being the last attribute to be modified to meet potential fire behaviour objectives:

1. Reducing surface fuel load.
2. Increasing crown base height.
3. Reduce crown bulk density

Reducing surface fuel loading will decrease the potential for sustained ignition and crown fire initiation, ultimately achieving potential surface fire intensity levels below the critical surface fire intensity threshold, to a target of 2,000kW/m. Increasing the crown base height through removing ladder fuels will reduce the potential for crown fire initiation, rendering a higher critical surface fire intensity. In many instances, surface and ladder fuel modification alone is sufficient in meeting fuel management objectives. In some instances, reducing crown bulk density and crown closure is necessary, reducing the potential for crown fire spread and spread rate and/or encouraging a fire transition from crown to surface.

As previously outlined, each treatment area is unique in its objectives, fire behaviour, stand attributes, and site

Figure 22. Adaptation of fuel arrangement figure from Northwest fire Science. 2017. Fire Facts: What is Fuel.2. From left to right: forest stands can be classified into 3 fuel layers, surface, ladder, and crown fuels. In the event of sufficient fuel loading and continuity under the right conditions, surface fires can ignite and spread. Ladder fuels allow for vertical fire spread from surface to crown fuels. Sufficient loading in the crown allows for crown fire spread.

[31] Martinson E.J., and Omi P.N. 2013. Fuel treatments and fire severity: A meta-analysis. Rocky Mountain Research Station.

attributes therefore each requires its own specific and measurable fuel targets. When considering treatment targets be aware of possible unintended consequences. Most importantly when addressing the secondary outcomes of a fuel treatment one must ultimately consider that the impact of no treatment at all can be far greater. Once a treatment is completed, assess if the treatment met prescribed fire behaviour targets. Long term monitoring should follow treatment implementation to assess for unintended consequences that need to be addressed.

The type, quantity, arrangement, and state (dead or alive) of fuels make up the fuel complex. The fuel complex considers characteristics that dictate a fuels availability to burn, impact fire behaviour, and need to be considered and described in treatment targets. The moisture content of dead and live fuels plays influence into fire behaviour. Dead fuels have lower moisture contents, facilitating higher heat release from fuels and ultimately fire behaviour such as rate of spread and fuel consumption. Treatments should target and prioritize the removal of hazardous, dead surface, ladder, and crown fuels.[33]

Targeting dead fuels must be considered from a pest and pathogen perspective. Consideration of time since exposure to pest or pathogen epidemic or endemic dictates what treatments should take place. A proactive approach to treatments that considers the future state of a stand and likelihood of pest, disease, and climate change impacts is recommended.[34]

4.4.1 Complexities in Setting Treatment Targets

When specifying the treatment targets, or the extent to which surface fuel load, crown base height, and crown bulk density will be modified, interactions between these attributes must also be considered.

4.4.1.1 Influences on within-stand environmental parameters

When specifying treatment targets consideration of post treatment stand structures influence on environmental factors must be considered. Environmental factors play influence into moisture content and dynamics in fuels, ultimately influencing fire behaviour. For example, overstory crown closure shades surface fuels on the forest floor, limiting solar radiation. If a fuel treatment target is to reduce crown bulk density, overstorey thinning will be prescribed, ultimately decreasing stand density and crown closure. A reduction in crown bulk density would decrease potential crown fire spread. However, secondary

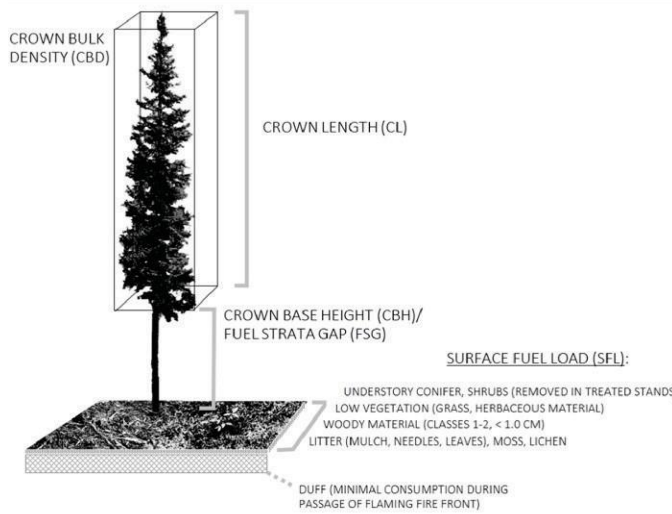

Figure 23. Diagram of prioritized stand attributes that are modified during fuel treatments from Beverly et al. 2020.[32]

effects of this treatment would be increased in-stand wind speeds and solar radiation. A treatment that reduces crown closure and opens up the stand will increase solar heating and reduce moisture levels in surface fuels, especially fine fuels.[35] This could unintentionally increase surface fire intensity and the potential for crown fire initiation. To combat this secondary effect, consider reducing surface fuel load and/or increasing crown base height.[36]

4.4.1.2 Stand susceptibility to windthrow

If a fuel treatment target is to reduce crown bulk density, overstory thinning will be prescribed, ultimately opening the stand, and decreasing stand density. In doing so, residual stems may be subject to windthrow, increasing surface fuel loading within the treatment area. This would unintentionally increase potential surface fire intensity and potential for crown fire initiation. If site characteristics are conducive to wind throw, such as shallow soils, shallow rooting tree species, close canopy stands, and/or

[32] Beverly et al. 2020. Stand-Level Fuel Reduction Treatments and Fire Behaviour in Canadian Boreal Conifer Forests. Fire. 3, 35.

[33] Rossa C. 2017. The Effect of Fuel Moisture Content on the Spread Rate of Forest Fires in the Absence of wind or Slope. International Journal of Wildland Fire. 26

[34] Jenkins M. J., Hebertson E., Page W., Jorgensen C. A. 2008. Bark beetles, fuels, fire, and implications for forest management in the intermountain west. Forest Ecology and Management. 254. 16-34..

[35] Jesse K. Kreye, J. Kevin Hiers, J. Morgan Varner, Ben Hornsby, Saunders Drukker, and Joseph J. O'Brien. Effects of solar heating on the moisture dynamics of forest floor litter in humid environments: composition, structure, and position matter. Canadian Journal of Forest Research. 48(11): 1331-1342. https://doi.org/10.1139/cjfr-2018-0147

[36] Agee J.K., and Skinner C.N. 2005. Basic Principles of fuel reduction treatments. Forest Ecology and Management. 211, 83-96.

location on terrain is oriented unfavourably to prevailing winds, this must be accounted for and addressed at the treatment design stage. If patch retention can meet fuel management objectives, this will generally result in internal shelters reducing windthrow. If individual stem retention is necessary consider a gradient of density, where densest retention levels face prevailing winds. Or consider a progressive treatment plan where the stand is slowly opened over time to produce wind firm trees. Finally, another consideration is limiting level of thinning to minimize windthrow, and further reduce surface fuel load and/or increase crown base height to ensure fire behaviour targets are met.[37]

4.4.1.3 Introduction and Establishment of Noxious and Invasive Plants

Treatment activities including but not limited to thinning and prescribed burning is a disturbance on the land base that can both introduce and promote the spread of invasive plants. Invasive plants are non-native species free from natural pests or pathogens that manage their population and extent resulting in their ability to outcompete native species and alter ecosystems. Once an invasive species is introduced to an area, they are costly and difficult to manage and, in some cases, can increase flammable fine fuel loads and potential fire behaviour. When conducting fuel management treatments, consideration of invasive species establishment and impact is imperative. The Reference Guide and Manual of Best Practices for Prescribed Fire and Invasive Species provides information on incorporating invasive plant management into fuel management treatments.

4.4.1.4 Post-thinning understory regeneration

When specifying thinning targets one must consider regeneration response to increased growing space. Understory regeneration re-establishes surface and ladder fuels and as time progresses, regeneration recruits into the overstory. Each stand will have specific regeneration responses that are dictated by the fuel treatment, the pre-treatment stand, and environmental conditions within the stand, knowledge of the varieties of factors that play influence on regeneration is imperative to designing fuel treatment prescriptions and specifying treatment targets. Regeneration is a key factor in fuel treatment longevity and will influence monitoring and maintenance plans. When reducing regeneration is necessary, creating an environment inconducive to germination through mechanical damage or by fire may be appropriate. Promoting the establishment of mor desirable, fire resilient species should also be considered.[38]

4.4.2 Reducing Surface Fuels

Surface fuels include all combustible materials lying above the duff layer between the ground and ladder fuels that are responsible for propagating surface fires (e.g. litter, herbaceous vegetation, low and medium shrubs, tree seedlings, stumps, downed-dead round wood).[39] Surface fuels are commonly described by type (woody or nonwoody, deciduous or conifer), status (live or dead), and size (fine, large, and coarse woody material).

Figure 24: The fire in this photo is exhibiting ~2,000kW/m

Surface fuel loading and continuity influence the following potential fire behaviour factors:

- Flame length
- Torching
- Fire intensity

In reducing surface fuel load and continuity, fuel treatments can effectively reduce the potential for sustained ignition and crown fire initiation, as well as decrease surface fire intensity and spread rate.

