THE ROLE OF SHADED FUEL BREAKS IN SUPPORT OF WASHINGTON'S 20-YEAR FOREST HEALTH STRATEGIC PLAN: EASTERN WASHINGTON

by Charles Hersey and Ana Barros

A memo to land managers, partners and stakeholders on the role of fuel breaks in landscape-scale restoration and community protection in eastern Washington

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The role of shaded fuel breaks in support of Washington's 20-Year Forest Health Strategic Plan: Eastern Washington

A MEMO TO LAND MANAGERS, PARTNERS AND STAKEHOLDERS ON THE ROLE OF FUEL BREAKS IN LANDSCAPE-SCALE RESTORATION AND COMMUNITY PROTECTION IN EASTERN WASHINGTON

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ABSTRACT

Shaded fuel breaks, a common strategy proposed to reduce wildfire risk, often elicit diverse opinions from stakeholders, including firefighting professionals and members of the public. While the efficacy of using fuel breaks in support of fire operations is a common debate, the role of fuel breaks in support of broader forest health and treatment goals is not discussed as often. Washington State has an ongoing long-term strategy to accomplish bold forest health and resilience goals for eastern Washington. The 20-Year Forest Health Strategic Plan: Eastern Washington assesses the scale of forest health treatment needs and spatial treatment priorities based on an analysis of vegetation departure, drought vulnerability, wildfire risk, and exposure to communities in priority watersheds across central and eastern Washington. This analysis uses Potential Operational Delineations (PODs) as a spatial framework to identify treatment locations that have a dual benefit of addressing underlying forest health issues while also providing strategic locations for safe and effective fire management. In this context, it is important to discuss the roles of fuel breaks and landscape treatments in achieving the landscape resilience and community protection goals of the 20-Year Forest Health Strategic Plan. The objectives of this paper are threefold: clarify terminology surrounding fuel breaks and other treatment strategies considered as part of the 20-Year Forest Health Strategic Plan; review the available literature on fuel breaks in conifer systems; and examine the roles of fuel breaks and landscape treatments where appropriate for achieving multiple landscape restoration goals. We propose that fuel breaks and landscape treatments are complementary approaches that serve different landscape goals. Combining these approaches at the appropriate scale and location will significantly increase our capacity to protect communities, firefighters while improving forest health across all lands. A shared understanding of the objectives, strengths and limitations of landscape treatments and fuel breaks can foster social acceptance for action, reduce conflict in collaborative settings and increase the pace and scale of restoration.

INTRODUCTION

The value of fuel breaks in reducing wildfire risk elicits a range of diverse opinions from both proponents and opponents of the strategy. Fuel breaks are often offered as a panacea: If we just had them in the right places, we would significantly change fire outcomes by reducing the total area burned and limiting exposure of highly valued resources to high-severity fire under all conditions, all the time. Opponents believe the benefits of fire risk reduction are possible only under relatively mild fire conditions and that fuel breaks have little ecological value while potentially leading to negative ecosystem impacts. The controversy around using fuel breaks and their value is not new (Omi 1996, Ingalsbee 2005, Kennedy et al. 2019), but essential considerations of the role and effectiveness of fuel breaks are often lost in the discourse.

The 20-Year Forest Health Strategic Plan: Eastern Washington collaboratively sets goals and strategies under a shared vision for restoring forested landscapes by implementing landscape-scale treatments in priority areas. The strategic plan sets a goal of 1.25 million acres of scientifically based forest health treatments in priority landscapes by 2037. Landscape treatments encompass a broad array of different activities that establish ecologically appropriate forest vegetation structure, composition and pattern to restore resilient forest ecosystem function and processes. Treatments can include commercial thinning, prescribed fire, non-commercial thinning, managed fire, regeneration treatments and shaded fuel breaks.

In Washington, the Department of Natural Resources (DNR) has been working with partners to prioritize forest health treatments that benefit forest health and fire response operations, in what is referred to as the dual benefit of fuel treatments. This prioritization is one component of DNR's Forest Health Assessment and Treatment Framework, the state's analytical framework to assess forest health treatment needs in support of the strategic plan (WADNR 2020). When the topic of fuel breaks as a subset of forest treatments came up during the process of drafting the strategic plan, it elicited strong opinions and some misunderstandings about the role of fuel breaks in landscape restoration efforts.

