Forest Health Assessment and Treatment Framework

RCW 76.06.200

WASHINGTON STATE DEPARTMENT OF
NATURAL RESOURCES

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On the cover (clockwise from top left): Yakama Nation Fisheries aquatic restoration project placing large wood in river, photo by Yakama Nation Fisheries/Inter-Fluve; Tillicum thinning crew responsible for thinning 4,000 acres on the Okanogan-Wenatchee National Forest in the Tillicum priority planning area administered by the DNR Federal Lands Program, photo by John Marshall; Yakama Nation Fisheries 2019 Entiat River Stormy A Side Channel Restoration Project in the Lake Creek-Entiat River HUC 12, photo by Yakama Nation Fisheries/Inter-Fluve; Spring 2022 Virginia Ridge treated stand after Cedar Creek Fire, photo by John Marshall; Spring 2022 prescribed burn on DNR State Trust Lands, photo by DNR; and Upper Swauk priority planning area, photo by DNR.

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Executive Summary

Washington has more than 22 million acres of forestland. From the lush rainforests on our coasts, to the rugged sub-alpine forests along the Cascade Crest, and the pine-dominated hillsides surrounding the Columbia Plateau, forests are integral parts of our landscapes and communities that provide a wealth of benefits to our state. They provide sustainable forest products and jobs, clean air and water, wildlife habitat, and world-class outdoor recreation.

Forest ecosystems, as evidenced by recent wildfire seasons, are facing significant threats. Climate change is shifting precipitation patterns, increasing the rate and intensity of severe weather events. Drought is leading to tree die-off, increasing forest susceptibility to insect and disease outbreaks. Invasive species are threatening native plants and wildlife habitat. An increase in severe wildfires is endangering communities, while damaging our forests and infrastructure. The Washington State Legislature has recognized that our forests face unprecedented threats that require bold action, and provided direction and resources over several biennia.

RCW 76.06.200 requires DNR "to proactively and systematically address the forest health issues" and to assess, treat, and track progress. Washington Department of Natural Resources, in close coordination with our partners in shared stewardship, is working strategically to tackle our wildfire and forest health crisis at the pace and scale it demands. The submission of this biennial legislative report marks the fifth anniversary of the release of the 20-Year Forest Health Strategic Plan: Eastern Washington. The 20-Year Forest Health Strategic Plan is integrated into our statewide Forest Action Plan and is the framework focusing and directing implementation of the forest health assessment and treatment framework required by RCW 76.06.200. This report provides key information on the state's progress to create resilient forests through fulfillment of RCW 76.06.200.

DNR and our partners have made significant progress. Highlighted accomplishments since our December 1, 2020 report include:

- Assessment of forest conditions to quantify forest restoration and management needs across 37 priority landscapes covering 4,165,780 acres in eastern Washington. This greatly exceeds the statutory requirement of analyzing 200,000 acres of fire prone land each biennium.
- Presentation of new landscape evaluation summaries for 8 priority planning areas, providing a scientifically grounded blueprint of forest health treatment need and scale. Landowners can use these evaluations on a voluntary basis to improve their forests, and DNR can use them to track benchmarks and progress across each landscape.
- A commitment by DNR to analyze 10 more priority planning areas next biennium, representing an additional 1,108,883 acres. This expands our footprint to focus DNR resources on implementing the forest health plan with partners across 47 total priority planning areas totaling more than 5.2 million acres.

- Increase in the number and diversity of partnerships, leading to a corresponding increase in the size and complexity of forest health projects and wildfire risk reduction activities being planned and implemented across the state.
- Landowners invested significant resources to accelerate implementation of forest health treatments. DNR and our partners have reported 493,460 acres of forest health treatments across eastern Washington since the plan's adoption in 2017, impacting 309,556 footprint acres.
- Cutting-edge forest health monitoring, led by DNR scientists, to track progress toward our goals while monitoring the effectiveness of forest health treatments in the face of wildfire, drought, and insects and disease.

Assessing the resilience of forested landscapes and quantifying forest restoration needs have resulted in ground-breaking scientific work in Washington. We have bolstered our efforts to coordinate forest health and wildfire risk reduction activities. Between 2017 and 2022, DNR and partners assessed forest conditions and treatment needs on 37 priority landscapes in eastern Washington. The assessments identified the need for a range of forest health treatments on 962,070-1,385,820 acres to restore forest health and resilience, underscoring the need to not only meet but exceed the initial goal established by RCW 76.06.200 to assess and treat one million acres of land by 2033.

Within these assessments, DNR is working with partners to prioritize forest health treatments that benefit both forest health and wildland fire operations. This process of dual-benefit prioritization results in the identification of potential control lines (PCLs) and potential operational delineations (PODs), which aid in fire suppression and response.

Forest health treatments take multiple forms, including commercial harvest, non-commercial thinning, prescribed burning, and in places where appropriate, managed wildfire. Conducting treatments at a scale commensurate with the restoration need and in coordination with multiple landowners is an extraordinary logistical, economic, and social challenge. Each landowner maintains their own set of management objectives, requirements for environmental review, and unique priorities and barriers that impact their ability to increase the scale of treatments. Since 2017, landowners and managers in eastern Washington have reported implementation of 493,460 acres of forest health treatments, impacting 309,556 footprint acres. Treatments are reported by category: commercial, non-commercial, and prescribed fire.

In many cases, more than one kind of treatment is needed on a given acre to meet forest restoration objectives. Treatment data reported to DNR is uploaded into Forest Health Tracker, a novel all-lands online tool used to compile and display forest health project information from across Washington. This tool can be used to understand where investments in forest health treatments are being implemented, identify areas prioritized for treatment, and evaluate opportunities to better achieve cross-boundary outcomes.

Tracking progress, however, is about more than just counting acres. Understanding how forest conditions are changing requires that we monitor and evaluate forests at multiple scales. A primary goal of the 20-Year Forest Health Strategic Plan is to "develop and implement a forest health resilience monitoring program that establishes criteria, tools, and processes to monitor forest and watershed conditions, assess progress, and reassess strategies over time." Monitoring is essential for reporting and accountability, building shared understanding and trust, and informing adaptive management to increase the effectiveness of our work over time. Assessing the progress made towards our goals under the 20-Year Forest Health Strategic Plan Monitoring Framework requires answering two main questions:

- *How are forest conditions and associated forest health indicators changing over time?*
- *What are the outcomes of forest health treatments?*

Since our last legislative report, meaningful advancements in monitoring have played out at two ends of the spatial spectrum: stand level treatment monitoring and regional remote-sensing change detection. During the last biennium, DNR staff and partners developed a common methodology to collect data on completed treatments and to assess if treatment objectives were met. In some locations, monitoring data is supplemented by the use of photo monitoring and drones to expand our perspective and document a point in time. DNR scientists also utilize satellite imagery to detect and monitor changes in forest conditions at a landscape scale, providing an additional line of evidence to evaluate the impacts of disturbances like wildfire, drought, and insects and disease.

Forest ecosystems are inherently dynamic, and the collective effort of our monitoring partners combined with the use of tools such as drones and satellite imagery increase our ability to more accurately and effectively assess forest resilience and treatment outcomes across eastern Washington.

Wildfire is the primary disturbance agent affecting eastern Washington forests. Following the 2021 wildfire season, DNR scientists released the first Work of Wildfire Assessment. The report formalizes an approach for evaluating the impacts of wildfires on forest resilience. In 2021, wildfires affected 463,345 forested acres in eastern Washington. The assessment found that those wildfires had both positive and negative effects on forest resilience and wildfire risk reduction objectives. Severe impacts occurred on an estimated 125,000 acres in dry forests and portions of moist forests. Conversely, fires likely had beneficial effects on landscape resilience and wildfire risk in many locations. Low- and moderate-severity fire (<75% tree mortality) occurred across an estimated 230,000 acres of dry and moist forests, reducing hazardous fuels and tree densities. The assessment found many examples where prior forest health treatments gave fire managers more options to directly engage and safely manage fires.

Prescribed fire is a critical management tool for reducing forest fuels that contribute to high severity wildfire and tree mortality. Low intensity fires are intentionally applied by trained practitioners to improve forest ecosystem health and resiliency. DNR made significant progress this biennium in increasing the use of prescribed fire in eastern Washington in policy and practice. This year, for the first time in more than a decade, DNR implemented prescribed burns on state trust lands. Policies have been developed to ensure the highest standards of safety will be met for prescribed fire.

The agency launched a Certified Burner Program to increase the number of trained professionals who can safely plan and implement prescribed fires. Additional case studies in this report highlight the work of Washington Department of Fish and Wildlife, Chelan County, Kalispel Tribe of Indians, and other partners, all of which are working to increase their use of prescribed fire. Prescribed fire across all-lands is a key strategy to improving forest health outcomes and reducing wildfire risk.

Reducing the impact of wildfires on values at risk, such as homes, timber resources, drinking water, critical habitat, and infrastructure requires not only investments in healthy forest landscapes, but also fuel breaks, defensible space, and home hardening. DNR published a white paper in 2021 entitled, *The Role of Shaded Fuel Breaks in Support of Washington's 20-Year Forest Health Strategic Plan*. The paper summarizes key findings from the scientific literature and makes recommendations to guide integrated implementation of fuel breaks with landscape-scale forest health treatment activities. Fuel breaks are not a replacement for landscape-scale restoration. Both will be required to effectively reduce wildfire risk. This report is delivered in concert with DNR's 10-Year Wildland Fire Protection Strategic Plan report, which details additional activities to promote safe and effective fire suppression and response. Both the forest health strategic plan and the wildfire strategic plan benefit from initiatives like Wildfire Ready Neighbors and must continue to be implemented in close coordination with one another.

A key focus of future monitoring, and an emerging area of concern among scientists and practitioners, is the role of drought as a disturbance agent in our forests. Scientists predict that climate change will lead to increased incidence of drought. In 2021, Washington experienced a historically dry spring, followed by a record-breaking heat wave. The abnormal conditions affected water supplies across Washington, prompting a drought emergency for most of the state. Drought has profound impacts on forest health, and low fuel moistures influence how fire spreads. Following the 2014-2015 drought, forest health scientists at DNR mapped more than 1.5 million acres affected by wildfire and estimated that 3.4 million trees had been recently killed. The impacts of the 2021 drought will continue to play out over the next few years.

This legislative report highlights the investments DNR and our partners are making to prepare forests for drought and improve watershed resilience. Leading practitioners from Yakama Nation and Colville Confederated Tribes contributed their insights about aquatic evaluations, watershed restoration needs, and drought mitigation projects to this report. Integrating aquatic restoration into uplands forest management will be essential to ensure our forests, fish and wildlife, and downstream water users are prepared for future drought.

Developing a durable and actionable strategic plan requires cooperation and partnerships. The 20-Year Forest Health Strategic Plan was crafted with input from Tribes, conservation groups, timber industry, county governments, federal agencies, and other state agencies. This collaborative approach remains a signature theme of plan implementation. Collaborating is predicated on the idea that wildfire knows no boundaries, and thus we must work with our neighbors in order to effectively reduce risk. Partners and stakeholders remain involved at every level of the implementation process – from the statewide Forest Health Advisory Committee to stand-level monitoring occurring in recently treated forests.

This collaboration is also being facilitated through critical investments like the Building Forest Partnerships Grant Program, which supports diverse interests working together towards shared forest health goals. Partnerships and collaboration have led to increased success in coordinating the implementation of cross-boundary forest health treatments, and remain a key part of our strategy moving forward. Numerous case studies and success stories were contributed by partners for this report and are highlighted throughout.

DNR commissioned a third-party social science monitoring assessment to evaluate the perspectives of highly engaged partners and stakeholders. The assessment included surveys and interviews with more than 120 unique individuals from across the state. Key findings include that partners remain committed to the goals of the plan, and see the strategy as guiding the assessment of forested conditions and the implementation of forest health activities. Significant progress is being made from the perspective of engaged stakeholders, however additional work is needed to effectively align and coordinate implementation timelines and cross-boundary treatments.

Another emerging area of work associated with the implementation of the 20-Year Forest Health Strategic Plan is environmental justice and equity. The most vulnerable populations in society often bear disproportionate impacts from unhealthy ecosystems and natural disasters. Wildfires spread dense smoke across the region, impacting human health and quality of life. Degraded forest conditions impact the cultural, spiritual, and economic connections between people and the natural world. As part of the on-going implementation of the 20-Year Forest Health Strategic Plan, DNR is actively developing an *Environmental Justice Implementation Plan for Forest Resilience*. The environmental justice plan, which is intended to supplement the Forest Action Plan and 20-Year Forest Health Strategic Plan, is being crafted in partnership with environmental justice leaders and affected communities. The actions identified in the plan will foster more equitable outcomes and reduce negative impacts associated with poor forest health to the most vulnerable Washingtonians.

Rural economic activity and community well-being are inextricably linked to the health and resilience of Washington's forests. This year the U.S. Climate Alliance, in partnership with research firm RTI International, conducted an economic analysis of the 20-Year Forest Health Strategic Plan. The researchers found that implementing the strategic plan supports 1,518 to 2,572 jobs and $67.6 to $112.4 million in annual wages (Woolacott et al. 2022). Having forest health workers and contractors available to conduct forest health treatments, however, is a significant challenge, especially as many landowners seek to significantly increase their treatment footprint.

This biennial legislative report showcases the story of an entrepreneur in eastern Washington who started a new small, forest health business and is working in partnership with private, state, and federal landowners. Private industry is an essential partner in achieving the state's forest health and wildfire risk reduction goals. Continued investments in workforce development, biomass utilization technologies, and small businesses remain a critical part of our collective work.

Historic investments in forest resilience and wildfire risk reduction have been made by Washington State and our federal partners over the last two years. The Washington State Legislature adopted second substitute House Bill 1168 in 2021, which established the Wildfire Response, Forest Restoration, and Community Resilience account. The legislation provided an initial $125 million for the 2021-2023 biennium to implement the state's forest health and wildfire strategic plans as well as a commitment to continue this level of funding over the next four biennia.