[37] Schroeder, D. 2006 Considerations for Mitigating Windthrow due to Forest Fuel Treatments. FERIC

[38] Rossman AK, Bakker JD, Peterson DW, Halpern CB. Long-Term Effects of Fuels Treatments, Overstory Structure, and Wildfire on Tree Regeneration in Dry Forests of Central Washington. Forests. 2020; 11(8):888. https://doi.org/10.3390/f11080888

[39] DeBano L.F., Neary D.G., and Folliott P.F. 1998. Fire's Effects on Ecosystems. John Wiley & Sons, Inc.

When community risk reduction is the objective, fuel treatments aim to reduce surface fuel loading to achieve potential surface fire intensity levels below the critical surface fire intensity, to a maximum of 2,000kW/m. This target reduces the potential for sustain ignition and crown fire initiation. At a minimum, surface fuel loading and continuity because of fuel treatments cannot contribute to an increase in any of the above outlined fire behaviour.

The reduction of surface fuel loads is well documented in literature as being successful in moderating potential wildfire behaviour in pine and mixed conifer forests, especially when prescribed fire is used as the method of treatment. It's noted that treatments can remain effective for up to 10 years, but this varies by ecosystem.[40]

4.4.1.1 Types of Surface Fuels

Surface fuels are made up of the duff layer, herbaceous material and grasses, shrubs, leaf and needle litter, dead and downed woody material. Each of these surface fuel types affect the transition of fire from the surface to the crown and are therefore prioritized for reduction in fuel management. The size, type, load, and moisture content of the surface fuels influence its consumption and associated surface fire intensity.[41]

Figure 25. Prescribed fire being used as a tool to manage surface fuels.

Therefore, quantifying surface fuel loads in terms of size class when specifying treatment targets is imperative. Smaller diameter fuels should be prioritized for reduction because they require less heat to ignite and are consumed faster due to their surface to volume ratio. Targets should be set to describe the amount, continuity, and composition. Measurable targets for each class of surface fuel can be provided as a measurement of weight of combustible material per unit area (commonly kilograms per square meter or tonnes per hectare). Further guidance and tools for setting surface fuel loading targets can be found on the Tools for Fuel Management webpage.

Fuel management in B.C. classifies dead and downed woody debris into 3 categories based on diameter:

- Fine Woody Debris (≤7cm diameter)
- Large Diameter Woody Debris (>7 – 20cm diameter)
- Coarse Woody Debris (>20cm diameter)

B.C. Wildfire Service is currently developing a standard to survey and categorize duff layer, herbaceous material and grasses, shrubs, and leaf and needle litter to accurately include them into fuel management targets.

There are a few ways to mitigate surface fuel loading; pile and burn, burying, and broadcast burning. Piling and burning is the most common method used in B.C. It allows for centralized, controlled burning, with minimal expertise in burn operations. Piles are left to dry throughout the summer months and burned during fall or winter to reduce unwanted spreading. Most piling and burning that occurs in B.C. occurs roadside from processing debris, with in block debris often remaining onsite, or piled and burnt within the block.

Using a method such as broadcast burning can effectively reduce most fuels on site with a continuous fuel gradient and proper burning conditions. It was found that broadcast burning of cutblock slash that was <3cm in diameter averaged 91% consumption.[42] With most small fuels consumed, it is not likely that a wildfire would be able to spread through a cutblock. Currently, a minimal amount of broadcast burning is occurring in the province, because of concerns over air quality, and the potential for fire escapes.

[40] Martinson E.J., and Omi P.N. 2013. Fuel treatments and fire severity: A meta-analysis. Rocky Mountain Research Station.

[41] Hanes, Chelene & Wang, Xianli & Groot, William. (2021). Dead and down woody debris fuel loads in Canadian forests. International Journal of Wildland Fire. 30. 10.1071/WF21023.

[42] Macadam A.M. 1987. Effects of broadcast slash burning on fuels and soil chemical properties in the Sub-boreal Spruce Zone of central British Columbia. Canadian Journal of Forest Research. 17(12): 1577-1584.

4.4.1.2 Wildfire Hazard Abatement

Hazard abatement is a post-industrial activity (i.e. timber harvesting) requirement to reduce the potential threat arising from fuels left on the land base. Hazard abatement requirements are specified in the Wildfire Regulation. They are designed to promptly identify and abate fire hazards, and they are also used to ensure fuel hazards are not increased to a high level of potential fire behaviour.

Abating fire hazard alters fuel characteristics, mitigates the risk to values, and minimizes wildfire suppression costs; both at the site of the industrial or prescribed activity and in the surrounding area. In some cases, achieving minimum legal requirements for hazard abatement, may still result in significant slash loads remaining on site following harvesting. Consideration should be given to further reduce the hazard to lower levels that foster fire resiliency. For more information go to Wildfire Hazard Assessment & Abatement.

4.4.2 Debris Management

Regardless of treatment type and method prescribed, all fuel treatments have one thing in common that must be considered at the Fuel Management Prescription development stage, well in advance of the treatment - the residual fibre, waste wood resulting from the treatment, and the provisions made to dispose of it. Failure to accommodate this part of the process at the planning stage may increase risk, increase treatment costs, or cause potential revenue loss, and may prevent future treatments from occurring. This is especially prevalent when the option for debris disposal selected is to burn it on site as there may be burning bylaws in place, open burning prohibitions in effect, legislation (OBSCR, Wildfire Act) that must be adhered to, health concerns, and public opposition. All efforts should be made to utilize harvested stems before deciding to burn them.

Debris management is an essential part of fuel treatments. If debris is left on site following a fuel treatment the managed area may become ineffective or enhance fire behaviour on site (often increasing the threat considerably). There are multiple methods to manage debris on site, and the appropriate method must be chosen with careful consideration. For more information on this subject please refer to Appendix B of this document, or find additional resources the Tools for Fuel Management BC. Government website.

4.4.3 Increasing Height to Live Crown

Ladder fuels facilitate the vertical spread of fires from the surface to the crown. Ladder fuels are commonly described by their composition (deciduous vs conifer) and continuity. Crown base height is the vertical distance between the ground and the lowest point of the crown of an individual tree. The dead components of a crown can be considered in crown base height when they are sufficiently able to sustain vertical fire propagation. Crown base height and the presence of ladder fuels influences:

Figure 26. Burn box for debris management to limit site disturbance during a fuel management project in Ellison Provincial Park.

- critical flame length,
- torching, and
- crown fire initiation

Increasing crown base height can reduce the potential for torching and crown fire initiation and increase critical flame length. Fuel treatments such as pruning residual trees and removing understory trees reduce ladder fuels.

Different tree species have different characteristics with respect to fire. Species differ with respect to canopy characteristics (e.g., canopy density, crown width, etc.), flammability and fire resistance and resilience. Crown base height is an additional variable driving crown fire. Species with a greater tendency to self-prune thus increasing crown base height, may be less likely to promote crown fire. Species that do not self- prune well at desired densities (i.e., increased density increases self-pruning) may require pruning treatments in order to achieve fire management objectives.

Understory trees should be removed when they have the potential to transfer fire from the surface to the crowns, and the lower branches of large trees should be pruned to reduce ladder fuels (stratification between the ground and tree crown).

In instances where desired surface fuel targets are unachievable (e.g., prescribed fire not possible), an increase in CBH may be an alternative to reduce crown fire initiation, but it must be understood that the risk of surface fire spread will still exist.

4.4.4 Decreasing Canopy Bulk Density

Crown fire spread begins with torching and is supported by the density of the crown and the rate of spread. The density of the crown can be expressed through canopy bulk density which is a measure of the amount of foliage in each volume of crown stand level. Crown bulk density is the density within a single crown or a tightly spaced clump of trees and is highly variable by species in B.C.

As mentioned above, different tree species have different characteristics with respect to fire. Generally broadleaf species, Douglas fir, ponderosa pine, and western larch are less flammable than other coniferous species and as a result, may reduce fire behaviour. Canopy bulk density is a key variable driving the development of crown fire and species with less dense crowns may be less likely to initiate or propagate crown fire. Dense stands however tend to increase the likelihood of crown fire over less dense stands. Reducing the number of trees on the site to achieve a reduction in crown fire potential by reducing canopy fuels (Canopy Bulk Density) is a common objective of fuel treatments. Thinning may not be the best approach for every ecosystem, or fuel type, for example; coastal stands, or stands susceptible to windthrow. Although active crown fire spread begins with torching it is sustained by the characteristics of the overstory crowns.

Thinning has been a common element of fuel treatment design. *"Thinning treatments have demonstrated the greatest reductions in wildfire severity, but only if those treatments produce substantial changes to canopy fuels, shift the diameter distribution towards larger trees, and are followed by broadcast burning or other means of surface fuel removal. Until the residual activity fuels are disposed, they will largely offset much of the hazard reduction benefit achieved from opening the canopy"*. [43]

While the removal of trees will result in the desired reduction in canopy bulk density and canopy continuity its effectiveness varies by the thinning method and ecosystem. For example, when thinning is focused on the upper canopy, crown fires will still spread in the lower portions. Thinning targets need to be set for all relevant canopy layers including smaller limbs and trees.[44] Focusing on reducing the smaller understorey trees will reduce the vertical continuity of the stand and subsequent overstory thinning (horizontal canopy continuity) targets can vary more widely. If not, all understory stems are removed at the time of treatment, it is critical that the treatment unit be monitored overtime to assess changes in fuel stratum characteristics.