We identified the need to describe a common terminology and clarify the expected role of fuel breaks within the broad set of landscape tools to improve forest health, restore landscapes and protect communities. We also identified the need to compile the existing body of knowledge on fuel breaks in a way that emphasized studies focusing on fuel breaks strengths and limitations. The recent passage of House Bill 1168 (Washington State Law 2021) – which calls for potential control lines and strategic fuel breaks as one of the many actions proposed to increase the pace and scale of forest management and community protection – underscores the need for this paper to inform landscape-scale planning and implementation in a timely fashion.

This paper's objectives are threefold: clarify terminology surrounding fuel breaks and other treatment strategies considered as part of the Forest Health Assessment and Treatment Framework; review the available literature on fuel breaks in conifer systems; and examine the appropriate role of fuel breaks and landscape treatments in achieving multiple landscape restoration goals.

WHAT ARE LANDSCAPE TREATMENTS, FUEL BREAKS AND POTENTIAL CONTROL LINES?

Landscape treatments

Landscape treatments in forested areas of eastern Washington take place across areas spanning hundreds or thousands of acres. Vegetation is manipulated to reduce fuel loads and establish ecologically appropriate vegetation structure, composition, and pattern in order to restore resilient ecosystem functions and processes.

The two key components of landscape treatments are that they are large and variable in terms of post-treatment vegetation structure (Fig. 1). Landscape treatment areas contain pockets of untreated, dense forests, openings with no trees and large areas of thinned forests with a range of basal areas that are typically 50 to 70 percent lower than pre-treatment conditions. Variability in stand and landscape vegetation patterns that mimic historical fire-dependent systems is created through the individuals, clumps and openings method (Larson and Churchill 2012).

Landscape treatments may be achieved through mechanical treatments (commercial thinning, non-commercial thinning and mastication), prescribed fire and managed fire i.e., when a lightning ignition is being managed for natural resource objectives (Huffman et al. 2020). Treatments can be designed to meet multiple landscape goals: increase forest resiliency, reduce uncharacteristic fire severity, restore and improve forest response to drought (Barros et al. 2019). Treated areas also often exhibit reduced fire intensity, which also benefits fire operations.

Fuel breaks

Fuel breaks are vegetated areas, linear or in blocks, where fuels are reduced in both volume and flammability by vegetation treatments and land management practices such as silvicultural treatments, grazing, or game management (Ascoli et al. 2018). This is done so that fires burning into them can be controlled more effectively and safely. Fuel breaks can effectively contain wildfire spread to the extent that they provide opportunities for effective fire operations. However, in the absence of adequate resources and safe conditions to engage, standalone fuel breaks are unlikely to stop fire spread (Syphard et al. 2011b, Syphard et al. 2011a).

A shaded fuel break (Fig. 2) is one specific type of fuel break where some degree of forest canopy cover remains (Agee et al. 2000). Shaded fuel breaks are typically linear treatments of varying widths (typically 100 to 400 feet) adjacent to a control feature (road, ridgeline, etc.) where overstory and understory forest vegetation is reduced to provide safe areas for effective fire suppression, use of prescribed fire and managed fire.

Many fire managers recognize that the primary objective of a fuel break is to provide wildland firefighters safer ingress and egress, defendable containment lines and shorter response times to fires (Moriarti et al. 2015). Fuel breaks are commonly constructed during a wildfire incident as part of the incident's emergency management response. They are used as a primary containment strategy in areas where line construction immediately adjacent to the fire is not safe for firefighting personnel or effective due to terrain or other natural resource considerations. Fuel breaks can also be identified as alternative or contingency lines. Fire management teams routinely construct contingency fuel breaks at the same time they work to implement their primary response strategy.

Fuel breaks can also be planned and constructed in anticipation of future wildland fires or as a part of implementing prescribed fire. When a wildland fire occurs, they can serve as control locations from which to carry out suppression operations.

Potential Control Lines and Potential Operational Delineations

Potential control lines (PCL), also referred to as potential control locations, are defined as features that provide a benefit to fire operations. We use the term fire operations broadly to include a variety of management objectives, including full suppression, prescribed fire and managed fire. On the landscape, PCLs correspond to roads, water bodies, fire scars and other landscape features that provide safe and potentially effective control lines due to their strategic locations and lack of fuel.