The federal government passed the Bipartisan Infrastructure Investment and Jobs Act, which was signed into law in November 2021. That legislation invests more than $3 billion in hazardous fuels treatments across the country. The USDA Forest Service announced the national 10-Year Strategy to Confront the Wildfire Crisis in January 2022, which was followed by a commitment to direct resources in four counties east of the Cascades through the Central Washington Initiative.

These state and federal investments, and the additional resources they leverage, are vital to delivering on our strategic plans and legislative direction to increase the health, vibrancy, and resilience of our state's forests and communities today and into the future.

For the 2023-2025 biennium, DNR is requesting full funding of the Wildfire Response, Forest Restoration, and Community Resilience Account at $125 million. Of this funding, approximately $94.8 million worth of expenditures is maintenance level funding to DNR, while the remaining $30.2 million is for partners implementing our forest health and wildland fire strategic plans. These include state agencies, federally recognized tribes, local governments, fire and conservation districts, nonprofit organizations, forest collaboratives, and small forest landowners. DNR is well positioned to serve as fiscal and programmatic steward of all funds that are not directly appropriated to other state agencies. DNR assures the legislature that the comprehensive funding package identified in this proposal meets the minimum appropriation thresholds established in legislation that forest health activities funded by the Account shall not be less than 25% and community resilience activities funded by the Account shall not be less than 15% of the biennial appropriated funding.

To accomplish these objectives, DNR is requesting the following funding:

(1) **Maintenance-Level Request:** DNR requests maintenance level funding of approximately $94.8 million, which includes just over $34 million specific to implementation of forest health assessments, treatments (including technical assistance to small forest landowners), and progress tracking work consistent with forest restoration and community resilience objectives in our strategic plans.

(2) **State Agency Requests:** To facilitate an all-lands, all-hands approach DNR supports a strategy in which direct allocations are provided to those state agencies producing core deliverables consistent with these plans. For the 23-25 Biennium, DNR supports the direct allocation request from the Washington State Conservation Commission (SCC) for $5 million to deliver community resilience and forest restoration projects through conservation districts statewide. DNR also supports the non-account requests for the Washington Department of Fish and Wildlife (DFW) and Washington State Parks (Parks) including DFW's request for approximately $6M from the dedicated capital-funded Forest Resiliency Account – Hazardous Fuels Reduction and Forest Health (25F), and Parks' request of approximately $1M in capital funding, and $500K as a component of the General Fund operating budget.

(3) **Policy Level Pass-Through Request:** To ensure funding is provided in a transparent, consistent, and accessible manner to non-state entities, DNR requests the remaining $25.2 million in available funds from the Account be provided to the agency for direct disbursement through DNR's existing programs that provide ability to pass-through funding to implementation partners.

Released in 2017, the 20-Year Forest Health Strategic Plan laid the foundation and catalyzed action to increase the health and resilience of Washington’s fire prone forests and communities at the pace and scale of the threats facing them. Tremendous progress has been made in the past five years, but looking ahead, there is no doubt about the work still to be done.

This report builds on the foundation presented in our 2018 and 2020 legislative reports, and demonstrates the orchestrated impact of leveraged resources under a common vision. DNR remains committed to completing the 20-Year Forest Health Strategic Plan. With strong legislative, scientific, and collaborative support, we will meet and exceed our shared goals.

Introduction

The purpose of this report is to summarize progress toward meeting the direction of RCW 76.06.200, which requires DNR "to proactively and systematically address the forest health issues," and to assess, treat, and track progress. The 20-Year Forest Health Strategic Plan serves as the high-level framework currently focusing and directing implementation of RCW 76.06.200's forest health assessment and treatment framework.

Wildfires are increasing in complexity and costs, and have impacted numerous human communities and forest ecosystems. The risk and extent of wildfires in the western United States are growing due to a combination of factors, including climate change and drought, human ignitions, and a history of fire suppression leading to uncharacteristic fuel build-up in fire dependent forests. Our states' success in addressing the wildfire crisis is linked to our ability to restore healthy forest ecosystems and prepare forests and communities for climate change.

Washington State Department of Natural Resources, in partnership with Washington Department of Fish and Wildlife and USDA Forest Service, signed one of the first Shared Stewardship Investment Strategy Agreements in the country to do the right work in the right places at the right scale. Through these partnerships, state and federal agencies have leveraged tens of millions of dollars to accelerate the planning, implementation, and monitoring of forest health treatments. The Washington State Legislature has provided leadership in advancing forest health policy, as well as funding that led to the development of the 20-Year Forest Health Strategic Plan: Eastern Washington, an ambitious strategy that is leading to increased coordination. More recently, the Legislature passed House Bill 1168, which created a new account and dedicated funding for proactive forest management and restoration.

This report provides an overview of Washington's progress in implementing the forest health assessment and treatment framework required by RCW 76.06.200. Information and updates provided herein build on the two previous Forest Health Treatment and Assessment biennial reports to the Legislature:

- 2020 Forest Health Assessment and Treatment Framework Report
- 2018 Forest Health Assessment and Treatment Framework Report

This report complements other reports requested by the Legislature that are being implemented by the Washington State Department of Natural Resources, including:

- RCW 76.04.516 Report to the Governor and the Legislature: HB 1168
- Forest Health Treatment Prioritization and Implementation Report

Washington State Forest Health Legislation

RCW 76.06.200

In 2004, the Commissioner of Public Lands was designated as the state's lead to improve forest health (RCW 76.06). Concurrent with this designation, the Washington State Legislature emphasized the need for coordination across land ownerships – federal, state, local, private, and tribal – in recognition that forest conditions on one property can pose risks to adjacent properties. In 2016, the Legislature passed a provision in House Bill 2376 Section 308 that provided funding and directed the Washington State Department of Natural Resources (DNR) to develop a 20-Year Forest Health Strategic Plan to "treat areas of state forestland that have been identified by the department as being in poor health."

Senate Bill 5546

In 2017, the Legislature passed several forest health laws related directly to DNR. Senate Bill 5546 directed DNR to develop an assessment and treatment framework designed to proactively and systematically address forest health issues facing the state. Specifically, the framework must endeavor to achieve an initial goal of assessing and treating 1 million acres of land by 2033. DNR must use the framework to assess and treat acreage in an incremental fashion each biennium. The framework consists of three elements: assessment, treatment, and progress review and reporting. Meanwhile, Engrossed Second Substitute House Bill 1711 directed DNR to develop and implement a policy for prioritizing forest health treatment investments on state trust lands to reduce wildfire hazards and losses from wildfire, reduce insect and disease damage, and achieve forest health and resilience at a landscape scale. The law established a forest health revolving account to permit depositing revenue from forest health treatments on state trust lands and applying funds toward future forest health treatments on those lands. Finally, the Legislature directed DNR to utilize and build on forest health strategic planning initiated under HB 2376 Section 308 to promote efficient use of resources to the maximum extent practicable.

House Bill 1784

In 2019, the Legislature passed House Bill 1784 requiring DNR to prioritize treatments for the dual benefit of forest health and wildfire response as part of the all-lands Forest Health Assessment and Treatment Framework in support of the 20-Year Forest Health Strategic Plan. HB 1784 amends RCW 76.06.200, Forest Health Assessment and Treatment Framework (treatment framework), to require prioritization of forest health treatments that maximize forest health outcomes and planned tools for wildfire response operations. Specifically, it directs DNR to: "prioritize, to the maximum extent practicable ... forest health treatments that are strategically planned to serve dual benefits of forest health maximization while providing geographically planned tools for wildfire response (and) ... attempt to locate and design forest health treatments in such way as to provide wildfire response personnel with strategically located treated areas to assist with managing fire response. ... These areas must attempt to maximize the firefighting benefits of natural and artificial geographic features and be located in areas that prioritize the protection of commercially managed lands from fires originating on public lands."

This report includes a detailed methods section that describes how HB1784 has been integrated into the treatment framework and meets the statutory requirements of RCW 76.06.200 to provide:

- A list and summary of treatments conducted under the framework in the preceding biennium.
- A request for appropriations to implement the framework in the following biennium, including assessment work and conducting treatments identified in previously completed assessments.
- A summary of forest health treatment needs and forest health treatment spatial priorities for the forest health priority planning areas.

HB1168

Second Substitute House Bill 1168 officially became state law on July 25, 2021. This historic legislation provides a significant increase in available resources to address wildfire risk and the forest health crisis Washington faces. The legislation states that "it is the intent of the legislature to take immediate action to increase the pace and scale of forest management across different land ownerships and fully fund the 20-Year Forest Health Strategic Plan and activities developed to facilitate implementation of the Washington State Forest Action Plan." To fulfill this legislation, the legislature established a Wildfire Response, Forest Restoration, and Community Resilience Account in the state treasury. The bill states that appropriations for forest health activities funded by this new account shall not be less than 25% of the funding appropriated each biennium. Importantly, funding in the account may not be used for emergency fire costs or suppression costs.

This legislative report includes informational updates as they relate to DNR's implementation of HB1168, as described in Section 3(d) of the legislation:

> *Progress on implementation of the 20-year forest health strategic plan as established through the forest health assessment and treatment framework pursuant to RCW 76.06.200 including, but not limited to: Assessment of fire prone lands and communities that are in need of forest health treatments; forest health treatments prioritized and conducted by landowner type, geography, and risk level; estimated value of any merchantable materials from forest health treatments; and number of acres treated by treatment type, including the use of prescribed fire.*

HEAL Act

Senate Bill (SB) 5141, also known as the Health Environments for All (HEAL) Act, effectively became law on July 25, 2021. The bill establishes environmental justice mandates for seven agencies in Washington, including the Department of Natural Resources. Studies have found that communities with high percentages of people of color, as well as those who routinely experience economic hardship, are disproportionately exposed to environmental hazards and risks, which can result in cumulative environmental health impacts. The HEAL Act was put in place as a first step to formally prevent potential future hazards and mitigate current inequities.

The act defines environmental justice as "the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, rules, and policies. Environmental justice includes addressing disproportionate environmental and health impacts in all laws, rules, and policies with environmental impacts by prioritizing vulnerable populations and overburdened communities, the equitable distribution of resources and benefits, and eliminating harm."

Mandates from SB 5141 include developing plans for equitable community engagement, including tribal consultation, incorporating environmental justice into agency strategic plans, earmarking certain budget percentages to funding environmental justice programs, projects, and partners' work, as well as developing assessment tools to determine successes and challenges of environmental justice implementation work.

Governor Jay Inslee and members of the Environmental Justice Task Force at the signing of the HEAL Act. Photo by Washington Environmental Justice Task Force.

Washington State Forest Action Plan

The 2020 Washington State Forest Action Plan set new priority actions for the state while incorporating other strategies at the Washington State Department of Natural Resources (DNR), such as the 20-Year Forest Health Strategic Plan, the Wildland Fire Protection 10-Year Strategic Plan, and the Plan for Climate Resilience. Congress took action in 2008 to require all states to develop a Forest Action Plan. Washington first published a Forest Action Plan in 2010. The state released a revised version in 2017 prior to adopting the 2020 edition.

Not only do forest action plans set a clear vision for improving forests in each state, they also qualify states for millions of dollars in federal funding from the U.S. Forest Service's (USFS) state and private forestry programs. Numerous public agencies and private landowners benefit from these investments. In Washington, more than 215,000 small forestland owners collectively manage 6.5 million acres of land. There are 12 million acres of private land under state fire protection, and Washington has 558 rural fire departments. These partners, among others, benefit directly from the Forest Action Plan.

Within the plan, DNR and partners selected priority landscapes in western Washington to focus forest health and resilience work, and to compliment the priority planning areas identified in the 20-Year Forest Health Strategic Plan: Eastern Washington. Scientists and practitioners from DNR, University of Washington, USDA Forest Service, Washington Department of Fish and Wildlife, Natural Resources Conservation Service, and U.S. Fish and Wildlife Service worked together to identify and map relevant resource values. The map provided the foundation for DNR staff and partners to select the initial set of priority landscapes. Focusing agency investment in priority landscapes is intended to foster coordinated planning, active management and restoration, and cross-boundary collaboration.

The Washington State Department of Natural Resources publishes an annual, in-depth report highlighting efforts undertaken by DNR and its partners in line with the 23 goals and 159 priority actions established by the Forest Action Plan to guide implementation through June 30, 2025. The most recent report published in January 2022 tracks success stories and important milestones reached since the USFS and DNR formally adopted the Forest Action Plan on Oct. 26, 2020. You can find the 2020 Washington State Forest Action Plan and the most recent annual report at this link: https://www.dnr.wa.gov/ForestActionPlan

20-Year Forest Health Strategic Plan: Eastern Washington

Forest Health is defined as the condition of a forested ecosystem reflecting its ability to:

- sustain characteristic structure, function, and processes;
- be resilient to fire, insects, and other disturbance mechanisms;
- adapt to changing climate and increased drought stress;
- have capacity to provide ecosystem services to meet landowner objectives and human needs.

In 2017, the 20-Year Forest Health Strategic Plan was developed with individuals representing over 30 organizations that collectively determined a shared set of objectives to guide DNR and stakeholders work together in the fire-prone forested landscapes of eastern Washington.

Vision: Washington's forested landscapes are in an ecologically functioning and resilient condition and meet the economic and social needs of present and future generations.

Mission: Restore and manage forested landscapes at a pace and scale that reduces the risk of uncharacteristic wildfires and increases the health and resilience of forest and aquatic ecosystems in a changing climate for rural communities and the people of Washington.

Goal 1: Conduct 1.25 million acres of scientifically sound, landscape-scale, cross-boundary management and restoration treatments in priority watersheds to increase forest and watershed resilience by 2037.

Goal 2: Reduce the risk of uncharacteristic wildfire and other disturbances to help protect lives, communities, property, ecosystems, assets, and working forests.