Stand density affects canopy bulk density, canopy base height (due to self-pruning), and within-stand environmental parameters (e.g. temperature, humidity, windspeed, fuel moisture levels, understories vegetation, etc.). The fire behaviour implications of varying density are species dependent due to different tree silvicultural characteristics that result in different crown characteristics, flammability, and silvics (e.g. shade tolerance, etc.). Implications of a specific density of residual mature trees following a partial cut harvest are very different from the same density (and species) of seedlings being established following a clear-cut harvest. Fire behaviour implications will change as the stand grows and develops and need to be considered. Deciduous trees are to be maintained in stands as they are not volatile and hence only coniferous trees are considered in fuel treatments.

Certain stand thinning methods can be used to reduce the potential for active crown fire spread through reductions in canopy fuel loading, in particular, canopy bulk density.

[43] Martinson E.J., and Omi P.N. 2013. Fuel treatments and fire severity: A meta-analysis. Rocky Mountain Research Station.

[44 / 45] Peterson D.L., Johnson M.C., Agee J.K., Jain T.B., McKenzie D., and Reinhardt E.D. 2005. Forest Structure and fire hazard in dry forest of the Western unites states. General Technical Report. 628: 30.

[46] Graham R.T., Harvey, A.E., Jain T.B., and Tonn J.R. 1999. Effects of thinning and similar Stand Treatments on Fire Behaviour in Western Forests. USDA General Technical Report PNW-GTR-463.

However, while all thinning treatments technically result in reductions in canopy fuels, they will not all be effective in reducing the potential for torching and crown fire spread.[45, 46]

4.4.5 Stocking Standards and Species Conversion

Prescriptions should consider the use of alternative stocking standards and species conversion as a strategy to promote fire resiliency. The BCWS has developed a Fire Management Stocking Standards Guidance Document to support the development of fire resilient stands. Deciduous species are ideal for regenerating areas with because of their higher moisture content foliage making them less flammable. Additionally, they have reduced fire intensity and crowning potential most times of the year. Some conifers are fire resilient, such as larch, Douglas fir, and ponderosa pine.

Figure 27. Deciduous stands are effective anchor points for fuel breaks.

Regenerating these species at low densities reduces the crown bulk density and continuity of crown fuels, reducing the potential for crown fire spread. Although, wide spacing can lead to an increase in surface fuels (grass and shrub species) and a lower height to the base of the live crown, a surface fire with some torching is less threatening and easier to suppress than a crown fire. When considering species conversion to meet fuel management objectives, it is imperative to consider the needs of fire-sensitive versus fire-requiring species and ecological essential processes. The Fire Management Stocking Standards Guidance document details conifer and broadleaf tree's ability to resist fire.

4.4.5.1 Integrating Deciduous

It is important to consider deciduous (or broadleaf trees) as an essential part of the environment. There have been human processes over the last century to reduce deciduous trees in the forest, to make room for more economic returns from conifers. Deciduous not only brings important ecological processes into the ecosystem, but they are also very fire resilient species, and can be integrated into landscape planning as fuel breaks from encroaching wildfires.,[47, 48] It's important to note the Fire Management Stocking Standards Guidance Document when considering a species conversion or when stocking a stand post-harvest. Live deciduous trees are less flammable than conifers because of the following differences:

- Moisture content
- Surface area to volume ratio
- Chemical composition

For these reasons, the proportion of conifer stems in a mixed wood stand directly influences its flammability. It should be noted that what time of year plays influence into the flammability of deciduous overstory, as well as grasses, herbaceous plants, and shrubs in the understory. If they have not flushed yet in the spring, they are more susceptible to ignition.[30]

4.5 MAINTENANCE PLANNING

Successful fuel management treatments consider future maintenance requirements at the planning stage. Fuel Management Prescriptions must include future maintenance and monitoring requirements that are cost effective and feasible. Every fuel treatment has a length of time for which it will be effective. Some maintenance needs are not known in advance and therefore monitoring will determine if treatments require future maintenance.

4.5.1 Fuel Treatment Longevity

Fuel treatment longevity is characterized by a fuel treatments effectiveness in reducing undesirable fire behaviour. Specifically, the effectiveness and associated longevity of a fuel treatment can be evaluated by measuring

[47] Conedera M., Lucini L., Valese E., Ascoli D., and Pezzatti G.B. 2010. Fire resistance and vegetative recruitment ability of different deciduous trees species after low- to moderate-intensity surface fires in southern Switzerland. VI International Conference on Forest Fire Research.

[48] Watts S.B., and Tolland L. 2005. Forestry Handbook for British Columbia. The Forestry Undergraduate Society, UBC. 5th ed.

the fuel load and if associated potential fire behaviour meet the treatment objectives Fuel treatment longevity depends on several factors including:

- Treatment design
- Treatment outcome
- Site specific characteristics
- Stand specific characteristics
- Fuel accumulation
- Climate

Figure 25 breaks down specific characteristics of each of these factors that influence treatment longevity. Depending on which fuel strata you treat the longevity of treatment will vary. Studies show that surface fuel maintenance must occur at a higher frequency than ladder and crown fuels. This is a result of biomass accumulation, site productivity strongly influences the longevity of a treatment but in surface fuels, is hard to predict underlining the need to monitor to determine the frequency of maintenance. Additionally, how a treatment is administered, mechanically, manually or via prescribed fire plays influence into how often maintenance is required. Studies show that the most ideal treatments are mechanical thinning followed by a maintenance burn within the next four years.

Vegetation and regeneration response to treatments also influences treatment longevity, depending on the treatment type and species, an increase or decrease in vegetation growth and regeneration can occur[44].

4.5.2 Maintenance Frequency

Prescriptions should specify the frequency at which maintenance is necessary in addition to a monitoring regime that may dictate or modify maintenance frequency. Considering the factors outlined above in figure 25, maintenance frequency can be established.

When available, using historical fire frequency as a benchmark may be helpful in determining treatment longevity. It is important to consider the difference between how long it takes fuels to build up and the length of time that can pass before maintenance occurs to maintain potential fire behaviour below thresholds outlined in a fuel management prescription. Maintenance frequency is dictated by the longevity of a fuel treatment. Fuel treatment longevity depends on a multitude of factors, many of which are site and treatment specific. There is no definite timeline along which maintenance should occur and therefore monitoring of a site's response and fuel accumulation over time is critical.

Long term periodic maintenance can compliment other management objectives (core grasslands, wildlife habitat management areas, powerlines, etc.). Fuel treatment areas that are created with commercial timber harvesting may have a limited period of effectiveness following harvest if the area re-vegetates to conifers and builds up fuel over time. Utilizing fuel treatments and fire management stocking standards will help maintain a relatively fire resilient state for longer periods of time. As noted above, where fuel treatments utilize existing

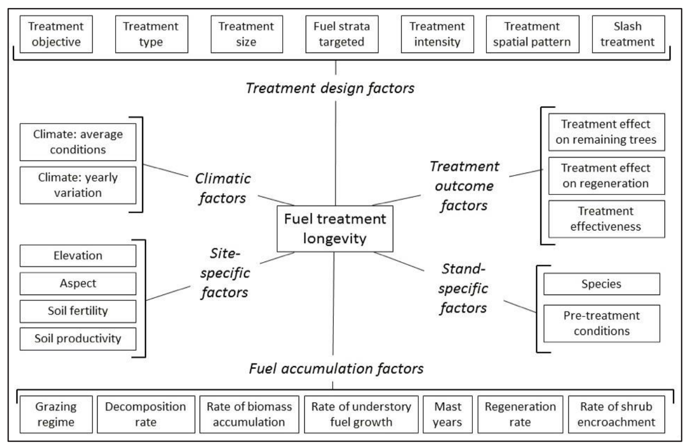

Figure 28. Factors affecting fuel treatment longevity [49]

natural and man-made fire resilient features, maintenance is less of an issue, but may still have to be monitored if being utilized for access.

Consideration of timing of maintenance is important based on the growth rate of a particular stand/species. A maintenance plan is required based on the length of time the treatment will be effective, including re-treatment triggers such as increased fuel load (kg/m2) or a reduction in inter-tree spacing. Treatments should be monitored and re-treated at the most economical time frame. For example, it may be more economical to use prescribed fire to maintain forest encroachment while the regen is small enough to kill-off with fire. Not only should certain points in a stands succession trigger maintenance but secondary effects of a treatment including increased pest/disease occurrence or windthrow must also be incorporated into a maintenance plan.

[49] Yocom L. 2013. Fuel Treatment Longevity. Ecological Restoration Institute.

If the fire resiliency of initial fuel treatments declines over time, fuel treatments can be relocated to other areas of the landscape.

4.5.3 Fuel Treatment Maintenance Activities

Once the treatment type and method has been selected, land managers and forest professionals should consider maintenance treatments at the same time to avoid any conflict later. Common fuel treatment maintenance activities include:

Cultural and Prescribed Fire Cultural and prescribed burning can be an effective treatment to reduce fuels and conifer ingress (if done before the conifers become resistant to fire). If cultural and prescribed fire is anticipated, the initial treatment should be designed as a logical burn unit. Given the proximity of some fuel breaks to private residences, significant public relations are likely to be required to gain acceptance of this method.