PCLs are defined by their strategic value to fire operations. They are used to efficiently contain, flank and back fires. Under

Figure 1. Landscape-scale view of forest health treatments at landscape scale and detail (inset) of a typical treatment pattern. Landscape treatment areas contain pockets of untreated, dense forests, openings with no trees and large areas of thinned forests. At the stand level (inset), vegetation treatments mimic fire effects with snags, clumps and openings of trees.

appropriate conditions, PCLs can also act as anchor points for burnout operations (Maestas et al. 2016). These operations can occur during an incident that is managed for full suppression or a lightning ignition being managed for natural resource objectives.

PCLs can also be identified through the Potential Operational Delineation (POD) process as part of pre-suppression planning efforts during the off-season. PODs are systems that divide the landscape into manageable units to constrain the spread and size of fires or allow safe fire use, depending on pre-defined management goals (Caggiano 2019). They consist of a network of PCLs identified by firefighters using a combination of analytics, local knowledge of past fire behavior and landscape conditions (Dunn et al. 2020, Thompson et al. 2020).

DNR uses PODs to prioritize landscape treatment needs in eastern Washington's priority planning areas (WADNR 2020). PODs are used to align forest health and fire operation goals by creating a spatial template to prioritize locations where landscape treatments and fuel breaks can be combined to improve POD and PCL conditions (Fig. 3). PCLs and PODs are prioritized and combined to highlight opportunities for treatments that provide a dual benefit of forest health and wildfire response opportunities (Fig. 3). For more details on the prioritization of PODs and PCLs for dual benefit see WADNR (2020).

What is the difference between a PCL and a shaded fuel break?

PCLs in a high-risk area might be selected for fuel management work to harden the line, connect portions of a PCL and improve its safety and effectiveness for fire operations (Fig. 2). In conifer forests, a common approach is to implement a shaded fuel break along the PCL where a combination of canopy and surface fuel reduction occurs within a variable distance of each side of the PCL.

The primary purpose of a shaded fuel break along a PCL is to create a safer, more accessible area for fire operations and reduce fire exposure in high-risk areas. While thinning and prescribed burning to reduce fuel continuity and remove ladder fuels may increase forest resilience along that narrow treated area, in landscapes that have extensive forest health restoration needs, fuel breaks alone are not adequate to increase forest resiliency and reduce risk to values at scale. Addressing underlying forest health issues to change fire behavior and reduce risk to resource

Figure 2. A shaded fuelbreak along the road creates a potential control location and provides safe opportunities for fire management.

values at a landscape scale requires significant investments in comprehensive landscape treatments that may include shaded fuel breaks.

WHAT DO WE KNOW ABOUT THE EFFECTIVENESS OF FUEL BREAKS IN CONIFER FORESTS?

Fuel break effectiveness depends on a number of factors, including some of which are beyond our control, like weather conditions. One way of assessing fuel break effectiveness is by quantifying how often the fuel break was an effective control line, or in other words, how often did the "potential" in the potential control line come to fruition. The majority of what we know about fuel break effectiveness comes from non-forested systems in southern California (Syphard et al. 2011b, Syphard et al. 2011a). One empirical study on non-forested systems in four national forests showed that of the 95 fires that crossed into the study area during a 28-year period, only 53 reached a fuel break (Syphard et al. 2011b). Of those 53 fire events that did reach a fire break, 23 saw fire progression stop along the fuel break, almost assuredly due to adjacent firefighting activities. Fuel breaks failed to hold the remaining 30 fire events. The primary reasons were: suppression resource availability was limited; the wind shifted to a more challenging setting; a fuel break was not well maintained; no fire suppression resources were deployed to the fuel break. These results provide empirical evidence that fuel breaks by themselves will not stop wildfires. Firefighter operations at the right time and made possible by a fuel break in the right place may stop a wildfire. In other words, fuel break effectiveness is determined by the treatment's ability to give firefighters access and create conditions to engage the fire event.