Goal 3: Enhance economic development through implementation of forest restoration and management strategies that maintain and attract private sector investments and employment in rural communities.

Goal 4: Plan and implement coordinated, landscape-scale forest restoration and management treatments in a manner that integrates landowner objectives and responsibilities.

Goal 5: Develop and implement a forest health resilience monitoring program that establishes criteria, tools, and processes to monitor forest and watershed conditions, assess progress, and reassess strategies over time.

Tieton Priority Planning Area in Central Washington. Photo by DNR.

Environmental Justice Implementation Plan for Forest Resilience

The 2021 HEAL Act tasked the Department of Natural Resources to engage with Washingtonians who are currently or have traditionally been underrepresented in natural resource partnerships, decision spaces, and stewardship opportunities. In response, DNR's Forest Resilience Division hired a permanent environmental justice forest health planner dedicated to environmental justice.

DNR is focused on building relationships and listening to those affected by environmental inequities, in order to build a better shared understanding of the relationship between forest resilience and environmental justice. The process of defining the nexus between these two important issues and engaging voices that historically have been left out of forest health decisions will take several years. To date, the work of integrating environmental justice into our forest health and resilience strategic plans and programs of work is introspective, and has involved internal reviews, focused time and education on different prongs of equity, internal agency working groups, and improved documentation of gaps, blind spots, and needs.

Initial goals and objectives to integrate environmental justice and forest resilience include:

- increasing the number and quality of partnerships with people and communities of color;
- increase accessibility of programs and services that are culturally and linguistically applicable to communities and individuals who communicate in top tier languages other than English;
- host regular trainings for all DNR employees on environmental justice; and
- environmental justice reviews and updates to division policies, directives, and programs.

To better understand what environmental justice means in relation to forest management, forest planning, and stewardship - DNR organized and hosted the Environmental Justice Speakers Series, *What Makes a Just Forest?* The speaker series focused on identifying actions that lead to more equitable forests in Washington. It featured presentations from experts in the fields of environmental justice history and philosophy, Latino forest workers' rights, Indigenous land stewardship, First foods and medicines, and forest resilience ties to equity. It provided a baseline of potential focus areas of initial environmental justice work, and increased the working knowledge of DNR staff on a host of important topics.

Environmental Justice and Forest Resilience Work Group

In February 2022, DNR worked with the Forest Health Advisory Committee (FHAC) to establish an Environmental Justice and Forest Resilience Work Group to identify opportunities for DNR to implement the 20-Year Forest Health Strategic Plan and State Forest Action Plan with respect to environmental justice considerations. The work group also made recommendations on tools and processes to identify highly impacted communities and prioritize investments from the Wildfire Response, Forest Restoration, and Community Resilience Account.

The work group included committee-appointed members, along with partners representing the interests of tribes, rural communities, and Latino residents. The group spent four months reviewing current datasets, past research, and existing tools related to environmental justice, to see which existing products could be useful for prioritizing funding. Through this work, the group found that equity-focused toolkits do not exist specifically for forest health and resilience. This is due to several factors, including:

- **Most environmental justice work has focused on urban environments**. As most of DNR's work concerns areas in and around forestland, many "equity" datasets are not as fully applicable as they are for other agencies or organizations. DNR Urban and Community Forestry has used many of the available datasets, including the Washington Health Disparities Map, to conduct more equitable outreach and provide technical assistance to cities and municipalities.

- **Many geospatial datasets are inequitably dispersed.** Data collection often includes similar issues around injustices such as program inclusion, outreach, and partnership. As such, data is often sparse in underserved areas and within communities that have been historically underrepresented in decision-making processes. This makes these datasets largely ineffective for use as a tool in visualizing high-priority areas, at least from a geospatial perspective.

- **Data is often collected at different scales, making it difficult to compare and use datasets together.** When some of these datasets are summarized to a common scale, it can lose its efficacy or appropriateness. For example, language maps at a county scale can make it difficult to determine where translation materials are needed, and in what languages.

Under certain circumstances, geospatial datasets may help DNR focus initial outreach efforts. However, use of data needs to be complemented with engagement. The recommendations from the Environmental Justice and Forest Resilience Work Group suggest that the most impactful approach is to solicit direct input from the communities that have been highly impacted from current and past forest health decisions. DNR will continue to directly engage with affected communities to define the connections between environmental justice and forest resilience, and to gather input on how to be inclusive of diverse community partners.

Summit Trail Fire on the Colville Reservation. Image was taken in July 2022. Photo by DNR.

Overview of Report Content

This report includes eight chapters. The content of the report is organized to give the reader an ability to review the document from cover-to-cover or to read individual chapters and sections of the report. While each chapter does build on the previous one, those who choose to review individual chapters will find that the content stands on its own, and is clear and accessible regardless of the order the content is read.

The chapter that follows this introduction is focused on the 20-Year Forest Health Strategic Plan priority planning areas. It provides an overview of the geographic focal areas where the DNR is partnering with landowners to accelerate the implementation of forest health treatments across ownership boundaries and at scale. The third chapter describes the Forest Health Assessment and Treatment Framework, as required by RCW 76.06.200. The framework includes the methodological approach and data used to quantify restoration needs and treatment objectives in priority planning areas. The fourth chapter applies the framework and summarizes the treatment need results for 37 priority planning areas in eastern Washington.

The fifth chapter describes a methodological approach to assess aquatic restoration needs. The methodology adopted for this report was contributed by leading fisheries biologists and scientists at Yakama Nation Fisheries. The chapter also highlights recent aquatic restoration case studies and success stories that enhance watershed conditions and forest resilience in priority planning areas.

Partnerships are critical to the successful implementation of the Forest Health Assessment and Treatment Framework and 20-Year Forest Health Strategic Plan. Wildfire, drought, and insects and disease don’t respect land ownership boundaries. Chapter six provides numerous examples of how DNR is working with tribal, federal, state, and private landowners and partners to accelerate the planning and implementation of forest health and wildfire risk reduction activities. The majority of the content written in this chapter was authored by our partners, a testament to the commitment of our partners to the forest health strategy and what we have collectively achieved over the last five years.

The seventh chapter is focused on monitoring. The 20-Year Forest Health Strategic Plan monitoring framework identifies three levels of monitoring: regional, planning area, and stand-level. At each of these levels, scientists and managers are evaluating treatment outcomes, critical data that will inform adaptive management. Significant advances in monitoring capabilities, utilizing technologies such as satellite imagery and drones, are accelerating our ability to measure change and will undoubtedly increase the efficacy of our forest health investments over time.

The document ends with a description of the 2023-2025 forest health budget appropriations request. This chapter will provide the reader with information about how DNR and our partners can sustain and grow this important work in the next biennium.

The reference section and appendices are intended to provide readers with a detailed description of the scientific basis for the forest health activities led by DNR, as well as the landscape evaluation summaries for our 2022 priority planning areas.

Prescribed fire near Roslyn, Washington. Photo by DNR.

20-Year Forest Health Strategic Plan: Priority Planning Areas

Forest health and wildfire risks in eastern Washington are so widespread that it is logistically impossible to address them all at once. A prioritization process remains essential to focus state and partner resources in high-priority landscapes, and to successfully implement the treatment framework. Authority and direction contained in the framework directs DNR's efforts to improve forest health across all ownerships in large landscapes.

Every two years since the plan's adoption, DNR and partners have identified priority planning areas to focus investments towards accelerated planning and implementation. While DNR programs may invest outside of priority planning areas, they help to focus and leverage forest health resource allocation towards a common objective. The first step of the framework is to select which watershed(s) will form the priority planning areas to analyze forest health treatment needs across all lands.

Priority Planning Area Definition

A priority planning area is one or more HUC 6 watersheds that contain high priority state and/or local forest health needs. DNR identifies priority planning areas through a data driven prioritization process at the HUC 6 watershed scale, followed by stakeholder feedback and engagement. Once a priority planning area is selected, DNR commits to conduct the forest health assessment across all land ownerships in that landscape as well as partner to implement and monitor forest health treatments and forest conditions over time. Priority planning areas are also sometimes referred to as priority landscapes.

2018, 2020, and 2022 Priority Planning Areas

In March of 2018, DNR finished identifying the first set of priority planning areas to evaluate for forest health treatment needs under the treatment framework in the 2018 and 2020 planning cycles (Figure 1).

To guide this process, DNR first completed a data-driven prioritization of watersheds. Watersheds were scored based on a variety of forest health, wildfire risk, and value-based variables. The process to prioritize watersheds used two groups of metrics, or tiers:

- Tier 1 included metrics that represent forest health and wildfire risks: fire risk (fire probability and fire intensity), insect and disease risk, forest restoration opportunity, and projected increase in drought stress (climate change effects).

- Tier 2 included metrics that represent values at risk: aquatic resources (cold-water stream miles in 2040, habitat conditions, and stream miles with threatened or endangered fish), wildlife habitat, wildland-urban interface proximity, clean drinking water, and timber.

Scores for each metric were derived from one or more datasets representing the best available, current science. A detailed description of the methodology and results of the watershed prioritization process are available in Appendix 1, pages 42-52, of the 20-Year Forest Health Strategic Plan and Appendix A of the 2018 Forest Health Assessment and Treatment Framework Report.

Robust stakeholder feedback and engagement built off the watershed prioritization process to identify state and local high-priority forest health needs and opportunities. The watershed prioritization informed boundaries of priority planning areas, but community and resource managers in each landscape ultimately determined final lines on the map. Ongoing collaboration and planning may adjust the priority planning areas boundaries over time, as needed.

RCW 76.06.200 requires DNR to assess a minimum of 200,000 acres of fire-prone lands each biennium to identify forest health treatment needs. DNR recognized that providing these assessments — high-level, scientifically grounded blueprints that identify the need and scale of active management — would be key to catalyzing action in each priority planning area. Through 2022, 39 priority planning areas were selected to focus all-lands forest health analysis, treatment, monitoring, and coordination efforts. The 39 priority planning areas comprised 4,434,008 acres, greatly exceeding the minimum required by the legislature. DNR chose to assess more than the minimum acreage required by the legislature early on to reflect the urgency for strategic proactive action guided by science, catalyzing change by providing communities and landowners in these priority landscapes appropriate tools and resources to address the crisis.

New Priority Planning Areas in 2024

Applying previous watershed prioritization work, ongoing collaboration, and focused stakeholder outreach, DNR has identified eight new priority planning areas to be assessed by December 2024. The new priority planning areas identify forests where active management and investments can improve forest health conditions based on scientific analysis and where partnerships and projects already exist to maximize strategic use of resources.

The Confederated Tribes of the Colville Reservation and DNR created a joint priority planning area for the 2024 planning cycle to achieve shared forest health goals. The priority planning area is called Inchelium and contains several HUC 6 watersheds on the Colville Reservation around the community of Inchelium. Inchelium is the first joint planning area between DNR and a tribal sovereign nation.

Wildfires in two 2022 priority planning areas resulted in the assessments being temporarily postponed. Assessment for the Chewuch planning area was moved to the 2024 cycle to account for post-fire conditions following the 2021 Cub Creek fire, and the Asotin planning area was moved to the 2024 cycle as well to account for postfire conditions following the Lick Creek fire. In total there will be 10 additional priority planning areas analyzed for forest health treatment needs by December 2024.

To date, DNR has selected 47 priority planning areas representing more than 5.2 million acres to focus forest health assessments and investments. The priority planning areas provide a powerful footprint across eastern Washington to continue implementing the forest health plan with partners.

Teanaway Priority Planning Area. Image was taken in spring 2022 from Cle Elum Ridge looking north towards Mount Stuart. Jolly Mountain Fire (2017) burn scar is visible in the middle ground of the photo. Photo by DNR.

Figure 1. Priority planning areas for 20-Year Forest Health Strategic Plan (RCW 76.06.200)

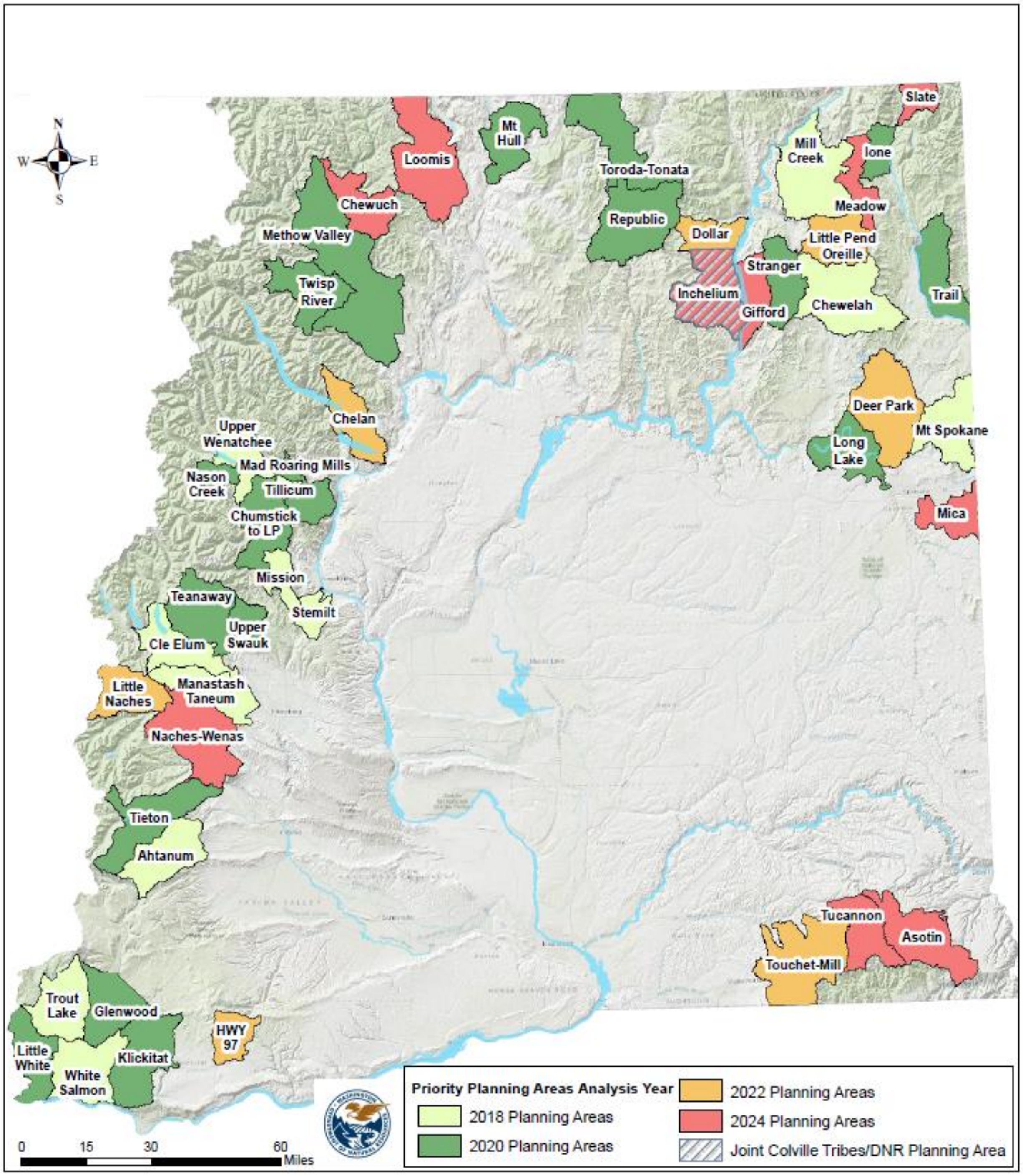


Table 1. Initial assessment year, acreage totals and forested acres by land ownership* class for all 47 priority planning areas of the 20-Year Forest Health Strategic Plan