This is especially valid when contemplating the use of cultural and prescribed fire for the maintenance treatment. When contemplating the use of cultural and prescribed fire as a maintenance treatment the following factors need to be considered during treatment planning:

- where the acceptance of fire in the area,
- smoke generation,
- treatment unit shape and size
- terrain,
- and access

Mechanical Slashing Mechanical slashing is an option if surface fuels are disposed of. Once regeneration is too advanced, a mechanical treatment will have to be conducted, which may be more expensive than prescribed fire. This can be said for hand/mechanical treatments where an increased amount or larger debris is more expensive to treat and remove.

Grazing Reestablishment of understory vegetation can often be slowed by strategic grazing programs. This can be done by bringing in cattle or other grazing livestock. The use of grazing for fuel treatment maintenance must consider ecological impacts, infrastructure for cattle (fencing), invasive plant management, and public acceptance. Additionally, the appropriateness of the grazing livestock will be dictated y the target grass fuel loads, the type of the grass and the biodiversity of the site. Grazing may help to slow the re-vegetation process and reduce grasses and other fuels that can facilitate the spread of fire and increase the period of effectiveness.[50]

4.6 MONITORING

Fuel management prescriptions in B.C. are complex due to the variability of ecosystems and their dynamic nature. Fuel types are constantly changing through natural (wildfires, succession) and man-made (harvesting, fuel treatments) disturbances that both increase and decrease the fire threat. In addition, values on the land base are increasing through development of residential and industrial infrastructure. In addition, environmental values are evolving and changing their relative priority in response to climate change (Community Watershed) or pressures to habitat (Caribou) and resources (Timber). Monitoring for maintenance and for efficacy are both important to a robust fuel management programs ability to continually improve and adaptively manage.

Monitoring the efficacy of fuel treatments in mitigating fire impacts is critical to understanding their applicability to B.C. diverse landscapes. The BCWS works under a continuous improvement model that includes monitoring fuel treatment activities that feedback into updates to response, fuel types and fuel management prescriptions.

Fuel management prescriptions must include information and recommendations on long term needs for monitoring for future maintenance needs. Monitoring can include target assessments post treatment to test the result against what was in the prescription. Indicators that are to be monitored should be outlined in the prescription. Indicators, such as surface fuel loading levels or regeneration density, must illustrate the effectiveness of a treatment or when a maintenance treatment is required.

Using systems such as RESULTS are appropriate tools to ensure that monitoring of fuel treatments is triggered, assessed, and maintenance treatments can then follow if required.

[50] Davison, J., 1996. Livestock grazing in wildland fuel management programs. Rangelands Archives, 18(6), pp.242-245.

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Appendices

Appendix A Hand, Mechanical, and Prescribed Fire Treatments

Multiple fuel treatment types can be used to target reduction or redistribution of specific fuel layers and to promote more fire resilient trees through retention and restocking. The types of treatments foreseen for fuel management units may include:

1. Timber harvesting including clearcutting, patch cutting, selective cutting, shelterwood, and harvesting for biofuel. This type of activity could be completed by forest licensees including BCTS as part of their license agreement, through an Innovative Timber Sale license as part of the Forests for Tomorrow initiative, or some other form of small-scale salvage.
2. Fuel abatement including slash burning, under burning, pile and burning, and chipping with removal; again, completed by licensees or as a stand-alone treatment paid for separately.
3. Silviculture activities including the use of fire management stocking standards, pruning and spacing, and possibly the use of replacement vegetation.
4. Increased use of prescribed fire and managed wildfire to build resiliency.

Treatments

Once treatment areas are selected, there are generally three treatment types to choose from. These are; hand and hand mechanical, mechanical, and prescribed fire. There are many factors that influence the choice of treatment type considering the work is occurring in the interface, these factors may include:

- Public acceptance and education
- Economics
- Treatment area size
- Timber merchantability
- Value added products (fence posts, rails, pulp, firewood, hog fuel, chips etc.)
- Potential for revenue generation
- Access
- Terrain
- Proximity to homes
- Values
- Recreation

Hand Treatments

Hand treatments are generally the most accepted by the general public when conducting fuel treatments in the interface, especially near homes. These treatment methods may include, forest floor clean up, pruning, hand pulling regen, planting, hand piling debris, dragging debris for off-site disposal, and burning hand piles on site. Although this is a highly accepted treatment type, if the choice for debris disposal is on site burning, provisions must be made well in advance of the treatment to ensure this method of disposal is acceptable and achievable.

Hand treatments are labour intensive and can be very expensive. Areas for this treatment type should be small and in locations where mechanical, or prescribed fire are not suitable or acceptable. Such areas that may not be acceptable include close to ecologically and cultural sensitive areas, recreation sites, etc. When working in the interface near homes, practitioners must account for equipment noise, safety, traffic, etc. In some jurisdictions, noise bylaws may be in place which could affect type of equipment used, and hours of operation, which may in turn affect productivity, cost, and project duration. This treatment type is often used in conjunction with other treatment types and methods. Hand treatments may, for example, be used in conjunction with prescribed fire and machines in areas where machines are unable to physically treat the stand as they would cause too much damage to the leave trees, or where hand treatments are done to the site before the prescribed burn commences.

Prescriptions tend to include operational treatments done by hand when reducing surface fuels. This is due to many prescriptions including pruning, hand piling, and burning. It is often easy to default to hand treatments, even though some operations can be accomplished through mechanical treatments, which are much cheaper, and is important that when this treatment type is selected, it will meet the objectives set out in the Fuel Management Prescription.

Mechanical

Mechanical equipment used in the interface to conduct fuel treatments may have varying levels of acceptance provincially. The knowledge among the average person regarding equipment and what can be achieved with it is highly variable, where perceptions and opinions can often change provincially and within the same community in different locations. Equipment is noisy and is destructive in appearance to the general public, and this combined with certain perceptions or past poor practices makes this choice less accepted. Use of equipment with clear objectives and appropriate supervision with skilled operators can make this choice of treatment type an excellent option.

This treatment type is often used in conjunction with both prescribed burning and hand treatments. Mechanical treatment areas may be larger in size and can be more cost effective. In all cases, treatments should be planned to realise economics of scale, revenue generation, and the generation of any value-added products that could offset or reduce the cost of the treatment. Sources that fund these activities may be looking for the most acceptable cost effective and efficient treatment types and methods are selected.

Cultural and Prescribed Fire Application

Where cultural and prescribed fire is being considered, it should be included within the fuel treatment prescription. Doing so includes that activity within the referral, engagement, and consultation processes so that it is likely not required at the burn plan development stage. The objectives of the burn and some desired general fire effects should also be identified within the prescription. In addition to defining objectives, prescribing foresters need to consider including language in the prescription that addresses utilizing prescribed fire as a potential maintenance treatment option when financially viable and ecologically appropriate. Where and when funding is available, a pro-active approach should be taken to complete work on the front-end of a project so that in the future, site preparation is minimized when preparing to conduct a prescribed burn. Because the implementation of cultural and prescribed fire is dependent on suitable weather, indices and site conditions, a contingency plan to deal with potential residual debris should be included in the funding application.

If possible, layout blocks with burning in mind and consult experienced practitioners to assist in designing blocks that complement the terrain, fuel type and burn plan objectives. Take advantage of existing terrain features and fuel type changes as natural control lines, though following timber types that have irregular snaking borders may pose operational challenges when it comes time to burn. During the harvesting phase, strategically placed skid trails may also serve as advantageous control lines that will complement the tactics of a future prescribed burn.

Consider guard construction, (one fuel break option), as part of the harvesting/treatment layout around the perimeter of the block when appropriate. Build guards that are suitable for the site-specific fuels and terrain. Some factors to consider are guard size, guard type (hand or machine), how the guard will be supported (sprinklers, adjacent fuel break, crew, etc.), guard placement and consider future rehab requirements if applicable. Perhaps a guard is not required, and a pre-burn fuel break can be established another way. Avoid sharp angles when constructing guards or fuel breaks as these pinch points are common failure areas due to radiant heat. If a block is prepped for burning and circumstances prevent a prescribed burn from occurring at the planned time, revisit guards and prepped areas to ensure they are still suitable fuel breaks (as vegetation may have had time to re-establish).

Treatments that are to be managed using cultural prescribed fire have different considerations compared to operational treatments. It is important to consider the characteristics of a project site and what influencers will affect local fire behaviour. Some key influencers are time of year, fuel, topography, weather, and indices.

Typically, the time of year that practitioners plan to burn a project site are in fall and spring. These seasons can be advantageous when conducting operations as seasonal conditions can improve the level of control one has when conducting a burn. Some operational advantages of these seasons may include increased moisture/ snowpack adjacent to a treatment polygon and shorter daylength.

Fuel is a key characteristic when considering when and where to burn. Avoid unnecessary accumulations of debris along the perimeter during harvesting and strategically place wildlife tree patches and retention trees with future prescribed burning in mind. With heavy surface fuel loading, a fire may be high in severity and cause more damage than is recommended in the prescription, as well as can potentially challenge or escape the treatment polygon boundary. This can also be the case with a high amount of ladder fuels within the treatment area, as the ladder fuels can cause fire to reach the crown. It may be considered in these cases to use an operational treatment before burning an area. Though a potentially costly option, an operational treatment could remove fuel loading on the area while meeting objectives.