A common concern about the ecological impacts of fuel breaks is that these treated areas can provide establishment sites for nonnative plants. Open patches, fuel breaks, or landscape treatments generated from high severity disturbances (e.g., wildfire or thinning) are vulnerable to invasion by nonnative plants, particularly grasses (Gray 2005, Sutherland and Nelson 2010, Willms et al. 2017, Kerns et al. 2020). These plants can then invade surrounding areas, particularly after a disturbance event. Nonnative invasions can alter fire regimes by changing the spatial and temporal fine fuel structure on the landscape (Kerns et al. 2020).

Nelson et al. (2008) examined the effects of thinning and prescribed fire on understory plant composition in conifer forest of eastern Washington (USA). The authors found that treatments had no effect on native plants, but that nonnative plants showed a small increase in cover and richness. Furthermore, results showed that nonnative plants were significantly less abundant in treated stands covering larger areas than on adjacent roadsides (Nelson et al. 2008). This is in agreement with other studies that have found roads act as corridors or agents for nonnative plant dispersal (Parendes and Jones 2000, McDougall et al. 2018).

One study sampled 24 fuel breaks in California and found that nonnative plant species were more abundant in fuel breaks than the adjacent wildlands (Merriam et al. 2006). Fuel breaks in coast scrub shrub lands had the highest relative nonnative cover on average (68.3 percent). In contrast, fuel breaks in coniferous forests had the lowest cover of nonnative plant species on average (4 percent).

The method used to build the fuel break is also associated with relative nonnative plant cover. Fuelbreak construction methods that heavily disrupt the soil seed bank, reduce litter cover, duff depth and canopy cover were associated with more nonnative plants. For example, fuel breaks constructed using bulldozers had more nonnative cover than fuel breaks built by hand crews. Mechanical thinning led to less growth of nonnative plant cover (Merriam et al. 2006).

Other ecological effects of fuel breaks may include reduction in carbon, increased sedimentation potential that affects hydrological systems, direct impacts on habitat due to fuel manipulation, edge effects and landscape-scale habitat fragmentation (Shinneman et al. 2019). Little is known about