Planning Area	Year	Total Acres	Forested Acres	Total Forested Acres by Ownership Class					
				Federal	State	Private	Municipal or NGO	Tribal	Other
Ahtanum	2018	120,477	89,217	722	54,671	8,090	2,783	22,905	46
Asotin	2024	149,152	93,329	61,444	7,327	24,547	10	0	0
Chelan	2022	98,051	31,342	26,390	409	4,326	0	0	218
Chewelah	2018	195,408	158,352	83,667	7,068	67,026	387	145	58
Chewuch	2024	94,250	83,846	83,286	525	36	0	0	0
Chumstick to LP	2020	115,333	84,216	50,092	4,716	29,278	13	0	116
Cle Elum	2018	109,396	80,300	20,608	6,298	39,307	13,243	0	844
Deer Park	2022	181,171	90,497	0	5,014	82,795	2,436	0	252
Dollar	2022	61,238	50,767	45,873	442	4,326	0	117	10
Gifford	2024	71,962	39,016	1,336	4,182	33,457	0	10	31
Glenwood	2020	104,501	83,758	2,439	35,401	38,064	118	7,736	0
Highway 97	2022	60,398	37,415	12	116	35,760	1,104	423	0
Inchelium	2024	146,263	121,779	742	0	20,441	0	100,566	30
Ione	2020	44,248	41,784	28,407	3,729	9,424	0	0	224
Klickitat	2020	149,649	103,274	2,205	19,962	78,128	1,403	1,576	0
Little Naches	2022	95,433	92,914	87,238	0	21	5,653	0	2
Little Pend Oreille	2022	92,994	81,148	38,921	14,720	27,408	0	0	98
Little White	2020	95,750	84,705	65,764	3,955	14,632	330	0	23
Long Lake	2020	103,291	41,253	275	7,602	32,365	648	7	356
Loomis	2024	198,991	149,802	19,556	115,491	14,470	0	0	284
Mad Roaring Mills	2020	65,008	33,325	24,340	3,129	5,796	0	0	59
Manastash Taneum	2018	104,072	65,833	25,272	31,312	2,019	7,228	0	1
Meadow	2024	60,235	59,050	42,391	11,260	5,272	0	0	128
Methow Valley	2020	338,246	182,937	147,457	16,699	18,722	3	0	58
Mica	2024	72,608	39,178	0	1,222	31,845	5,974	0	136
Mill Creek	2018	186,306	162,060	50,337	18,477	93,112	0	0	133
Mission	2018	49,121	32,743	21,353	859	10,356	125	0	50
Mt Hull	2020	105,431	34,809	18,248	1,347	14,757	4	201	252
Mt Spokane	2018	121,767	95,814	0	19,463	75,873	353	0	124
Naches-Wenas	2024	180,858	121,981	57,716	35,987	8,913	341	0	266
Nason Creek	2020	31,679	29,243	17,640	491	10,976	0	0	136
Republic	2020	180,553	144,350	92,220	6,394	34,975	17	10,631	112
Slate	2024	35,948	34,905	32,598	0	2,146	113	0	49
Stemilt	2018	38,961	22,613	2,463	9,648	7,665	2,828	0	9
Stranger	2020	89,904	72,061	547	17,798	53,696	0	0	19
Teanaway	2020	132,120	111,696	56,024	46,130	6,749	2,738	0	55
Tieton	2020	148,634	117,781	100,139	12,618	4,449	446	106	23
Tillicum	2018	14,326	11,241	9,190	145	1,906	0	0	0
Toroda-Tonata	2020	153,611	117,345	82,816	8,361	26,068	0	45	55
Touchet-Mill	2022	203,750	110,794	39,354	1,486	59,987	1,298	8,669	0
Trail	2020	105,242	94,948	40,033	8,400	41,596	1,140	3,728	51
Trout Lake	2018	117,153	105,015	65,443	18,290	21,278	0	4	0
Tucannon	2024	98,616	80,099	63,108	6,122	10,869	0	0	0
Twisp River	2020	111,918	82,349	78,623	826	2,697	0	0	204
Upper Swauk	2020	39,175	35,450	34,524	31	747	0	0	147
Upper Wenatchee	2018	74,777	66,277	56,254	862	8,900	0	0	261
White Salmon	2018	126,688	104,022	6,260	27,174	69,822	181	164	421

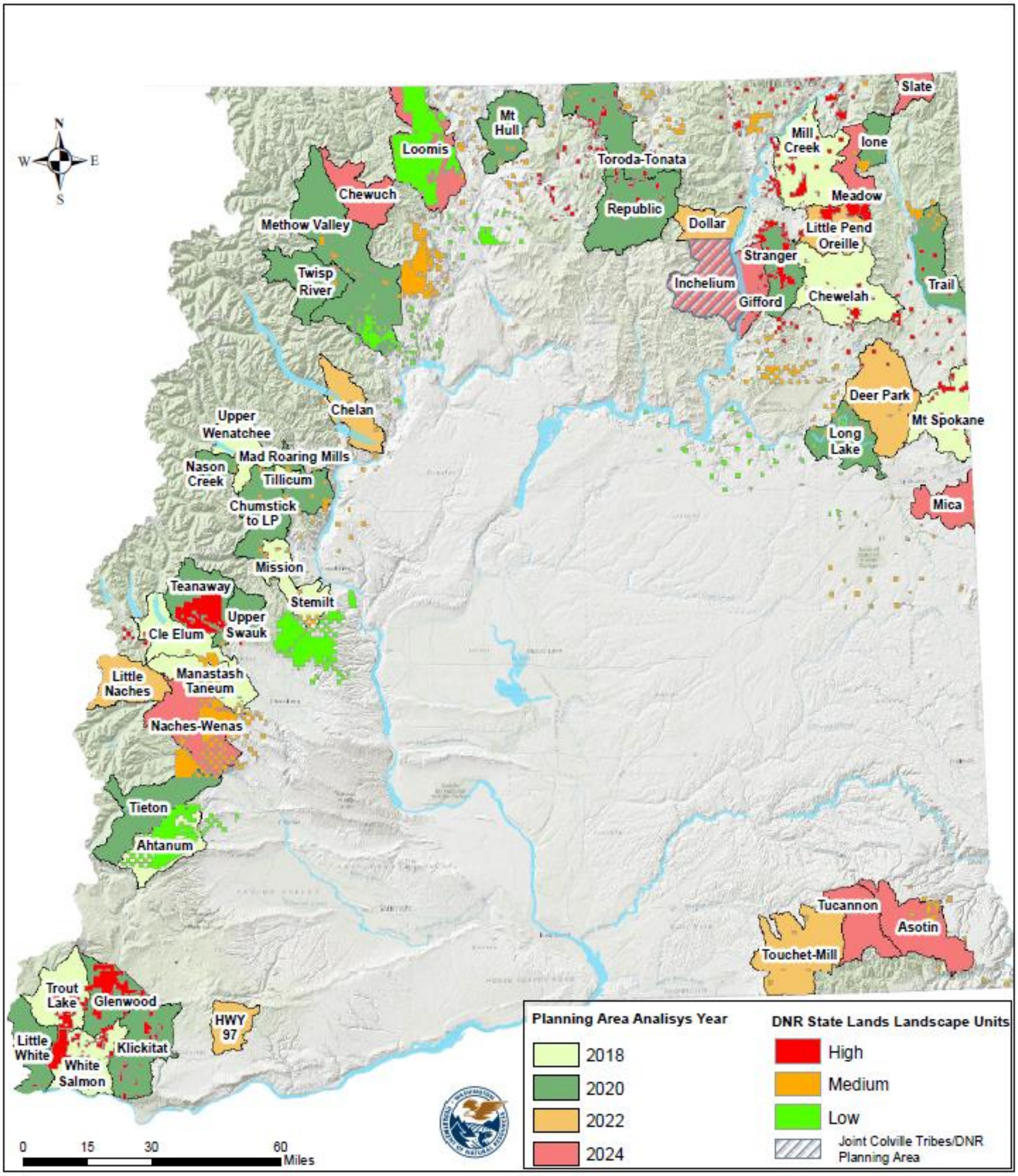
*Private land includes both industrial and non-industrial private lands. Report generated based on October 2020 priority planning areas, forested raster layer form May 2020 and ownership layer from July 2020. NGO is a nongovernmental organization.

Overlap of 20-Year Forest Health Strategic Plan priority planning areas with Engrossed Second Substitute House Bill 1711 DNR State Trust Lands Priority Landscapes

The all-lands process that led to the identification of priority planning areas for implementation of RCW 76.06.200 is different from DNR state trust lands' prioritization process to implement E2SHB 1711. Under Engrossed Second Substitute House Bill (E2SHB) 1711, DNR's obligation is to prioritize state trust lands for forest health treatment according to its values and goals related to timber production, wildlife habitat, and wildfire risk, among other values. E2SHB 1711 prioritization identifies high, medium, and low priority landscapes for forest health treatment to inform treatment needs for the next two, six and 20 years. Many of the state trust lands priority treatments occur in the forest health plan's priority planning areas, ensuring that DNR's work to fulfill legislative direction is done in concert for landscape-level change (Figure 2). For details on the prioritization process and treatments on DNR state trust lands, see the E2SHB 1711 legislative report.

DNR State Trust Lands Virginia Ridge forest health treatment project in 2019 in the Methow Valley Priority Planning Area. Photo by John Marshall Photography.

Figure 2. Map showing priority planning areas of the 20-Year Forest Health Strategic Plan and DNR state trust lands priority landscapes.



Forest Health Assessment and Treatment Framework Methodology

Following the identification of priority planning areas, DNR assessed the current condition of each landscape and its level of resilience to future disturbances and climatic change using a terrestrial landscape evaluation (hereafter referred to as a landscape evaluation). The landscape evaluation serves as the assessment component of the Forest Health Assessment and Treatment Framework outlined in RCW 76.06.200.

A landscape evaluation is a data-driven approach to understanding the current condition of a landscape, its level of resilience to disturbances and climate change, and its ability to provide an array of ecosystem services over time (Hessburg et al. 2015). Ecosystem services are commonly defined as the benefits people obtain from ecosystems, including cultural values, regulation of climate, and provision of food, freshwater, fuel, fiber, and other goods. A landscape evaluation includes detailed information about vegetation departure from historic conditions, fire risk, projected climate change effects and associated drought stress, wildlife habitat, and other resources. Evaluations are first conducted without consideration of land ownership or road access in order to fully assess landscape condition and forest health treatment needs. Management objectives of different public and private landowners, as well as road access, are later incorporated into the evaluation process.

DNR defines resilience as the ability of a landscape to sustain desired ecological functions, associated human needs, and critical landscape processes over time and under changing conditions. In terms of wildfire, a resilient landscape is able to adapt to a warming, drying climate and increases in wildfire by shifting to tree species that are more tolerant of drought and wildfire, as well as incorporating fuel structures and landscape patterns that are aligned with future climate and fire regimes. A resilient landscape is resistant to large-scale, high-severity fires, and drought-induced tree mortality that can lead to rapid, destabilizing shifts in conditions that make adaptation much more challenging.

The primary outputs of landscape evaluations are an estimate of overall treatment need and spatial prioritization of treatment locations. Evaluations include assessments of fire risk to forest ecosystems, current and future drought vulnerability due to climate change, forest structure types that are overabundant relative to desired reference conditions, and wildlife habitat needs. Landscape patterns are also analyzed to assess whether vegetation is overly fragmented or aggregated in ways which affects habitat suitability, and fire and insect behavior. This information and data are synthesized to quantify the shifts in vegetation conditions and patterns that are needed to create a landscape that is resilient to wildfire, drought, and drought-related insect outbreaks, while also sustaining closed-canopy forests (Hessburg et al. 2015). Overall treatment needs are estimated in the landscape prescription and then broken down by specific forest types (e.g., cold, moist, or dry), structure (tree size and density), and species composition in some cases.