Topography is also an essential piece to consider when determining if prescribed fire within a treatment polygon is a viable option. Steep slopes can have the same affect on fire behaviour as wind. Fire will always move uphill so it is particularly important to consider identified values both adjacent and above slope of the treatment area, and if a guard or some form of fuel break should be considered. Avoid mid-slope guards that will be a challenge to hold/ support during active burning. If possible, go to the top of a terrain break, or even better, over the top. Other topographic features may allow for the ease of fire movement, and it is important to make note of these areas if the burn is to stay within the treatment polygon. Be prepared for overnight, downslope winds that may challenge guards during the night.

The range of indices and weather conditions must be identified in the burn plan and will be specific to producing the type of fire that will meet the objectives of the burn plan. Conducting a burn outside of the identified indices and weather conditions can result in a burn not meeting the objectives of a treatment and/or pose risk to crews and identified values. Examples of potential outcomes could be a patchy and discontinuous burn or a fire that is difficult to control and contain within the treatment polygon. It is important to anticipate changing weather and indices well in advance of when a burn is planned to take place. This could be as early as several weeks prior as weather and indices may become increasingly favourable quite suddenly. Monitor indices closely and engage in discussions with the identified Burn Boss and Ignitions Specialist in the weeks leading up to a potential burn window. Winds, temperature, relative humidity, and indices on the day will determine if the burn conditions are favourable or if the burn should be delayed. Ongoing communications should occur with the person responsible for Burn Plan implementation. Ultimately, the decision to burn or not is the responsibility of the identified Burn Boss.

Appendix B Treatment Types

Combining Prescribed Fire with Mechanical and Manual Treatments

Prescribed fire and mechanical treatments are commonly used in combination to modify vegetation for fire hazard reduction throughout the western U.S. For example, canopy and ladder fuels are first modified by mechanical thinning operations that target crown classes, stand basal area, and canopy bulk density. Surface fuels, including the logging slash created by mechanical thinning, are then reduced using prescribed fire. The types and sequence of fuel treatments selected for a given site depend on the amount of surface fuel present; the density of understory and mid-canopy trees; long-term potential effects of fuel treatments on vegetation, soil, and wildlife; short-term potential effects on smoke production; materials to be removed versus left on site; and costs.,[51,52]

"Prescribed fire removes (i.e., burns) the same fuel components on which wildfires depend—largely surface fuels (litter, grasses, and herbaceous fuels)—the amount and condition of which is a major determinant in fire ignition, spread, and ultimately burn severity. In contrast, most mechanical treatment practices (thinning, chipping) tend to focus on large woody material that contribute only a limited portion of the fuel available to burn in wildfires. Prescribed burning may require added mechanical activities to improve the result or the practicality of conducting prescribed burns".[53]

Treatment options can range from convection or slope-controlled broadcast burns, line fires (backfires, heading fires, ring fires, etc.) or spot fires (spot grids, windrow and pile burning) using aerial deployment (with different fuels, gels, igniters, DAIDs, etc.) to manual lighting techniques with a broad range of backup in anything from newly logged areas to mature forest under a broad range of fire weather indices.[54]

Treatment Types

Table 7 summarizes a range of treatment types in relation to their effectiveness in terms of each fuel treatment principle. Few treatment types are effective on all fuel layers; therefore, treatments are often prescribed in combination to achieve treatment principles and objectives. For example, thinning from below will decrease ladder and crown fuels but will increase surface fuels and must therefore be combined with a surface fuel treatment such as cut, pile, and burn to adhere to all fuel treatment principles. The following section expands on each treatment type:

Thinning from Below

Thinning from below is the process of removing smaller trees that are below or within the canopy, while keeping the overhead canopy intact. This process reduces the amount of fuel available and reduces the ladder fuels, thus reducing the potential for crown fires. It is important to note that keeping the canopy as intact as possible is essential to creating an effective treatment. If the canopy is opened too much during the thinning process, the surface fuels will be more susceptible to drying out from an increase amount of direct sunlight, as well as increased winds to dry out fine fuels.

This treatment does not directly target tree limbs that are a large part of ladder fuels, and they will need to be targeted

Figure 29. Fuel treatment where thinning from below is being implemented.

[51] Cook P.S., and O'Laughlin J.O. 2014. Fuel Treatments in Idaho's Forests: Effectiveness, Constraints and Opportunities. University of Idaho policy analysis group Report No 35.

[52] Peterson D.L., Johnson M.C., Agee J.K., Jain T.B., McKenzie D., and Reinhardt E.D. 2005. Forest Structure and fire hazard in dry forest of the Western unites states. General Technical Report. 628: 30.

[53] Calkin D. E., Cohen J.D., Finely M.A., and Thompson M.P. 2014. How risk management can prevent future wildfire disasters in the wildland urban interface. 111(2): 746-751.

[54] McCulloch L. 2015. Draft Van Jam Fire Management Plan. FLNRO.

Treatment Type	Description	FUEL TREATMENT PRINCIPLES			
		Surface Fuels	Ladder Fuels (crown base height)	Crown Fuels (crown spacing)	Fire Resilient Trees
Thinning from below	Cutting of entire trees (ladder and crown fuels). Requires secondary method to reduce surface fuels.	Increase	Decrease	Decrease	Increase
Pruning	Cutting both dead and living limbs (ladder fuels) from lower tree bowls. Requires secondary method to reduce surface fuels.	Increase	Decrease	No effect	No effect
Prescribed fire	Resource management open burning and broadcast slash burning. Often requires secondary method to change fuel arrangement to control flame length and crown fire initiation.	Decrease	Decrease	No effect	Increase
Cut, pile, and burn	Cutting and piling of non-merchantable stems and surface fuels that are then burned.	Decrease	Decrease	No effect	No effect
Cut and scatter	Cutting and scattering or cutting, chipping, and scattering of ladder fuels and surface fuels that are then left on site to decompose.	Conversion (temporary increase)	Decrease	No effect	No effect
Cut, chip and haul away	Cutting and chipping into a truck for offsite disposal.	Decrease	Decrease	No effect	No effect
Mastication and Mowing	Excavator mounted mowing/slashing/grinding of standing stems up to practical size limit that scatters debris on site to decompose.	Conversion (temporary increase)	Decrease	No effect	No effect
Grazing	Allowing livestock to graze and consume fine fuels.	Decrease (only edibles)	No effect	No effect	No effect
Species conversion	Retaining larger, more fire-resistant species and restocking with lower flammability species following thinning to alter long-term stand fuel hazard.	No effect	No effect	Decrease (long-term)	Increase

Table 5. Treatment type and its influence on each fuel treatment principle.

Considerations	Commercial Thinning	Pre-Commercial Thinning
Criteria for treatment	>50m3 of merchantable timber	<50m3 of merchantable timber
Effectiveness	Ladder fuels, crown fuels, fire resilient trees	Ladder fuels, crown fuels, fire resilient trees
Other treatment required	• Surface fuel treatment • Pruning • Species conversion	• Surface fuel treatment • Pruning • Species conversion
Typical equipment	Chainsaw, ATV, skidder, mechanical harvester, cable yarder etc.	Chainsaw, ATV etc
Slope limit	Equipment dependant	Equipment dependant
Timing considerations	• Beetle flight periods • Habitat work windows	• Beetle flight periods • Habitat work windows
Rehabilitation considerations	• Access • Sediment and erosion control • Invasive species management	• Access • Sediment and erosion control • Invasive species management
Monitoring and maintenance	• Regeneration growth rates vary by ecosystem type • Periodic surface/ladder fuel retreatment required except with species conversion	• Regeneration growth rates vary by ecosystem type • Periodic surface/ladder fuel retreatment required except with species conversion
Advantages	• Only treatment type effective on crown spacing • Can offset treatment costs through commercial timber sale or biomass (when market develops)	• Only treatment type effective on crown spacing • No silvicultural obligation
Disadvantages	• High administrative burden • Potential increase in surface fire intensity due to increased drying of surface fuels • Increase in growth of understory becoming new ladder fuels or attracting wildlife (human/wildlife conflict) • Increase in blowdown • Potential damage to retained trees • Extensive site disturbance from machine traffic depending on season	• High cost • Potential increase in surface fire intensity due to increased drying of surface fuels • Increase in growth of understory becoming new ladder fuels or attracting wildlife (human/wildlife conflict) • Increase in blowdown • Potential damage to retained trees • Moderate site disturbance from machine traffic depending on season
Administration	• Forestry Licence to Cut • Timber cruise and ECAS submission • RESULTS and ESF submission • Competitive process required for merchantable volume exceeding 2,000 m3 • Silviculture obligation • Private timber mark • Check if municipal bylaws or other jurisdictional regulation applies	• Free Use Permit • DM Letter of authorization (FRPA Section 52) • FRPA exemption for offsite disposal • Check if municipal bylaws or other jurisdictional regulation applies

Table 6. Considerations regarding thinning from below.

through pruning. Other treatments need to coincide with thinning from below as this process will increase the amount of available surface fuels, and not be an effective treatment on its own. Treatments that could potentially be paired with thinning from below to reduce surface fuels include pile and burn, chipping, or removal from site.