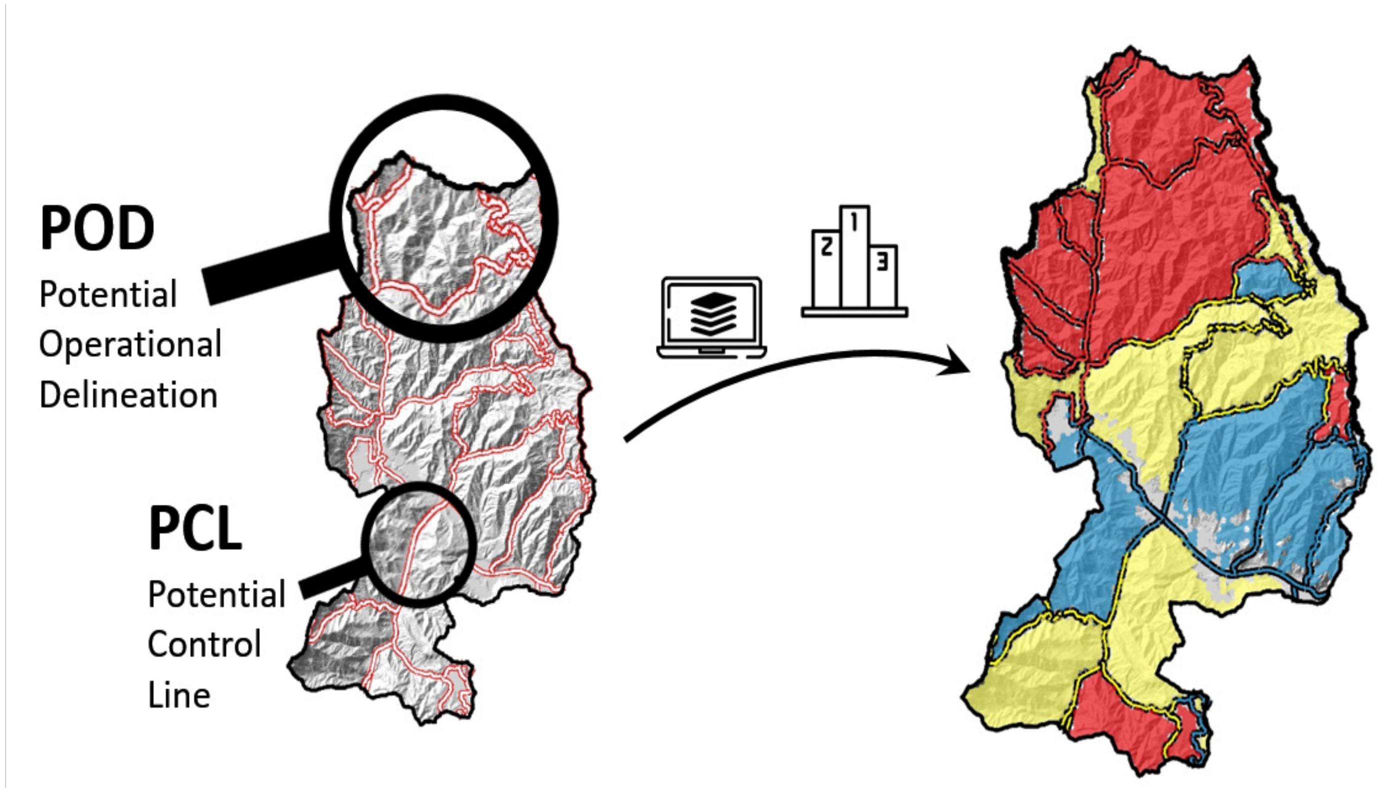

Figure 3. Potential wildland fire Operational Delineations (PODs) for the Chumstick to LP prioriy planning area. PODs correspond to large landscape areas completely surrounded by potential control lines (PCLs). PCLs can be ridgelines, roads, old fire scars or treatments and correspond to locations where firefighters have a strategic opportunity to engage and control wildfires (left map). In the Forest Health Assessment and Treatment Framework, PCL and PODs are prioritized and combined to highlight opportunities for treatments that provide a dual benefit of forest health and wildfire response benefit (right map). Red areas show first priority, yellow areas show second priority, and blue areas show third priority. For more details on the prioritization of PODs and PCLs for dual benefit see WADNR (2020).

the economic, ecological and social costs of building fuel breaks during fire incidents relative to pre-built fuel breaks.

CONSIDERATIONS FOR THE USE OF SHADED FUEL BREAKS IN SUPPORT OF POTENTIAL CONTROL LOCATIONS (PCLS)

We propose that shaded fuel breaks and landscape treatments are complementary approaches that serve different landscape goals (Fig. 4). Combining these approaches in the most efficient locations and at the appropriate scale will significantly increase our capacity to protect communities, support firefighters, restore ecosystem function and processes and enhance these landscapes' resilience and adaptive capacity. A shared understanding of these approaches' roles, strengths and limitations can foster social acceptance and support for action, reduce conflict in collaborative settings and increase the pace and scale of restoration.

Despite substantial differences in fire regimes between the conifer forest of eastern WA and shrublands in southern California and the sagebrush steppe of the Great Basin, lessons learned from these ecosystems can be instructive to guide our work moving forward. These lessons, combined with DNR's work to evaluate landscapes based on the best available science on landscape restoration and wildfire risk, as well as the expertise developed through working collaborations with local land managers and partners are the basis for the six considerations described below.

The main goal of a fuel break is to enhance the effectiveness of PCLs and its contribution to forest health is indirect

It has been widely recognized by policymakers, managers and scientists that the pace and scale of landscape treatments falls short of what is needed to address the existing backlog of treatment needs across fire-adapted systems in the western United States (North et al. 2012, Vaillant and Reinhardt 2017, WADNR 2020, North et al. 2021). While fuel breaks play an important role by creating opportunities for fire operations, they are not substitutes for large landscape forest health treatments

The forest health treatment needs for eastern Washington are extensive. In forested watersheds, on average, 30 to 50 percent of the forested acres are in need of forest health treatment (DNR 2020). As part of the Forest Health Assessment and Treatment Framework, DNR assesses the forest health treatment need for priority watersheds through a terrestrial landscape evaluation. A landscape evaluation is a data-driven approach to understanding the current condition of a landscape, the level of resilience to disturbance and climatic change and its ability to provide an array of ecosystem services over time (Hessburg et al. 2015).