Locations within the target landscape are then prioritized for treatment based on the same data sources. Wildfire transmission to homes is added to highlight locations where fire starts pose the highest risk to homes. The goal of the landscape treatment prioritization is to identify where treatments will accomplish the greatest amount of fire risk reduction and climate adaptation work, while also reducing fire risk to communities. In addition, locations best suited to sustain large tree, closed canopy forests over time are identified in a companion layer to help managers meet wildlife habitat, timber production, and carbon storage objectives.

In addition to terrestrial conditions, an aquatic evaluation may be conducted to summarize conditions of watershed function, including the stream network and associated fish habitat, riparian vegetation, and sediment flows. Restoration opportunities to reduce road-related effects, reconnect floodplains, or enhance in-stream habitat are identified and prioritized. DNR does not have the expertise or resources to conduct aquatic evaluations in all priority planning areas. The next section of this report provides an overview of aquatic evaluation methods and example of how DNR is leveraging partnerships to accomplish this important work.

The landscape evaluation process is utilized by DNR to assess and prioritize forest health treatment needs in priority planning areas as required by RCW 76.06.200. This process provides a common scientific basis, set of data products, and a language for landowners to understand current conditions, risks to different resources, and future trends. It further encourages cross-boundary coordination and builds consensus around treatment targets. Evaluations provide a benchmark for tracking progress towards desired forest health conditions.

It is important to note that landscape evaluations are living documents – wildfires and other major natural disturbances will occur in priority planning areas at all stages of the planning and implementation process. Wildfires have affected several priority planning areas since the passage of RCW 76.06.200. It is expected that wildfires will burn more acres than can be treated over the life of the forest health strategic plan, and will thus shift vegetation conditions over hundreds of thousands of acres in both positive and negative directions. Given the dynamic nature of landscapes and the timeframe of the 20-Year Forest Health Strategic Plan, updates to landscape evaluations will occur as treatments and natural disturbances change conditions on the ground, as input datasets for current conditions are improved, and as methodologies are refined based on new science and monitoring results.

Methodology

The methods used to conduct landscape evaluations and prescriptions are based on the best available science regarding landscape restoration (Hessburg et al. 2015, Spies et al. 2018), quantitative wildfire risk assessment (Scott et al. 2013), analysis of cross-boundary wildfire transmission (Ager et al. 2019a) and climate change adaptation strategies (Halofsky et al. 2016, Littell et al. 2016). The approach utilizes the framework for landscape evaluations developed for the Okanogan-Wenatchee National Forest (OWNF) Restoration Strategy (Hessburg et al. 2013). In addition, input from local land managers and stakeholders is incorporated at various stages of the process for specific planning areas. A summary of the core components is provided below.

1. **Identify ownership types and management objectives:** Spatial distribution of different ownership types and corresponding management objectives provides important context for the types of treatments and long-term forest structures possible in different parts of a priority planning area. DNR updated its ownership layer for eastern Washington based on 2019 county parcel Geographic Information System (GIS) layers, DNR State Uplands ownership information, Forest Service ownership layers, and other sources.

2. **Map vegetation and forest types:** A consistent vegetation-type layer was built foreastern Washington. First, an improved forest mask was built from a combination of LANDFIRE, NLCD (National Land Cover Dataset), and Nature Serve. Forest type (potential vegetation type) was derived for forested areas from the potential vegetation type layer of the 2012 Integrated Landscape Assessment Project (ILAP) (Hemstrom et al. 2014). Improvements to ILAP done by Jan Henderson of the Forest Service from 2012 to 2014 for much of northeast Washington and the eastern Cascades were also included. For non-forest areas, LANDFIRE existing vegetation type data was used. Vegetation types were grouped into cold, moist, and dry forests. Dry forests are ponderosa pine and Douglas-fir dominated landscapes that historically had low severity fires every five to 25 years. Moist forests historically had mixed severity fires. They include sites in draws, north facing aspects, and valley bottoms that had fire return intervals of 80-200 years or more, and that were typically dominated by fire intolerant conifers, such as grand fir or western red cedar. They also include sites that historically had more frequent fire (about every 30-100 years) and were typically dominated by Douglas-fir, western larch, and ponderosa pine. Cold forests are mid-to-upper-elevation forests that historically had high-severity fires every 80-200 years or more and were dominated by subalpine fir, Engelmann spruce, lodgepole pine, as well as other conifers.

For the planning areas in southeastern Washington, vegetation group was derived instead from a combination of FSVeg Potential Vegetation Groups and the USFS Region 6 Potential Natural Vegetation (PNV) subzone layer. A crosswalk between PNV subzones, FSVeg Potential Vegetation Groups, and the DNR Potential Vegetation Group classes for USFS lands in the Blue Mountains was created by DNR scientists in 2021 in collaboration with USFS Region 6 ecologists. The PNV vegetation data was used in place of ILAP and LANDFIRE data when creating the vegetation group layer outside of USFS lands to better align with existing high quality data layers that the USFS uses in these planning areas.

3. **Map current forest structure and species composition:** Current condition information for forest structure and composition was obtained in two ways based on the systems used in the national forest in that area. For priority planning areas in northeast and southeast Washington, as well as south and east of Mount Adams, 2015-2019 Light Detection and Ranging (LiDAR) or 2017 Digital Aerial Photogrammetry (DAP) data were used. The DAP process produces forest structure data from National Agriculture Imagery Program (NAIP) aerial imagery similar to those produced with LiDAR, and the methods used to analyze these data are identical. Gradient nearest neighbor (GNN) data was used to fill in small portions of planning areas where LiDAR or DAP does not exist. Eight structure classes were defined based on canopy cover classes (open: less than 40 percent cover; moderate: 40 to 60 percent cover; closed: more than 60 percent cover) and three tree size classes (large: overstory diameter (OD) greater than 20 inches; medium: OD of 10 to 20 inches; small: OD under 10 inches). For reporting, the eight classes were condensed. Data for planning areas along the eastern Cascades was obtained through photo-interpretation of digitized, stereo imagery using the OWNF Restoration Strategy (USFS 2012) approach. To ensure consistency in evaluation summaries, results for seven structure classes used in this photo interpretation (PI) system were condensed into the same classes used in the LiDAR based approach.

4. **Assess departure from reference conditions:** Current forest conditions are compared with historical and future reference conditions to assess how healthy, or out of whack, the priority planning area is. This does not mean that these reference conditions are the end goal. Instead, they provide a baseline for conditions DNR scientists think are resistant and resilient to large scale, high-severity disturbances while providing a range of other ecosystem services such as clean water, recreation, and wildlife habitat (Franklin and Johnson 2012, Hessburg et al. 2013). The primary outputs of a departure assessment are the number of acres of different structure and vegetation type classes that are too high, too low, or within range relative to the reference condition range. Departure of

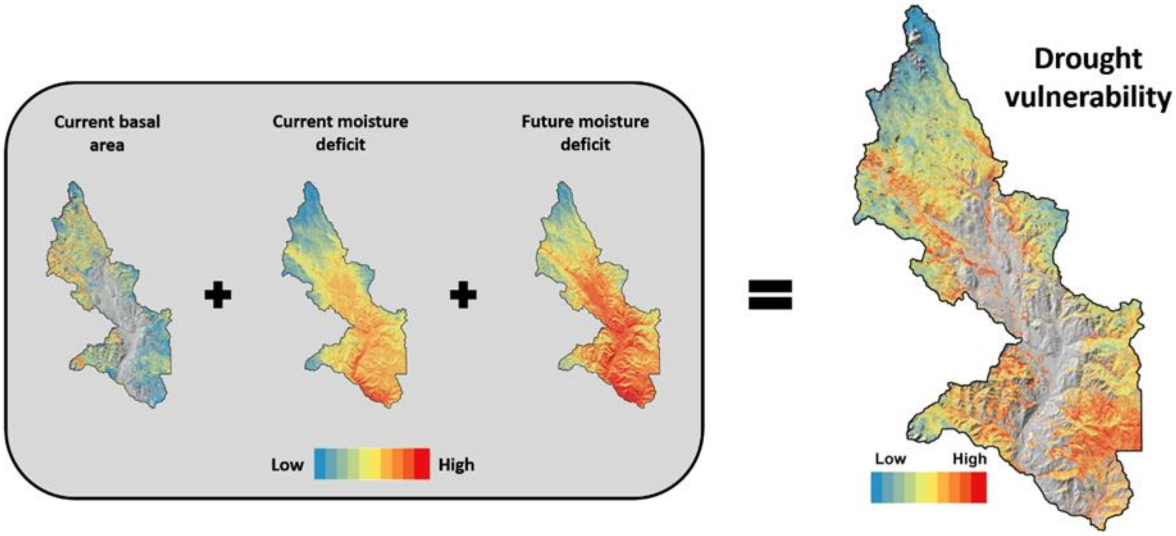
species composition (cover type) and pattern are also assessed and added where they do not overlap with forest structure departures. A map of departed structure classes was then created to identify where treatments should be focused to address departures. Similar to forest structure, two different methodologies were used. For planning areas with LiDAR current condition data, reference conditions were derived from state and transition models (STM) that were developed for the ILAP project and the Colville National Forest plan revision and updated by DNR scientists. For areas with PI current condition data, historical and future reference conditions from early to mid-20th century aerial photographs were used (USFS 2012).

5. **Assess wildfire risk:** Data products from the 2017 Pacific Northwest Quantitative Wildfire Risk Assessment (Gilbertson-Day et al. 2018) were used to quantify fire risk across each planning area. DNR staff calculated fire risk (expected net value change) by combining annual fire or burn probability, expected fire intensity as measured by flame length, and the response of different resources to flame length (Scott et al. 2013). Risk to homes, infrastructure, and forest (overstory tree mortality) was calculated and then combined. Risk levels were placed in six categories based on relative values across all planning areas: extreme, very high, high, moderate, low, and beneficial. Maps of conditional net value change – the risk of loss or benefit without fire probability factored in – were generated to examine expected loss or gain irrespective of fire probability in each planning area. Burn probability and intensity were derived from large-fire simulator FSim models that used patterns of fire weather, ignitions, and large fire spread from 1992-2015. This risk assessment did not directly include fire effects on wildlife habitat, watershed function, or other resources. Fire risk in non-forested shrub-steppe areas was only calculated for homes and infrastructure.

6. **Analyze drought vulnerability:** This analysis assessed vulnerability to current and potential moisture stress, and is the primary way climate change adaptation strategies were incorporated. Moisture stress, as measured by climatic water deficit (deficit), is a good predictor of vegetation type in moisture-limited ecosystems and is a primary driver of large insect outbreaks (Kolb et al. 2016). Deficit was calculated pixel resolution of 90 meters for the 1981-2010 and 2041-2070 time periods. Deficit levels were placed into four deficit zones – low, moderate, high, and extreme – that were then associated with vegetation groups for each planning area based on plot data and field verification. Maps of current and future predicted zones were generated for each planning area to assess the magnitude of the predicted effects of climate change (Figure 3). General areas within each planning area were identified where forest is unlikely to be supported in the future, where moist and cold vegetation types are likely to transition to dry vegetation types,

and where moist and cold vegetation types are likely to be sustained in the future. Finally, a drought vulnerability index was generated using current and future deficit along with forest density from either basal area (modeled from LiDAR) or canopy cover. There is considerable uncertainty in climate models regarding timing and mechanisms (e.g., fire, drought, regeneration failures) that will drive vegetation transitions. Predicted future vegetation maps should not be used as fine scale maps of predicted future vegetation.

Figure 3. Individual inputs to the drought vulnerability metric. The gray box shows individual metrics that constitute the drought vulnerability metric (right).



7. **Map habitat for focal wildlife species:** Focal wildlife species were identified for each priority planning area through a process that involved wildlife biologists from multiple agencies and tribes. Specific habitat requirements and the locations of that habitat for each species were mapped across all planning areas based on current conditions data and habitat classifications. The sustainability of this habitat was then analyzed based on fire risk and drought vulnerability to highlight locations across each planning area where treatments may be needed to build or maintain open canopy structure (e.g., higher fire and drought risk), as well as closed canopy, large tree structure (e.g. lower fire and drought risk locations). This information is intended to help managers identify key areas to protect, as well as where treatments can provide necessary habitat features to sustain focal species and address vegetation pattern needs, such as reducing fragmentation by building larger areas of contiguous habitat.

8. **Evaluate aquatic function:** These evaluations are conducted to better understand aquatic and riparian forest functions in the planning area and to determine restoration needs and priorities. They can include assessments of fish habitat, road impacts (e.g., the Geomorphic Road Analysis and Inventory Package, or GRAIP), water yield, or fire risk to drinking water areas. DNR currently does not have the capacity to conduct these evaluations and relies on partners to conduct them. The next section of this report, Aquatic Evaluation Methods and Watershed Restoration, includes more information on this topic.

9. **Estimate treatment targets:** Treatment needs for a priority planning area are first generated from the departure analysis. Dense structure-vegetation group classes (e.g., dry forest-large dense, moist forest-medium dense) that are higher than the reference range are selected. These are the classes where departure can be shifted through active management, as opposed to a passive approach. For these departed, dense classes, the number of acres needed to shift the class to the upper range of the reference range was calculated. This is the low end of the treatment range. The high end of the treatment range is the number of acres needed to shift the class to the midpoint of the reference range. In cases where small-dense classes are not currently departed but will soon be due to growth, treatment acres for small-dense classes were added. Targets for maintenance treatments in existing open, large, and medium tree size classes on dry and moist forest sites were added. Maintenance treatment targets were based on the estimated need to treat 50 to 75 percent of existing open canopy dry forest and 25 to 50 percent of open canopy moist forest over the next 10 to 15 years.

   Targets for each class were rounded to the nearest 250-500 acres and then added together to get the range of total treatment needed. Targets were adjusted for some planning areas based on a number of local site factors. The calculated treatment needs were then compared with a fire severity departure analysis that compares predicted fire severity across the priority planning area with desired ranges for low, moderate, and high severity in dry, moist, and cold forests. This served as an independent method of assessing treatment needs. Treatment needs were broken out by anticipated treatment type based on tree size class. As discussed in the results section, individual landowners will determine actual treatment types based on many factors.