Pruning

Removing both dead and living limbs (ladder fuels) from the lower boles of trees will reduce the risk of fire spreading into the crown of the stand. These limbs need to be disposed of in a method that is deemed site appropriate. This type of treatment may require periodic maintenance to maintain effectiveness.

Figure 30. diagram and example of crown base height.

The projected flame height generated from the existing surface fuel during a wildfire, or prescribed fire will determine the pruning height required. This must include the debris resulting from the pruning treatment if left to remain on site.

Cultural and Prescribed Fire

Using the prescribed burn treatment method has many benefits to the sites being treated, as well as some drawbacks. It is a great way of pre-emptively put fire onto the landscape at a safe time of year when it is unlikely that fire behaviour will get out of control, and personnel is onsite. It is a way to remove surface fuels while also keeping leave trees standing and alive. It can be a inexpensive way to remove surface fuels, as it doesn't require a lot of labour hours or machine time. Prescribed burning is also extremely beneficial to the site, restoring essential minerals and nutrients back into forms that can be taken up by vegetation.

Unfortunately, not every site will be a good choice for prescribed burning. Prescribed burning can be done on sites where stand characteristics include being an open stand, has spaced trees, and minimal amount of ladder fuels. If the forest does not have these characteristics, it could potentially do more harm than good, killing trees and creating an area where more site management needs to be done, such as for invasive plant management.

Considerations	Pruning
Criteria for treatment	Crown base height ~3 – 5 m
Effectiveness	Ladder fuels
Other treatment required	• Surface fuel treatment • Thinning
Typical equipment	Loppers, pruning saw, pole saw etc
Slope limit	No
Timing considerations	• Best October to February when pitch flow is low to avoid attracting insects • Habitat work windows
Rehabilitation considerations	None
Monitoring and maintenance	Repeat every 3 to 5 years until lowest branch is above desired height
Advantages	Low impact
Disadvantages	Labour intensive
Administration	Check if municipal bylaws or other jurisdictional regulation applies

Table 7. Factors for consideration when pruning.

Figure 31. Prescribed fire implementation

Prescribed burning also requires public acceptance, as people are concerned about the act of burning. Reasons for the publics concern includes: lack of knowledge around the procedure and ecological values of burning, fear, trusting the government, and smoke around their communities. Practitioners must also be aware of the legislation around prescribed burning to ensure it is adhered to. These pieces of legislation are the B.C. Wildfire Act and Regulations and apply for a burn permit with the local municipality. It is also important to note that many local governments, (Municipal and Regional Districts) may have their own bylaws for open burning within their jurisdiction in addition to the provincial legislation. Venting conditions must also be considered when commencing a prescribed burn.

Debris Management, Open Burning

Implementation of alternative, value-added methods of debris disposal is currently underway across the province. Methods include removing debris to be chipped and sold from mills for various uses, or the use of air curtain incinerators for biochar production.

For any pile burning deemed necessary, plans must be made well ahead of time to ensure this method of debris disposal is both achievable and acceptable in the location of the treatment area.

Air Curtain Incinerators: Air Curtain Incinerators can provide a long-term, cost-effective solution for onsite debris disposal in cases where mechanical removal of debris is not appropriate. The air curtain incinerator (ACI) is a device that directs a flow of forced air across an open chamber to aid in the combustion of organic materials when burning. Able to reduce emissions by up to 90%, this device can provide significant flexibility to burning operations in relation to the OBSCR. For instance, if located more than 1km from residences and businesses, and 2km from a school, hospital or community care facility, air curtain incinerators may be operated at all hours, and you do not need to check the ventilation index before burning. Materials can also be transported from within a 5km radius to be processed by an ACI. For a more complete guide to the approved use of air curtain incinerators, please see the OBSCR Air Curtain Incinerator Factsheet provided by the Ministry of Environment and Climate Change Strategy, as well as the Smoke Sensitivity Zone Map. More information on air curtain incinerators and their use can be found on the OBSCR Air Curtain Incinerators Flow Chart. For any slash pile burning deemed necessary, plans must be made well ahead of time to ensure this method of debris disposal is both achievable and acceptable in the location of the treatment area.

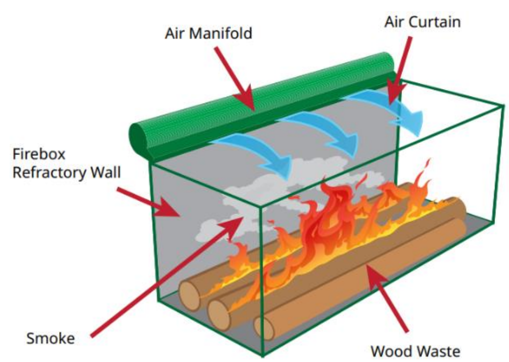

Figure ()(). Graphic of Air Curtain Burner function

Pile Construction for Burning: Piles should be constructed in a pyramid fashion wherever possible and should be a mix of fine debris in the center for ease of ignition, working in larger debris as the pile is increased. This becomes increasingly important when burning in the winter where the site has experienced rain, and or snow is present. Pile size should not exceed that which cannot be completely consumed in a normal workday. This will prevent leaving hot piles unattended overnight, and risking unwanted fire spread, and lingering smoke emissions.

Cured piles are easier to ignite, burn quickly resulting in more complete combustion producing less smoke. Letting piles cure will require leaving this potential hazard for several months, potentially increasing the risk of unwanted ignition, or even increasing the spread of a wildfire should one occur in the treatment area. When planning to cure and burn piles in the winter months, covering them is an option to keep the material dry, but adds to the treatment cost. There is a case to be made for burning in conjunction with the treatment for efficiency and cost effectiveness. Green piles when ignited produce more smoke, but this is short lived and burns hot with less visible smoke, especially if you keep feeding the pile.

Figure 32. Example of an effective burn pile

Pile Location: The appropriate location of piles will be dependent on the project sites location, time of year, remaining stand density, terrain, and accessibility. Piles should be in locations where flame contact and radiant heat generated will not damage the reserve component of the stand or spread to areas not intended for burning. This is especially important when working near private lands and homes where there are wooden fences and dry ground fuels. Where the site is accessible and is in a high public use area, piles should not be placed close to the roads or trails as this may increase the risk of human Ignition. This becomes increasingly important if the intent is to leave the piles for an extended period of time for curing

generated will not damage the reserve component of the stand or spread to areas not intended for burning. This is especially important when working near private lands and homes where there are wooden fences and dry ground fuels. Where the site is accessible and is in a high public use area, piles should not be placed close to the roads or trails as this may increase the risk of human Ignition. This becomes increasingly important if the intent is to leave the piles for an extended period of time for curing.

Pile Burning: There are many ignition tools on the market that may be used to ignite piles. The success and selection of these tools is dependent on the project size, access, terrain, condition of the debris piles, and if they are cured, green, wet, or have snow on them. These could include matches and paper, fuses, propane torch, hand torch with fuel mixture, and mobile torches. There are a few products on the market that can be used as an accelerant which are mixed with gasoline or diesel, and it is important to use acceptable products. Introducing forced air to ignited piles is always a good option, such as a leaf blower which allows for faster, hotter, more complete combustion with less smoke emissions. Practitioners must be aware of the legislation around open burning to ensure it is adhered to. These pieces of legislation are the B.C. Wildfire Act and Regulations, and the B.C. Ministry of Environment's Open Burning Smoke Control Regulation. It is also important to note that many local governments, (Municipal and Regional Districts) may have their own Bylaws for open burning within their jurisdiction in addition to the provincial legislation. Open burning prohibitions may be in effect as well. Depending on the treatment area size and the number of hand piles, it is important for practitioners to ensure the adequate resources are on hand for the number of piles ignited at any one time, to maintain control and allow enough time for the piles to burn out at the end of each work period. For late spring and early fall burning, when the ground is snow free, and piles may remain hot or can burn through the evening, provisions must be put in place to prohibit fire from broadcasting between piles. Constructing a fuel free break around each pile is recommended.