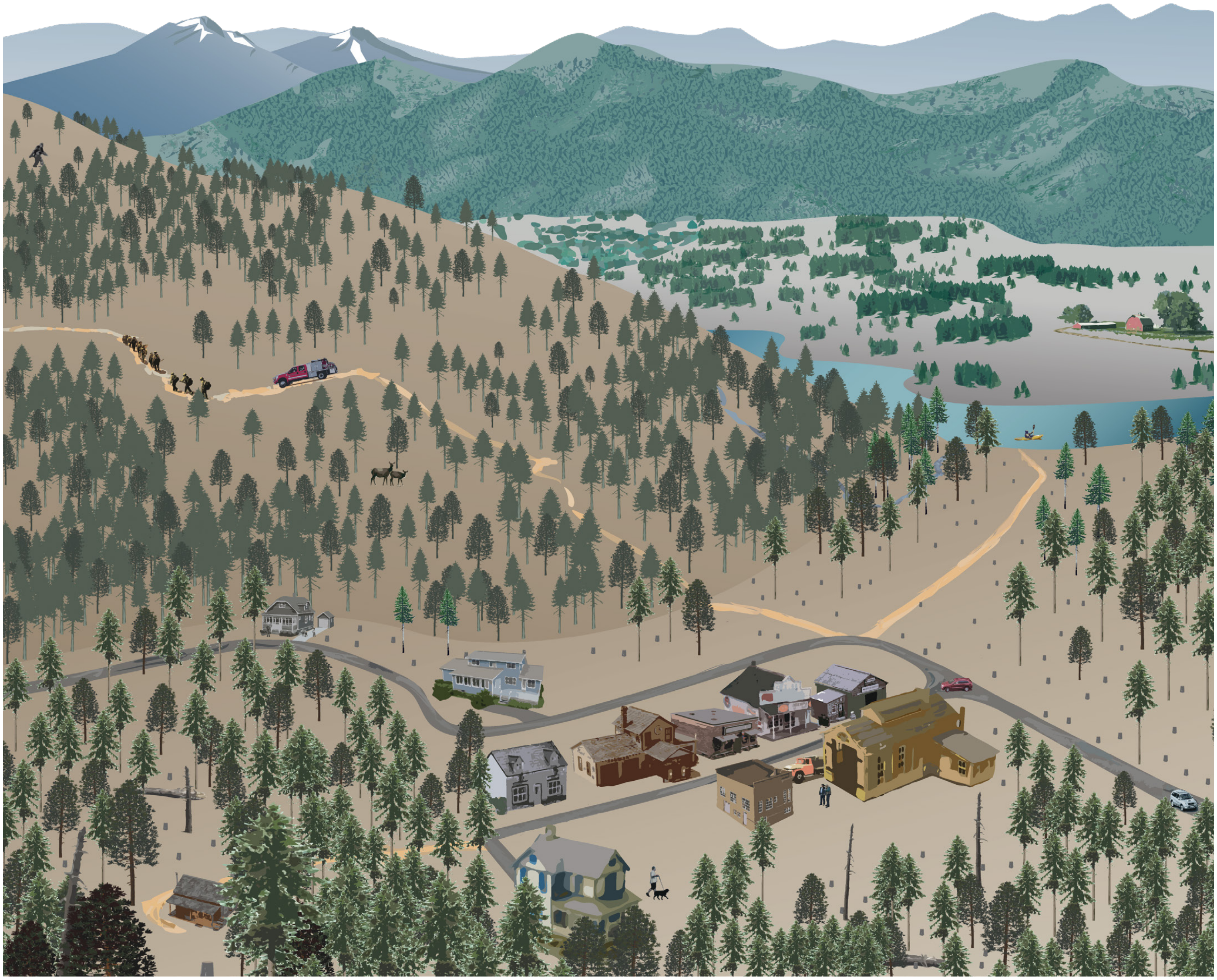

Figure 4. Landscape view of shaded fuel breaks enhancing PCLs. The river, roads, and forest roads are the PCLs. Some of these have been hardened with shaded fuelbreaks, e.g., the forest road leading to the river and road along with the town. These shaded fuelbreaks blend into landscape treatments going uphill to the left side of the figure.