10. **Evaluate operational feasibility and economics:** This analysis evaluates logging system type and projected revenues for potential treatment locations. Slope, road system, overstory tree size, and volume layers were fed into a tool that produced a map of operational units. Logging system type (ground, cable, helicopter) and potential revenue

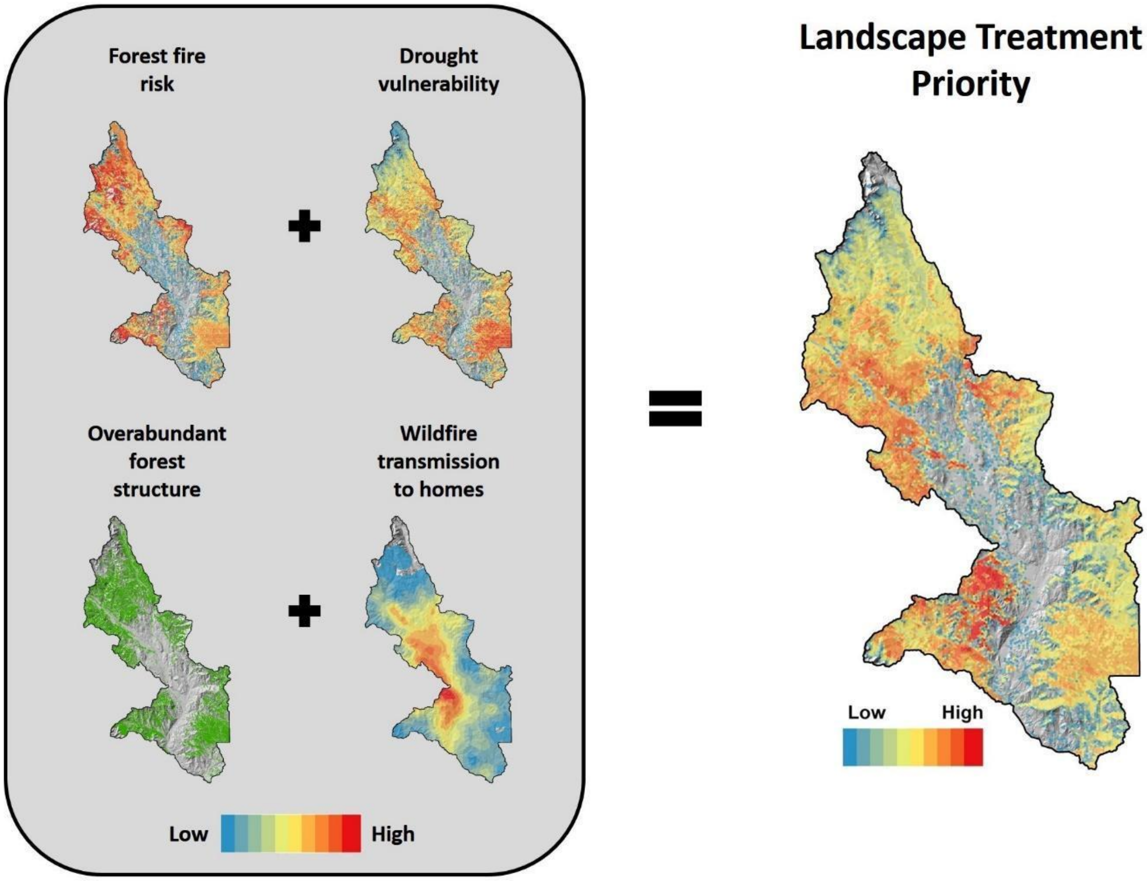
were generated based on parameters for maximum slope for ground-based yarding, maximum and average yarding distances, log prices and haul costs, among others. This information was intended as a general assessment showing which parts of a priority planning area are accessible for mechanical treatments or need fire-based treatments, as well as which areas are likely to generate revenue, be revenue neutral, or require investments. Managers can use this information for delineating operational units and to prioritize locations for field based operational assessments. This tool was recently upgraded and refined based on feedback from managers (see Logging Systems and Economic Analysis).

11. **Map dense forest, large tree sustainability:** While dense or closed canopy forests are overabundant in most of eastern Washington, they are still part of a resilient landscape. They provide important ecosystem services such as wildlife habitat, wood production, carbon storage, biodiversity, and hydrological functions, especially when they contain large trees. To help managers determine where to retain and manage for dense forests, locations were identified where this forest structure type is most likely to persist through future fires and climate warming. First, areas were mapped based on current condition data with closed canopies and large tree structures (quadratic mean diameter (QMD) greater than 15 inches and canopy cover greater than 50 percent), as well as potential areas that can develop this stand structure quickly (QMD greater than 12 inches diameter at breast height (DBH) and canopy cover less than 40 percent). Current and potential large-tree closed canopy areas were then scored with a sustainability index based on current and future moisture deficit and fire risk.

12. **Prioritize landscape treatments:** Locations within each priority planning area are prioritized for treatment based on three measures of forest health that are each described above and one measure of community wildfire risk that are given the same approximate weight (Figure 4). These include fire risk to forest ecosystems (methodology item 5), current and future drought vulnerability due to climate change (methodology item 6), and forest structure types that are overabundant relative to desired reference conditions (methodology item 4). Wildfire transmission to homes is then added to highlight locations where fire starts pose the highest risk to homes (Ager et al. 2019a). The goal of the landscape treatment prioritization is to identify where treatments will accomplish the greatest amount of fire risk reduction and climate adaptation work, while also reducing fire risk to communities. To ensure habitat for wildlife dependent on large-tree, closed canopy forest is incorporated into treatment planning, DNR recommends overlaying the large dense forest sustainability layer over the landscape treatment priority layer to help inform treatment locations. Note that this landscape-level treatment

prioritization does not currently include other factors that influence whether a specific site should be treated or not, such as cultural resources, species composition, sensitive soils, operational considerations, or economic objectives.

Figure 4. Individual inputs to the landscape treatment prioritization. The gray box shows individual metrics that constitute the landscape treatment priority metric (right). Warm colors represent higher values and cold colors represent lower values except for the overabundant forest structure map for which green shows presence. Individual metrics mapped at a resolution of 18-acre polygons were normalized to a score of one to 100. The metrics in the gray box were added to obtain the landscape treatment prioritization map shown on the right.

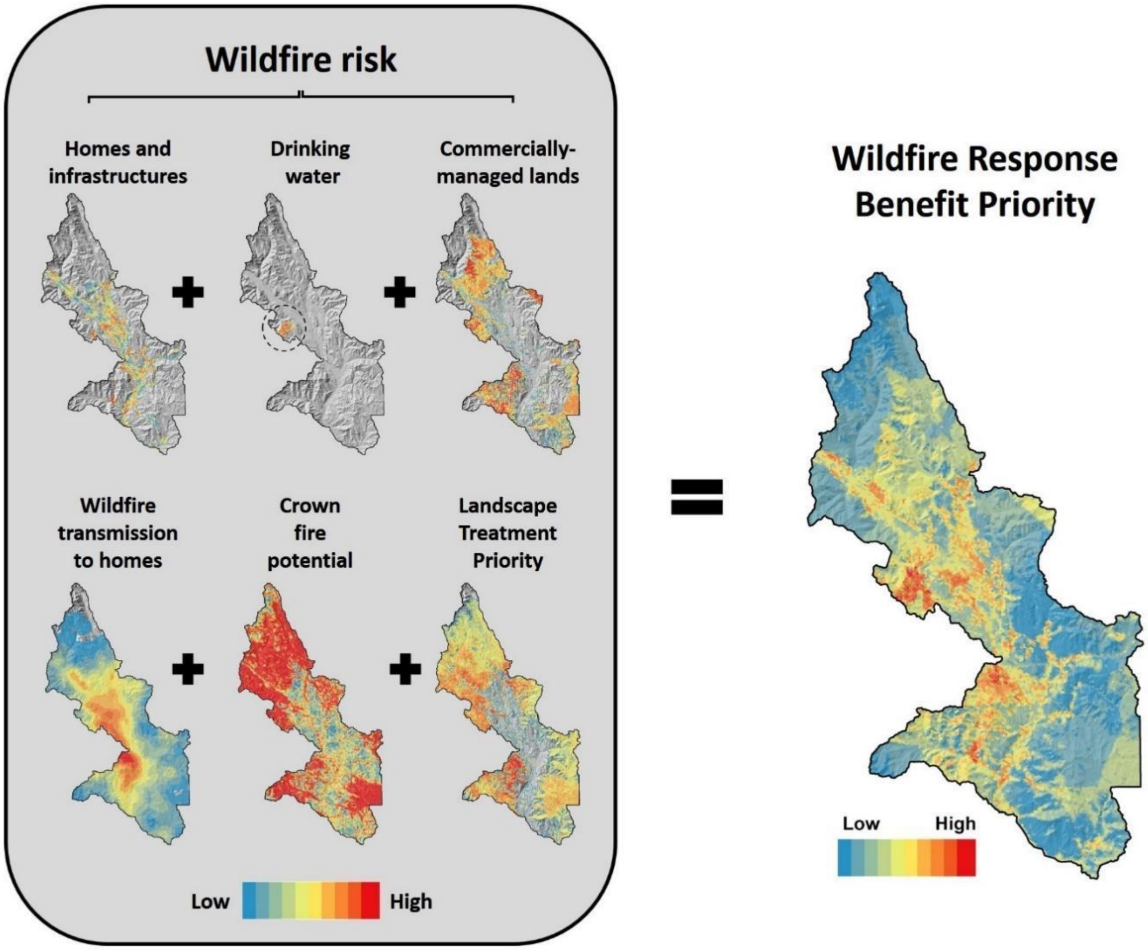


13. **Prioritize wildfire response benefit:** The wildfire response benefit metric identifies and prioritizes locations where values at risk that are more likely to be the focus of fire operations (homes and infrastructure, sources of drinking water, and commercially managed lands) coincide with areas likely to transmit wildfire to homes and generate severe fire behavior (Fig. 5). This metric also includes the landscape treatment prioritization map previously described in methodology item 12, again emphasizing the

concept of dual benefit. Specifically, the metric uses three risk layers for which risk is calculated using methods described in methodology item 5. Risk layers reflect highly valued resources: homes and infrastructures, commercially managed lands and sources of surface drinking water. Commercially managed lands were defined as a subset of forestland and include industrial, DNR trust lands, tribal land, Forest Service land where timber is a primary objective, and private non-industrial lands of more than five acres. Risk to homes was based on DNR's wildland urban interface map to identify where homes exist on the landscape. Infrastructures were mapped based on data products from the 2017 Pacific Northwest Quantitative Wildfire Risk Assessment (Gilbertson-Day et al. 2018) combined with local data where available. The location of surface sources of drinking water was based on a publicly available atlas of sources of drinking water from the Washington State Department of Health.

The wildfire response benefit metric also includes a transmission map (described above) and a crown fire potential metric modeled with FlamMap, assuming the 97th percentile fire weather for each priority planning area. All variables described above were converted to a score between 1-100 where 100 represents the maximum value for each variable in each priority planning area. High benefit areas may constitute strategic opportunities for forest health and fuel treatments. Additional work at the local level will be required to identify appropriate actions and assess treatment feasibility. In other areas of high response benefit, treatments along escape routes, resident and community fire mitigation activities (e.g., defensible space, home hardening), and improving signage and road conditions may be required.

Figure 5. Individual inputs to the wildfire response benefit priority metric. The gray box shows individual metrics that constitute the wildfire response benefit priority metric (right). Individual metrics, mapped at a resolution of 18-acre polygons, were normalized to a score of one to 100. The metrics in the gray box were added, using different weights, to obtain the wildfire response benefit map shown on the right. The landscape treatment priority metric weighted at 25%, and the metrics (3 wildfire risk layers, wildfire transmission to homes, and crown fire potential) collectively accounted for the remaining 75%.