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Considerations	Resource Management Open Fires	Category 3 Open Fires
Criteria for treatment	Un piled slash/surface fuels over an area of any size	• > 2 piles of 2 m height x 3 m width burning concurrently OR • 1 or more pile exceeding 2 m height x 3 m width OR • 1 or more windrow OR • Stubble or grass over an area >0.2 ha
Effectiveness	Surface fuels, ladder fuels, fire resilient trees	Ladder fuels, crown fuels, fire resilient trees
Other treatment required	Surface fuels, ladder fuels, fire resilient trees	Surface fuels
Typical equipment	• Bulldozer • Firefighting hand tools • Fire suppression system	• Excavator • Firefighting hand tools • Fire suppression system
Slope limit	All slopes	Machine dependant
Timing considerations	• An open burning ban is not in effect • Season for fire severity/fire effects • Venting Index good over burn period • Air quality good • Desired weather ranges and fire weather parameters met over burn period	• An open burning ban is not in effect • Venting Index good over burn period • Air quality good • Desired weather ranges and fire weather parameters met over burn period • Habitat work windows
Rehabilitation considerations	• Access and bladed fireguards • Sediment and erosion control • Re vegetation where fire effects were more severe than prescribed	Re vegetation of burn piles
Monitoring and maintenance	• Burn Boss • Suppression resources commensurate with burn complexity • Mop-up and patrol • Monitoring every 5 years for at least 20 years • Periodic retreatment required	• Fire is watched and patrolled by a person equipped with at least one firefighting hand tool in order to prevent the fire from escaping • Mop-up and patrol
Advantages	• Effectively consumes slash • Restores historic stand structure in dry forests	Effectively consumes slash
Disadvantages	• High administrative burden • Smoke management • Potential complaints • Potential escape • Soil damage or retained tree mortality • A landowner who does not comply with the Wildfire Act and Regulation may be liable if the fire escapes and becomes a wildfire • Can create fuels by killing understorey trees.	• Smoke management • Potential complaints • Potential escape • Soil disturbance, soil sterilization or retained tree mortality • A landowner who does not comply with the Wildfire Act and Regulation may be liable if the fire escapes and becomes a wildfire
Administration	• Check higher level plans • Check if municipal bylaws or other jurisdictional regulation applies • Letter of authorization required on Crown land • Approved burn plan • Obtain burn registration number • RESULTS and ESF submission • Compliance with Wildfire Act and Regulation • Compliance with the Environmental Management Act and Open Burning Smoke Control Regulation (OBSCR)	• Check if municipal bylaws or other jurisdictional regulation applies • Obtain burn registration number • Compliance with Wildfire Act and Regulation • Compliance with the Environmental Management Act and Open Burning Smoke Control Regulation (OBSCR)

Table 8. Considerations for the implementation of Category 3 and Category 4 Open Fires.

Considerations	Category 1 Campfire	Category 2 Open Fire
Criteria for treatment	0.5 m height x 0.5 m width	• < 3 piles of 2 m height x 3 m width burning concurrently OR • Stubble or grass over an area <0.2 ha
Effectiveness	Surface fuels	Surface fuels
Other treatment required	Thinning	Thinning
Typical equipment	• Shovel • 8 L of water	Fire fighting hand tools
Slope limit	All Slopes	All slopes if hand piled, otherwise machine dependant
Timing considerations	• An open burning ban is not in effect • Venting Index good over burn period • Air quality good • Habitat work windows	• An open burning ban is not in effect • Venting Index good over burn period • Air quality good • Habitat work windows
Rehabilitation considerations	Revegetation of campfire piles	Revegetation of burn piles
Monitoring and maintenance	• Fire must be constantly attended by a person equipped with at least one shovel or 8 L of water • Mop-up and patrol	• Fire is watched and patrolled by a person equipped with at least one fire fighting hand tool in order to prevent the fire from escaping • Mop-up and patrol
Advantages	Effectively consumes small loadings of surface fuel	Effectively consumes slash
Disadvantages	• Only suitable for disposal of small loadings of surface fuel over small areas • A landowner who does not comply with the Wildfire Act and Regulation may be liable if the fire escapes and becomes a wildfire	• Smoke management • Potential complaints • Potential escape • Soil disturbance, soil sterilization or retained tree mortality • A landowner who does not comply with the Wildfire Act and Regulation may be liable if the fire escapes and becomes a wildfire
Administration	• Check if municipal bylaws or other jurisdictional regulation applies • Compliance with Wildfire Act and Regulation • Compliance with the Environmental Management Act and Open Burning Smoke Control Regulation (OBSCR)	• Check if municipal bylaws or other jurisdictional regulation applies • Compliance with Wildfire Act and Regulation • Compliance with the Environmental Management Act and Open Burning Smoke Control Regulation (OBSCR)

Table 9. Considerations when implementing Category 1 or 2 open fires.

Considerations	Cut, Chip and Haul Away
Criteria for treatment	• Proximity to mill/facility to deal with chips • Ability to utilize biomass • Smoke sensitivity concerns
Effectiveness	Surface fuels, ladder fuels
Other treatment required	Thinning, Pruning
Typical equipment	• Chainsaw • Chipper with adequate diameter limit • Dumpster and haul truck
Slope limit	30%
Timing considerations	• Access may be limited seasonally • Habitat work windows
Rehabilitation considerations	Access
Monitoring and maintenance	None
Advantages	Surface fuel removed
Disadvantages	• High cost • Requires good access • Should not be used within 10 m of structures (FireSmart Zones 1) or in areas used for grazing
Administration	Check if municipal bylaws or other jurisdictional regulation applies

Table 10. Considerations when implementing cut, chip, and haul for debris management

Figure 33. Implementation of cut, chip, and haul for debris management.

Mastication with Removal

This treatment type can be used in conjunction with most other fuel treatment activities. The fuels that have been cut from the understory/overstory and are on the ground, are then chipped and hauled off site. This process can supply local mills with fiber and reduce carbon emissions from burning. Though this will usually cost more than other debris management activities. Funding can be available through the Crown Land Wildfire Risk Reduction program for this activity.

Targeted Grazing

Targeted grazing is typically used for short periods at high intensity to reduce fine surface fuel loading. Timing, duration, vegetation palatability, grazing species, and grazing intensity are all factors that need to be considered in relation to the objective of grazing for fuel management. Most commonly targeted grazing is used as a maintenance treatment.

Considerations	Grazing
Criteria for treatment	Grasslands and shrublands
Effectiveness	Surface fuels (edibles)
Other treatment required	Thinning and non-edible surface fuel reduction treatments
Typical equipment	Livestock (e.g., cows, sheep, goats, horses)
Slope limit	None
Timing considerations	Grazing season
Rehabilitation considerations	Revegetation and fencing if overgrazing or riparian area damage occurs
Monitoring and maintenance	Control of livestock movement to prevent overgrazing
Advantages	• Cost effective • Good maintenance treatment
Disadvantages	• Plants must be palatable to the grazing animal selected • Not ecologically appropriate in all locations (e.g., riparian areas) • Invasive plant invasions from seeds on or within grazers
Administration	Check if municipal bylaws or other jurisdictional regulation applied

Table 11. Considerations when using grazing as a debris management practice

Species Conversion

Considerations	Species Conversion
Criteria for treatment	• Site will support deciduous trees • Ecologically appropriate
Effectiveness	Crown fuels and fire resilient trees
Other treatment required	Thinning, surface fuel reduction
Typical equipment	Planting shovel Tree truck
Slope limit	No
Timing considerations	Planting in late fall preferred
Typical treatment targets	• X% deciduous trees • X% fire resilient conifer trees
Rehabilitation considerations	None
Monitoring and maintenance	Brushing in year 5 may be required to manage competition
Advantages	• No planting may be required if post-thinning retention leaves adequate stocking of preferred species • Good for longer term site management
Disadvantages	Opportunity cost of lower density of commercial timber
Administration	• Silviculture obligation (stocking standards must be met) • RESULTS and ESF submission

Table 12: Considerations regarding species conversion

Appendix C Fuel Treatments in Forested NDT4 Areas

When operating in the IDF ecosystems and performing wildfire threat reduction treatment the following principles should be applied:

1. The fuel reduction management regime and stocking levels should be based on the fire resilience of the "leave" trees. If the bark of the leave trees is smooth and resinous, the stocking level should be maintained at a higher level. The closed canopy will help maintain the surface fuel and moisture regime, thus keeping any surface fire at a lower intensity level. An appropriate guidance for stocking in these stands would be to manage to the minimum stocking standard level for the applicable site series.
2. As the tree matures, the bark will become thicker and "corky" in nature, the stocking level should decrease. This is the tree's defense against mortality in low to moderate intensity surface fires. An appropriate guidance for stocking in these stands would be to manage to ~50% of the minimum stocking standard level for the applicable site series.

Figure 34: Rock Creek

3. If the stand is managed for multiple values, a multiple entry cutting regimes may be the best practice. When using a "patch cut" treatment method, care must be taken to ensure crown separation, both vertically (manage ladder fuels in the clump) and horizontally (crown separation between clumps) is managed for fire threat reduction.
4. Surface and ladder fuel must be managed as part of any treatment.
5. All slash from the thinning treatment must be managed as part of the fuel and wildfire threat reduction.
6. Coarse woody debris (CWD) management should follow the Chief Forester's guidance and the FREP extension note #8. In keeping with the guidance of these documents, CWD should be kept to a minimum and only large piece size (>20 cm in diameter and >10 m in length) be left on site. The number of CWD pieces per ha should be between 15-20.
7. Prescribed burning may be required to manage the surface fuel loading as well. Care should be taken to minimize mortality to the leave trees.
8. The maintenance of these fuel treatments is an important component of continued wildfire threat reduction.

[55] Hunter M.E., Shepperd W.D., Lentile L.B., Lunquist J.E., Andreu M.G., Butler J.L., Smith F.W. 2007. A comprehensive Guide to Fuels Treatment Practices for Ponderosa Pine in the Black Hills, Colorado Front Range, and Southwest. General Technical Report.