The primary outputs of the landscape evaluation are a treatment target and a summary of vegetation conditions (forest structure and composition) that are under or over-represented relative to historical and future reference conditions, current fire and drought risk and wildlife habitat needs (WADNR 2020).

Narrow fuel breaks along PCLs contribute only in a minor way to directly achieving some forest health treatment needs and are primarily aimed at creating opportunities for firefighters to protect highly valued resources (communities, substations, protected habitat, water sources, etc.). Due to their extent, spatial layout, location and prescription, fuel breaks cannot produce the landscape-scale pattern of forest structure and composition required to achieve forest health and resilience objectives.

For example, in the Chumstick to LP forest health priority planning area in Chelan County, the forest health treatment need ranges from 36,500 acres to 53,000 acres representing 43 to 63 percent of the forested acres within the planning area (WADNR 2020). In the same planning area, there are 200 miles of proposed all-lands PCLs in strategic locations to create opportunities for firefighter engagement across that landscape (Fig. 3). Only a fraction of the PCL network requires shaded fuel breaks. Still, in the unlikely scenario that 200-foot wide fuel breaks were implemented along all 200 miles of the PCLs, this would total approximately 4,800 acres of treatment. This is nowhere near the bare minimum of 36,500 acres of treatments needed to restore landscape resiliency.

In forest types where fuel accumulation has led to forest health issues and uncharacteristic amounts of high-severity fire, PCLs (and their associated fuel breaks) can help improve and maintain forest health and resilience. By providing anchor points for fire use in public lands, PCLs can be used to support the expanded use of prescribed fire and managed fire, thus increasing the pace and scale of restoration. When PCLs are strategically placed, adequately maintained, and used by fire operations to prevent the effects of high-severity fire, they make positive contributions to forest health.

To establish effective PCLs, landscape treatments are better than fuel breaks

When possible, PCLs should be hardened with large landscape treatments that meet the dual benefit of improving forest health and supporting wildfire operations. Landscape treatments provide greater benefits than standalone shaded fuel breaks because they are the primary means to achieve forest health goals while providing greater fire operation benefits. Because of their sizes and prescriptions, landscape treatments are the type of treatments that best address the scale of the forest health crisis, reduce fire risk and restore ecologic functions of forest ecosystems.

The size of landscape treatments allows for variability in forest structure and composition to create mosaics of dense and open forest conditions, as well as patch sizes that reflect natural processes. In a landscape prescription for dry and moist-mixed conifer forest types, fuel variables that drive fire behavior (e.g., understory fuels, canopy base height, ladder fuels) are altered in ways that typically reduce spread rates and fire intensity over a large area adjacent to the PCL. Thus, landscape-scale treatments make PCLs more defendable (Hudak et al. 2011, Stephens et al. 2012).

Without appropriate maintenance, firefighting resources and in cases of extreme fire weather, fuel breaks are likely to fail

PCLs associated with shaded fuel breaks are effective only when they are well-maintained, there are adequate firefighting resources to engage fire events and weather conditions make it safe to do so. Fuel breaks do not stop fire spread passively; they only provide a strategic break in fuels that can be used by firefighters to stop the spread of fire. Communicating a realistic, tangible picture of their protective value to the public, news media and other stakeholders is critical. Failing to do so may create a false sense of security and a heavy reliance on fuel breaks in tandem with disinvestment in essential actions such as landscape treatments and fire-resistant building renovations and upkeep in areas prone to fire.

Even when fuel breaks are well maintained and firefighting resources are available, fires can and will spread across them, particularly during extreme fire weather conditions (Syphard et al. 2011b). Fuel breaks are about creating opportunities for safer engagement. Still, under extreme conditions, engagement may not be safe even on a well-maintained fuel break. This is particularly true in an era of fire events burning under extreme weather conditions, as the Pacific Northwest has experienced during recent fire seasons (Halofsky et al. 2020).

More than ever, it is crucial to set realistic expectations and carefully plan fuel breaks that increase the odds of success, while at the same time acknowledging that there are no guaranteed outcomes. Landscape treatments have similar limitations, but the likelihood of a large treatment impacting fire behavior is greater due to its spatial scale and arrangement (Schmidt et al. 2008, Tubbesing et al. 2019). In addition, landscape treatments accomplish ecological and forest health objectives regardless of their potential impact to wildfire behavior.