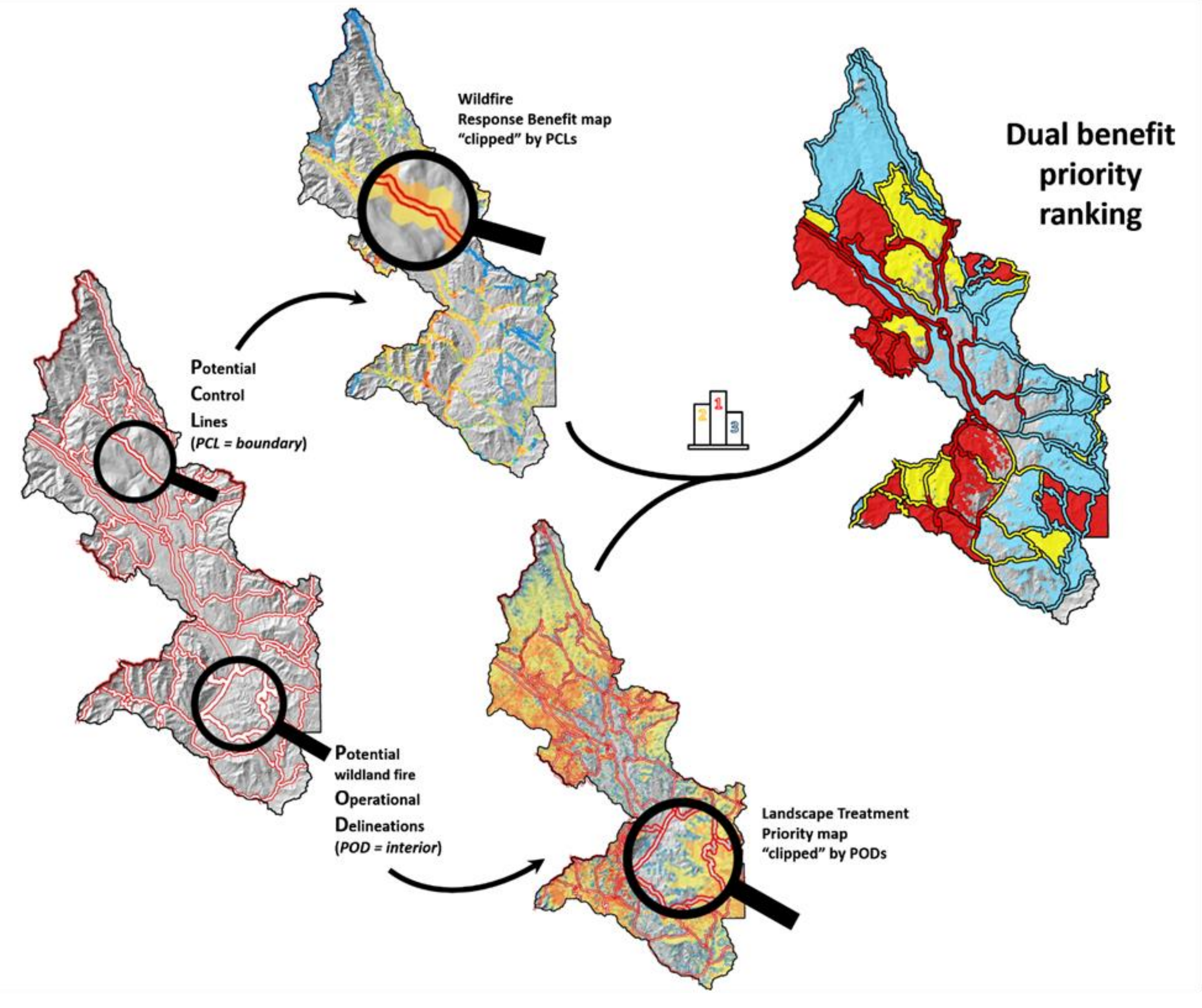


Prioritize for dual benefit using wildland fire Potential Operational Delineations (PODs): Wildland Fire Potential Operational Delineations (PODs) is a framework to conduct cross-boundary, pre-fire analysis and planning to increase wildfire response safety and efficiency (Thompson et al. 2016). In a PODs framework, fire operations personnel define large landscape areas that are surrounded by potential control lines – natural and artificial areas that provide strategic opportunities for fire operations (Fig. 6). Potential control lines can be roads, ridgelines, old fires, and treated areas. There are multiple uses for PODs landscape areas, including pre-fire response planning and the development of fire response plans for each landscape based on quantitative assessments of value at risk.

DNR used the PODs delineations for national forests as a starting point for PODs delineation across multiple ownerships within a given planning area. The goal of this process was to gather input from other agencies and create a set of all-lands PODs that reflect the expertise and fire management mandates of different agencies. The Keep It or Tweak It (KITTI) app was developed to support PODs delineation across jurisdictions. The app is accessible online on any browser and requires only that the user be registered with AGOL online. The tool is an easy and intuitive click-and-draw tool with various base and support layers to help inform the location of PODs. PODs are a living product that evolve as coordination and alignment between all agencies with wildfire responsibilities continues to grow.

The landscape evaluation process uses PODs to summarize, visualize and communicate dual-benefit priorities qualitatively using a three-priority ranking. Dual benefit refers to potential treatment actions that benefit both forest health (by restoring a resilient forest condition) and fire operations (by creating strategic opportunities for safer and effective fire engagement). Specifically, DNR used the landscape treatment priority metric to prioritize PODs and used the wildfire response benefit priority metric to prioritize potential control lines (PCLs). Individual values of the landscape treatment were summed across each POD and divided by the forested area in each POD. Priority rankings of PODs were based on the landscape treatment prioritization value per acre of each POD. To prioritize PCLs (the boundaries of PODs), DNR used the wildfire response benefit priority metric. DNR used ForSysX (Ager et al. 2019b) to create PCL projects based on each project's total wildfire response benefit value and rank each PCL project based on its wildfire response benefit value per acre.

Figure 6. From Potential Operational Delineations to priority rankings of dual benefit. Potential wildland fire Operational Delineations (PODs) correspond to large landscape areas surrounded by potential control lines (PCLs, shown in red with white fill). PCLs can be ridgelines, roads, old fire scars or treatments and correspond to locations where firefighters have a strategic opportunity to engage and where there is potential for fire control. Having a PCL does not guarantee successful outcomes. PODs were ranked based on the landscape treatment priority metric (see Fig. 9), and PCLs were ranked based on the wildfire response benefit priority metric (see Fig. 10). The dual benefit priority map shows PCL priorities and POD priorities combined in the same map to highlight opportunities for treatments that provide a dual benefit of forest health and wildfire response benefit. Red areas show first priority, yellow areas show second priority, and blue areas show third priority.



How are land managers and partners utilizing DNR forest health assessment data and analyses?

In the spring of 2022, DNR conducted an informal survey of land managers and partner organizations to better understand perceptions of the data products associated with implementation of RCW 76.06.200 and the 20-Year Forest Health Strategic Plan. The purpose of the survey was to understand how the information is utilized by land managers that are planning and implementing forest health treatments in priority landscapes.

The data products made available to the public and partners associated with the 20-Year Forest Health Strategic Plan include landscape evaluation summaries as well as all-lands GIS data products such as Lidar and DAP, fire severity maps and PCLs, moisture deficit, and, in some cases, change detection data showing the location of disturbances such as wildfire and management activities. DNR scientists also produce technical papers, reports, and publications.

The survey was conducted between May and June 2022 with responses from 13 partners representing USDA Forest Service, Conservation Districts, municipal government, non-governmental organizations (NGO), private industry, and state agencies. These partner organizations shared that they utilize DNR data in the following ways:

- Data helped me rethink my position on a topic I was working on
- Data supported more effective project communication
- Data helped build social license and public support
- Data helped inform my decision process
- Data informed funding priorities and grant writing
- Data complemented and/or confirmed alternative data sets

"We are using the Dual Benefit Analysis to prioritize treatments and as an important tool for leveraging funding. Partners working in North Central Washington, led by CCD, were recently awarded a $2.5 million Natural Resources Conservation Service RCPP grant to implement priority treatments on private forest lands near power grid infrastructure, reducing hazards, promoting forest health, and preparing the landscape for future wildland fire."
-Patrick Haggerty with the Cascadia Conservation District (CCD).

"The products produced by DNR help provide answers to key ecological questions that we ask when determining Historic Range of Variability and Future Range of Variability. And, they are a set of tools utilized when making land management decisions. The information is an important tool in our toolbox explaining to the public why we do what we do."
-Bart Ausland, Colville National Forest

"The research and data developed by DNR Forest Resiliency Division is an invaluable tool for helping private landowners and neighborhood coordinators with whom I work understand the environment in which they live, how that environment has changed in the last 100 years, and how it will continue to change in light of current forest conditions. This understanding is what enables community members to then begin developing strategies, lifestyle changes, and a shift in paradigms for how we all take responsibility for living in a fire-prone and fire-dependent ecosystem."

- Kathryn Heim, Fire Adapted Methow Valley

Landscape Evaluation and Forest Health Data Products

Forest Health Assessment and Treatment Framework data and associated products are publicly available at https://bit.ly/ForestHealthData

Aerial image showing pre-treatment forest condition on the Rainwater Wildlife Refuge, Confederated Tribes of the Umatilla Indian Reservation (CTUIR), in the Touchet-Mill Priority Planning Area. DNR and CTUIR are partnering to implement forest health thinning in this stand. Photo by John Marshall Photography.

Forest Health Treatment Need Assessment Results

Each biennium, DNR completes a set of landscape evaluations for newly identified priority planning to assess the forest health treatments needed within them. To date, DNR has assessed 37 priority planning areas encompassing 4,190,606 acres, including 2,971,849 acres of forest (Table 2).

The purpose of landscape evaluations is to set high-level forest health treatment target recommendations for each planning area so that DNR, landowners, and other stakeholders understand the level and types of treatments needed to create forest conditions that are resilient to large-scale disturbances. It also helps landowners work together to implement landscape-scale treatments and provide a benchmark to track progress on achieving resilient landscape conditions. It is important to note that estimated forest health treatment needs derived from a landscape evaluation exist within a range, rather than a set number, as fire-dependent landscapes are dynamic. Representing treatment needs as a range also accounts for potential tradeoffs in forest management goals among different landowners.

Based on landscape evaluations completed to date for 37 priority planning areas, DNR estimates that between 962,070 and 1,385,820 acres of treatments are needed to move these landscapes into a resilient condition. The range of treatment needs vary among planning areas, with an average identified need to treat approximately 33 to 47 percent of the forested area. The landscape evaluations distinguish treatment needs and anticipated treatment types for different structure classes.

Table 2. Summary of acres evaluated from 2018 to 2022 and treatment needs by priority planning area

Planning Area	Assessment Year (Initial)	Total Acres	Forested Acres	Assessed Treatment Need (acres)	Assessed Treatment Need (% of forest)
Ahtanum	2018	120,477	89,217	19,000 - 29,000	21 - 33
Chelan	2022	98,051	31,342	7,500 - 12,500	24 - 40
Chewelah	2020	195,408	158,352	59,000 - 80,000	37 - 51
Chumstick to LP	2020	115,333	84,216	36,500 - 53,000	43 - 63
Cle Elum	2020	109,396	80,300	22,000 - 35,500	27 - 44
Deer Park	2022	181,171	90,497	36,000 - 49,000	40 - 54
Dollar	2022	61,238	50,767	18,600 - 27,700	37 - 55
Glenwood	2020	104,501	83,758	23,500 - 32,000	28 - 38
Highway 97	2022	60,398	37,415	11,000 - 16,500	29 - 44
Ione	2020	44,248	41,784	16,500 - 21,000	39 - 50
Klickitat	2020	149,649	103,274	43,000 - 55,000	42 - 53
Little Naches	2022	95,433	92,914	25,500 - 43,000	27 - 46
Little Pend Oreille	2022	117,820	105,372	30,250 - 43,500	29 - 41
Little White	2020	95,750	84,705	17,750 - 27,500	21 - 32
Long Lake	2020	103,291	41,253	14,000 - 20,000	34 - 48
Mad Roaring Mills	2020	65,008	33,325	13,500 - 20,000	41 - 60
Manastash Taneum	2018	104,072	65,833	16,500 - 29,500	25 - 45
Methow Valley	2020	338,246	182,937	49,500 - 75,000	27 - 41
Mill Creek	2018	186,306	162,060	57,000 - 80,000	35 - 49
Mission	2018	49,121	32,743	10,406 - 10,406	32 - 32
Mt Hull	2020	105,431	34,809	12,000 - 18,500	34 - 53
Mt Spokane	2022	121,767	95,814	29,000 - 42,000	30 - 44
Nason Creek	2020	31,679	29,243	6,750 - 11,500	23 - 39
Republic	2020	180,553	144,350	46,500 - 64,000	32 - 44
Stemilt	2018	38,961	22,613	9,200 - 13,600	41 - 60
Stranger	2020	89,904	72,061	30,000 - 38,000	42 - 53
Teanaway	2020	132,120	111,696	38,500 - 60,000	34 - 54
Tieton	2020	148,634	117,781	38,000 - 60,500	32 - 51
Tillicum	2018	14,326	11,241	7,614 - 7,614	68 - 68
Toroda-Tonata	2020	153,611	117,345	51,000 - 66,000	43 - 56
Touchet-Mill	2022	203,750	74,775	22,000 - 27,500	29 - 37
Trail	2020	105,242	94,948	32,500 - 44,000	34 - 46
Trout Lake	2018	117,153	105,015	18,500 - 33,000	18 - 31
Twisp River	2020	111,918	82,349	26,000 - 36,500	32 - 44
Upper Swauk	2020	39,175	35,450	14,000 - 22,000	39 - 62
Upper Wenatchee	2018	74,777	66,277	15,500 - 27,000	23 - 41
White Salmon	2018	126,688	104,022	38,000 - 54,000	37 - 52
TOTAL	2018-2022	4,190,606	2,971,849	962,070 - 1,385,820	33 - 47

Table 3. Forest health treatment needs for all priority planning areas assessed between 2018-2022.

Planning Area	Forest Structure Class (acres)			
	Small Dense[1]	Medium-Large Dense[2]	Medium-Large Open[3]	Total treatment need
2018 Structure Class Total	**10,000 - 17,000**	**240,700 - 342,900**	**33,000 - 63,700**	**283,700 - 423,600**
2020 Structure Class Total	**17,750 - 30,900**	**378,500 - 516,100**	**113,250 - 177,500**	**509,500 - 724,500**
2022 Structure Class Total	**4,500 - 7,750**	**118,500 - 168,000**	**27,850 - 43,950**	**150,850 - 219,700**
Structure Class Total	**32,250 - 55,650**	**737,700 - 1,027,000**	**174,100 - 285,150**	**944,050 - 1,367,800**
Grand Total (2018, 2020, and 2022 planning areas)	**962,070 - 1,385,820 acres**			
Anticipated Treatment Type	[1] Noncommercial thin plus fuels treatment. May be fire only (prescribed or managed wildfire).			
	[2] Commercial thin plus fuels treatment if access exists. May be noncommercial, fire only (prescribed or managed wildfire), or regeneration treatment.			
	[3] Maintenance treatment: prescribed fire, managed wildfire, or mechanical fuels treatment. Target range corresponds to 50-75% of dry open and 25-50% of moist open forests.			
Notes	Grand Total includes acres from planned US Forest Service treatments in the Tillicum and Mission Maintenance planning areas that are not in the Structure Class Total.			

Table 4. Forest health treatment needs by structure class for priority planning areas assessed in 2018.