Appendix D Resources and Links

General Information

B.C. Wildfire Service Fuel Management

First Nations Emergency Services Society

FrontCounter BC

B.C. FireSmart

FireSmart Canada

Biogeoclimatic Zones

Legislation

Wildfire Act

Wildfire Regulation

Other Relevant Legislation

Risk and Hazard Assessment and Abatement

WUI Threat Assessment Worksheet

Fuel Hazard Assessment & Abatement in BC

Resource Management Burning

Fire Prohibitions and Area Restrictions

Venting Index (or phone 1-888-281-2992)

Open Burning Smoke Control Checklist

Guide to the Open Burning Smoke Control Regulation

Industrial and Resource Management Burning

Environment Canada Weather

Smoke Management Framework for British Columbia

Appendix E Consultation

It is required by provincial legislation to apply to the land manager for all authorizations to cut and/or remove trees on crown land when they are ready to advance to operational treatments.

- Consultation is required for public lands and is strongly encouraged for projects occurring within other ownership types. Engaging stakeholders improves the understanding of and opportunities to protect values and cultural uses in the area being treated.
- Consultation is essentially talking together for mutual understanding. A first step in planning consultation is to identify stakeholders according to their level of interest and influence in the project. What do they know already, and what do you want them to know? Accordingly, tailor your consultation approach to the audience and their level of project understanding and influence.
- Stakeholders, particularly on public land, often include individuals and groups with a wide spectrum of interests. It may be necessary to consult stakeholders such as local government, industry, ranchers' associations, tenure holder's recreation user groups, utility companies, FLNRORD, and adjacent landowners or non-governmental organizations. Some level of public consultation should occur if the treatment area is subject to public use, contains a value identified in a management plan or higher-level plan, is adjacent to private property or is highly visible from major transportation routes.
- The crown must meet its obligations to consult with First Nations on proposed activities. Once district or regional staff is aware that a fuel treatment plan has been accepted by the Fire Centre Fuel Management Specialist, the first step is to consult with all First Nations whose traditional territory will be impacted by the fuel reduction activities. Consultation should be carried out consistent with the current Provincial Consultation Policy and Guidelines and any applicable agreement between the crown and the First Nation (e.g. Forest and Range Interim Measures Agreements, Forest and Range Agreements, Forest and Range Revenue Sharing and Consultation Agreements, Socio-Economic Agreements, etc.).
- Consultation must be in good faith, and with the intention of substantially addressing the concerns of people whose interests may be affected. Clear and reasonable timelines for participation and information sharing are essential. Methods of communication should be appropriate to the level of engagement (i.e., from inform to collaborate) and may range from paper notifications, social media alerts and public open houses to workshops or participatory decision-making.
- When documenting the process, describe the scale of consultation, the method and the details of any meetings to be scheduled. Describe how specific concerns have been addressed within the prescription.

Appendix F B.C. Parks Fuel Management Case-Study

Project Description	West Arm Provincial Park Fuel Management
Funding Source	FESBC & WRR
Proponents & Partners	• B.C. Parks (Kootenay Section) • City of Nelson • Regional District of Central Kootenay • Anderson Creek Timber (forest licensee adjacent to the provincial park) • Svoboda Road residents (private lands adjacent to the provincial park)
Project Objectives	This project was initiated to reduce fuel loading to protect West Arm Provincial Park values and the City of Nelson from the threat of wildfire. **Values protection**: A large portion of Nelson's watershed (80%) lies within West Arm Provincial Park and includes infrastructures such as roads, pipelines, a small dam, spillway and intake house. The park contains a diverse range of habitats from lakeshore to subalpine. It protects high-elevation forests and alpine areas. West Arm Provincial Park features old-growth forests, internationally significant habitat for grizzly bear and mountain caribou, and archaeological values along the lakeshore. Fishing, canoeing, camping, and hiking opportunities are available in West Arm although no facilities exist. There are many high-use mountain bike trails. Prescription objectives were to reduce the fuel load in the park to protect park values as well as contribute to landscape-level wildfire risk reduction, including the City of Nelson, adjacent private property (Svoboda Road Residents), adjacent Forest Licensee (Anderson Creek Timber), CPR Railway, and Burlington Northern Rail Trail & Trestles.
Prescription Objectives	• Help protect West Arm Provincial Park's natural values from high intensity wildfire. • Improve public safety within West Arm Provincial Park. • Improve the ability of the B.C. Wildfire Service to protect West Arm Provincial Park values and contribute to landscape-level wildfire risk reduction. • Enhance natural barriers to reduce the continuity of fuel loads. • Demonstrate the principles and practices of FireSmart and fuel management to local communities, park visitors and the broader public. • Emulate the pattern of natural disturbances that have historically acted upon West Arm Provincial Park's ecosystems. • Accelerate succession to mature and older-growth forest structural conditions with often lower stand densities. • Increase the availability and diversity of wildlife habitat through the restoration of more natural mixed or semi-open forest conditions. • Minimize negative impacts to, and where possible enhance, West Arm Provincial Park values including cultural heritage, recreation, and visual quality; and, • Minimize negative impacts to, and where possible enhance, the many values of the treated forest, including source water protection and forest health.
Legal tests	Through careful planning and objective-setting that focused on improving ecological function, and managing and mitigating the risks associated with wildfire, this project meets the tests of the Park Act (the activity does not restrict, prevent, or inhibit the use of the park for its intended purpose, in accordance with Section 12(3) of the Act)
Authorizations	Forest License to Cut (Natural Resource District) and Park Use Permit (B.C. Parks) • MOTI Permit for Road Use • Property Use Agreement – one with the Svoboda residents and one with Anderson Creek Timber • Operations Agreement – between B.C. Parks, Anderson Creek Timber, and the Svoboda Road Residents • Permission from the City of Nelson to use a city street for hauling

Operational Considerations	**Access:** Work with MOTI and Svoboda Road Residents to ensure the road is effectively maintained and establish a schedule of road use for the project that is conducive to the residents' schedules. **Relevant BMPs:** Best Management Practices for Tree Removals in Parks and Protected Areas (including planning, harvesting operations and road design and engineering guidebooks) BMPs indicate timing of treatment should be on frozen soils or sufficient snow cover. To achieve project objectives, treatment could not be completed with snow cover. **Biological Values:** Fire Management Plan specifies park values that require protection, and these values were incorporated into the prescriptions. All prescriptions were reviewed by RPBios. **Partnerships:** Identify partners that can share costs, resources, and infrastructure **Funding:** Secure funding prior to beginning the project and ensure maintenance costs can be covered for subsequent projects **Public Engagement:** Four Open House meetings, radio interviews and newspaper articles
Relevant Assessments, Plans and Prescriptions for Statutory Decision Maker	2007 - West Arm Provincial Park Management Plan 2017 - West Arm Provincial Park Fire Management Plan 2017 - Archaeological Overview Assessment & Preliminary Field Review 2018 – B.C. Parks Impact Assessment (including First Nations consultation) 2018 - Fuel management prescription
Operational Implementation Timeframes	2019 and onwards. 2020 – 20+ hectare prescribed fire to enhance ecological resilience and wildfire risk reduction

Table 13. West Arm Provincial Park - B.C. Parks Fuel Management Case-Study.

Appendix G Fire Behaviour Modeling Software

FuelCalcBC and CFIS

One tool for determining desired Crown Base Height (CBH) pruning targets includes FuelCalcBC FuelCalcBC. Field data can be used to re-create a stand and then be entered into FuelCalcBC and treated to the appropriate species and densities to meet a target crown base height, canopy bulk density, and surface fuel loading. These results from FuelCalcBC can then be input into the crown fire initiation and spread model (CFIS) to evaluate fire potential and rate of spread. Having accurate and concise data is essential for the models to work as it is intended to. For example, the information CFIS gives with regards to percentage chance for crowning will not be accurate if this does not occur. Communication with WPOs on the programs inputs and outputs must be done to determine accurate information. These outputs can be done by creating an 'export report'.

CFIS has limitations that should be considered when running the program. The program does not consider slope effects on fire, and the effect it has on pushing the fire into the crown. It also does not take into account different fuel types, as it only considers the data inputs such as crown bulk density, and crown base height. Results for fuel types such as black spruce should be taken into consideration on their accuracy.

BurnP3 and Prometheus

BurnP3 and Prometheus are both very powerful tools when trying to consider where fuel treatments should take place and how fire will interact with an area. Prometheus considers how a fire might spread, at what rate, and where it will be in the future, at a single point of origin or from a fire perimeter. It is a very helpful tool when trying to understand how an active fire will react with the landscape in the coming days, or how a fire might react if one were to start. This can be extremely helpful when considering areas to fuel manage. BurnP3 runs 10,000 trials to give the 20-year burn probability of a fire starting in a region. It considers each pixel and how many times that area is burnt out of the 10,000 trial runs, and then gives a probability for the area. This can be a great tool in determining where fuel treatments should occur, and where harvesting in the future should take place. Output from burnP3 and Prometheus runs should include fire perimeter(s), fire intensities, and rates of spread across the area of interest. These parameters will assist in evaluating treatment scenarios. Contact local WPOs for information on Burn P3 products, Prometheus and scenarios runs.

All modelling must be done by competent, trained individuals that have a full understanding of the assumptions and limitations of the model. Many of the modelling products available require considerable set up and data/information collection. The lack of availability of trained individuals to run these models is an issue. It should not be assumed that modellers are always available. A minimum of one-month lead time is suggested for any Prometheus or Burn P3 requests to BCWS. For all provincially funded WRR projects, the use of modeling should be discussed with local WPO prior to use.