Work strategically because location matters

Shaded fuelbreaks should only be implemented along high-value PCLs, i.e., locations with strong strategic value for fire operations and where a landscape treatment is not feasible or needed. For example, shaded fuel breaks along property boundaries that do not correspond to a PCL are of limited utility for wildfire response, forest health, or community protection. Understanding where fires are more likely to occur and the dominant local fire flow patterns, combined with the location of communities and other highly valued resources (Syphard et al. 2011b, Syphard et al. 2011a), can help identify PCLs where complementary shaded fuel breaks create the strongest opportunities for fire management and where they are more likely to be needed.

If managed effectively, shaded fuel breaks are part of a coordinated, cross-boundary landscape strategy to create and maintain resilient forests and safe communities. The strategy relies on extensive landscape treatments and creating fire-adapted communities. When landscape treatments are not possible or extensive enough, standalone fuel breaks may provide value by enhancing PCLs. They should be prioritized in locations with elevated risk to highly valued resources and assets, with access to suppression resources and where they can be effectively maintained.

Plan for the landscape we have and the landscape we are working to achieve

Aligning forest health goals with fire management goals is crucial for preparing landscapes to receive more managed fire. One of the criticisms of fuel breaks is that they further fire exclusion, which increases the risk of a high-severity fire event. This view is contradictory to the need to reintroduce lower-severity fire in many fire-adapted forests (Ingalsbee 2005). We posit that the role of a fuel break can be dynamic, adapting to landscape and fire management needs over time.

A fuel break that can be used to stop fire can also be used to manage or light fire – though those varied objectives may lead to different prescriptions for fuel breaks (Ingalsbee 2005). The shift from a fire exclusion paradigm to one that allows a fire to occur where it is desirable, appropriate and safe will require a shift in the role fuel breaks play. Strategically positioned fuel breaks can help create and maintain resilient forests by providing opportunities for prescribed fire and managed fire. Otherwise, full suppression would still be the favored strategy.

The PODs framework provides a flexible, spatial template to address the full suite of fire management goals that vary across ownerships and over time. These goals can range from reintroducing fire into the landscape to identifying locations that warrant full suppression (e.g., near communities). For example, identifying PCLs and PODs based on fire and forest management goals is one way to create a holistic fuel break infrastructure that better complements landscape treatments and that aligns community protection and landscape restoration goals. Large landscape treatments within each POD will be maintained over time by prescribed and managed fire. A well-structured network of PCLs to support that maintenance will be needed to make sure resilience is sustained over time and that decades of investment in forest resiliency and community protection are not lost.

We need to improve our understanding of the tradeoffs

Moving forward will require comprehensive monitoring and scientific assessment of fuel breaks and landscape treatments in conifer systems. Key fuelbreak tradeoffs include optimal spatial designs, silvicultural prescriptions and maintenance schedules for various fire and fuel environments that minimize the negative effect on plant and animal communities (Shinneman et al. 2019).

Future research should also address the socioecological tradeoffs of implementing fuel breaks as part of pre-planning effort outside of the fire season (such as in PODs) compared to building the fuel break as part of emergency response during a fire incident. Regardless of if they are a primary, alternative or contingency line, fuel breaks take time and firefighting resources to construct. Time and firefighting resource availability will ultimately factor into strategic decisions, which will, in turn, impact the size and containment date of a wildland fire. Prioritizing and implementing fuel breaks as part of a PCL network through a collaborative PODs process that plays out during the off-season may increase social license for the fuel breaks and operational, economic and ecologic efficiencies.

Fuel break monitoring would allow data collection over time, improve our understanding of the tradeoffs and inform future management decisions. Fuelbreak monitoring could include, for example, long-term sampling protocols to evaluate and track vegetation recovery and the abundance of nonnative plant species near fuel breaks and adjacent wildland areas, both treated and untreated (Merriam et al. 2006). In years in which fuel breaks interacted with wildfires, conducting personal interviews with firefighters involved with suppression activities would further elucidate operational constraints and opportunities (Syphard et al. 2011a). These discussions would collect qualitative data on fuel break conditions, ease of access to fuel breaks and the number of available resources related to breaches of fuel breaks.

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