Planning Area (2018)	Forest Structure Class (acres)			
	Small Dense[1]	Medium-Large Dense[2]	Medium-Large Open[3]	Total treatment need
Chewelah[4]	500 - 1,000	50,000 - 65,000	8,500 - 14,000	59,000 - 80,000
Mill Creek	1,000 - 2,000	54,000 - 72,000	2,000 - 6,000	57,000 - 80,000
Mt Spokane[4]	1,000 - 1,500	23,500 - 33,500	4,500 - 7,000	29,000 - 42,000
Upper Wenatchee	-	15,000 - 25,000	500 - 2,000	15,500 - 27,000
Stemilt	-	6,200 - 7,900	3,000 - 5,700	9,200 - 13,600
Manastash-Taneum	3,500 - 6,500	11,000 - 19,000	2,000 - 4,000	16,500 - 29,500
Cle Elum[4]	1,500 - 2,500	15,500 - 24,000	5,000 - 9,000	22,000 - 35,500
Ahtanum	2,000 - 2,500	13,000 - 18,500	4,000 - 8,000	19,000 - 29,000
Trout Lake	-	17,500 - 31,000	1,000 - 2,000	18,500 - 33,000
White Salmon	500 - 1,000	35,000 - 47,000	2,500 - 6,000	38,000 - 54,000
2018 Structure Class Total	**10,000 - 17,000**	**240,700 - 342,900**	**33,000 - 63,700**	**283,700 - 423,600**
Tillicum[5]				7,614
Mission Maintenance[5]				10,406
2018 Total				**301,720 - 441,620**
Anticipated Treatment Type	[1] Noncommercial thin plus fuels treatment. May be fire only (prescribed or managed wildfire).			
	[2] Commercial thin plus fuels treatment if access exists. May be noncommercial, fire only (prescribed or managed wildfire), or regeneration treatment.			
	[3] Maintenance treatment: prescribed fire, managed wildfire, or mechanical fuels treatment. Target range corresponds to 50-75% of dry open and 25-50% of moist open forests.			
Notes	[4] Chewelah and Cle Elum acre targets were updated in 2020. Cle Elum includes an additional sub-watershed. Mt Spokane acre targets were updated in 2022.			
	[5] Full landscape evaluations were not conducted for Tillicum and Mission Maintenance. Acres for these areas reflect planned US Forest Service treatments and were added to the 2018 Subtotal range.			

Table 5. Forest health treatment needs by structure class for priority planning areas assessed in 2020.

Planning Area (2020)	Forest Structure Class (acres)			
	Small Dense[1]	Medium-Large Dense[2]	Medium-Large Open[3]	Total treatment need
Chumstick to LP	1,250 - 2,750	25,000 - 33,750	10,250 - 16,500	36,500 - 53,000
Glenwood	750 - 1,000	17,000 - 22,000	5,750 - 9,000	23,500 - 32,000
Ione	250 - 500	15,500 - 19,000	750 - 1,500	16,500 - 21,000
Klickitat	4,000 - 6,500	34,000 - 41,500	5,000 - 7,000	43,000 - 55,000
Little White	-	17,750 - 27,500	-	17,750 - 27,500
Long Lake	-	6,500 - 8,250	7,500 - 11,750	14,000 - 20,000
Mad Roaring Mills	7,500 - 11,250	1,000 - 1,750	5,000 - 7,000	13,500 - 20,000
Methow Valley	-	33,500 - 50,500	16,000 - 24,500	49,500 - 75,000
Mt Hull	250 - 900	6,750 - 9,600	5,000 - 8,000	12,000 - 18,500
Nason Creek	750 - 2,000	5,000 - 8,000	1,000 - 1,500	6,750 - 11,500
Republic	-	33,000 - 43,500	13,500 - 20,500	46,500 - 64,000
Stranger	500 - 1,000	23,500 - 28,000	6,000 - 9,000	30,000 - 38,000
Teanaway	1,500 - 3,000	26,000 - 40,000	11,000 - 17,000	38,500 - 60,000
Tieton	-	31,250 - 49,500	6,750 - 11,000	38,000 - 60,500
Toroda-Tonata	-	43,500 - 54,000	7,500 - 12,000	51,000 - 66,000
Trail	750 - 1,500	26,250 - 33,000	5,500 - 9,500	32,500 - 44,000
Twisp River	250 - 500	22,000 - 29,500	3,750 - 6,500	26,000 - 36,500
Upper Swauk	-	11,000 - 16,750	3,000 - 5,250	14,000 - 22,000
2020 Structure Class Total	**17,750 - 30,900**	**378,500 - 516,100**	**113,250 - 177,500**	509,500 - 724,500
Anticipated Treatment Type	[1] Noncommercial thin plus fuels treatment. May be fire only (prescribed or managed wildfire).			
	[2] Commercial thin plus fuels treatment if access exists. May be noncommercial, fire only (prescribed or managed wildfire), or regeneration treatment.			
	[3] Maintenance treatment: prescribed fire, managed wildfire, or mechanical fuels treatment. Target range corresponds to 50-75% of dry open and 25-50% of moist open forests.			

Table 6. Forest health treatment needs by structure class for priority planning areas assessed in 2022.

Planning Area (2022)	Forest Structure Class (acres)			
	Small Dense[1]	Medium-Large Dense[2]	Medium-Large Open[3]	Total treatment need
Chelan	1,000 - 2,250	-	6,500 - 10,250	7,500 - 12,500
Deer Park	1,500 - 2,500	27,000 - 35,500	7,500 - 11,000	36,000 - 49,000
Dollar	-	16,000 - 24,000	2,600 - 3,700	18,600 - 27,700
Highway 97	-	7,500 - 11,500	3,500 - 5,000	11,000 - 16,500
Little Naches	2,000 - 3,000	23,000 - 38,500	500 - 1,500	25,500 - 43,000
Little Pend Orielle	-	24,500 - 34,500	5,750 - 9,000	30,250 - 43,500
Touchet-Mill	-	20,500 - 24,000	1,500 - 3,500	22,000 - 27,500
2022 Structure Class Total	**4,500 - 7,750**	**118,500 - 168,000**	**27,850 - 43,950**	**150,850 - 219,700**
Anticipated Treatment Type	[1] Noncommercial thin plus fuels treatment. May be fire only (prescribed or managed wildfire).			
	[2] Commercial thin plus fuels treatment if access exists. May be noncommercial, fire only (prescribed or managed wildfire), or regeneration treatment.			
	[3] Maintenance treatment: prescribed fire, managed wildfire, or mechanical fuels treatment. Target range corresponds to 50-75% of dry open and 25-50% of moist open forests.			

Understanding forest health treatment need results

The results from the landscape evaluations do not mandate management actions or treatment targets for specific land ownerships. The data informs landscape-scale recommendations for priority planning areas as a whole. Landowners conduct their own field assessments, planning, and decision-making processes to determine specific treatments they can carry out to achieve a healthy and resilient forested landscape, while also meeting their own management objectives and regulatory requirements.

Forest health treatment needs in landscape evaluations are expressed as ranges of acres, because there is no single condition that represents a resilient landscape. These ranges are dynamic due to a combination of disturbances that are anticipated to shift over time. The treatment ranges also provide options for landowners to manage for and balance different objectives, while still meeting the overall goal of a resilient landscape more adaptable to a changing climate. For example, managing for the high end of treatment needs will emphasize fire risk reduction, increased resistance to drought and related insect outbreaks, higher water yield potential, and more habitat for wildlife species that use open canopy forests. Conversely, managing for the lower end of treatment need will emphasize habitat for closed-canopy dependent species, timber production, carbon storage, and reduction of road system effects on aquatic systems.

Based on tree size class, the majority of acres needing forest health treatment are commercially viable, although commercial viability ultimately depends on multiple factors. Individual landowners will determine the most appropriate treatment types in specific locations given their objectives, regulatory requirements, and operational and economic considerations.

A combination of treatment tools are needed to achieve forest resilience goals (Figure 7). Commercial and non-commercial mechanical treatments are generally the most effective and predictable tools for reducing canopy density and fire risk, provided that follow up surface and ladder fuel reduction treatments are completed using prescribed fire or mechanical methods (Schwilk et al. 2009, Fulé et al. 2012). However, it will not be possible in most planning areas to achieve the targets with mechanical treatments alone, due to limitations such as lack of access. Significantly increasing the use of prescribed fire will be critical. Managed wildfire is another important tool that can be used to accomplish needed work, when used in appropriate locations under the right circumstances. To help managers determine where different treatment types are most appropriate, a GIS tool was developed to map where mechanical treatments are likely possible, or where prescribed fire or managed wildfire will be needed.

The landscape evaluations establish clear targets for shifts in vegetation conditions required to create a resilient landscape. The scale of these shifts may seem difficult to achieve in some priority planning areas. The goal of having landscape evaluations within the forest health plan, however, is to provide land managers and partners with a data-driven blueprint to empower a common vision of treatment needed to leverage resources and foster creativity to meet the challenge at a meaningful scale.

Implementation of forest health treatments identified through the landscape evaluation process will likely take several biennia to accomplish in any given priority planning area. The pace and scale of forest health treatment implementation will be driven by common and unique factors for each priority planning area, such as the capacity of land managers and contractors to plan and implement treatments, ratio of commercial versus non-commercial treatments, ability to conduct prescribed fire treatments, forest products markets and mill capacity, road access, public support, ability to manage wildfires for resource benefits, funding levels for non-commercial treatments, and budget levels for public land management agencies. Achieving landscape restoration goals in each priority planning area will require local solutions as well as systematic support.

Pre-treatment stand condition of the Kalispel Moon commercial thinning project (Unit 43) on the Colville National Forest in the Trail Priority Planning Area. The project was planned using the Tribal Forest Protection Act and will be implemented in partnership with the Kaslipel Tribe of Indians and DNR. Photo by John Marshall Photography.

In addition, once forest health treatments are implemented in a priority planning area and a more resilient mix of dense and open forest structures exists, significant ongoing treatments will be needed to maintain a resilient landscape condition. Vegetation will continue to grow. Maintenance needs will vary by forest type, site productivity, landowner objectives, and other factors.

Finally, these landscapes are dynamic. Updates to landscape evaluations will occur over time as treatments, fires, other disturbances, and growth change forest conditions, input datasets for current conditions are improved, and methodologies are refined based on new science, monitoring results, and adaptive management.

As completing the recommended treatments in any one planning area will take time, stakeholders and landowners should expect several updates to landscape evaluations. These updates may include changes to treatment targets.

Figure 7. Forest health treatment toolbox**.** Examples from eastern Washington (clockwise from top left): Two images of commercial thinning treatments on DNR state trust lands in the Methow Valley planning area; landscape view of the 2018 Crescent Fire in the Twisp planning area; Washington Department of Fish and Wildlife's wildlife area after thinning (2017) and prescribed fire (2019) treatments in the Methow Valley planning area; 2020 prescribed burn treatment in the Stemilt planning area; non-commercial thinning of young forest stand.

Clockwise from top left, photos by John Marshall Photography, John Marshall Photography, DNR, DNR, Chelan County, and DNR.

The Role of Shaded Fuel Breaks in Support of the 20-Year Forest Health Strategic Plan

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 people often debate the efficacy of using fuel breaks in support of fire operations, the role of fuel breaks in support of broader forest health and treatment goals is not regularly discussed.

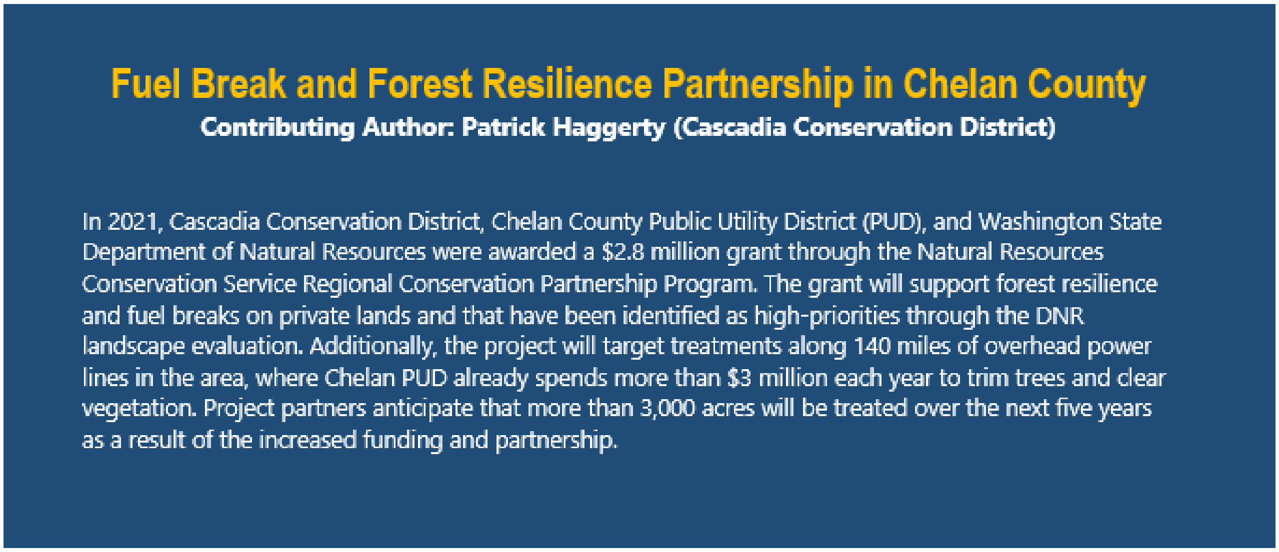
In January 2022, DNR published The Role of Shaded Fuel Breaks white paper to assist land managers and implementation partners considering fuel breaks for landscape-scale restoration and community protection in eastern Washington. The objectives of the memo were threefold:

1. clarify terminology surrounding fuel breaks and other treatment strategies considered as part of the 20-Year Forest Health Strategic Plan;
2. review the available literature on fuel breaks in conifer systems; and
3. examine the roles of fuel breaks and landscape treatments where appropriate for achieving multiple landscape restoration goals.

The memo proposes that fuel breaks and landscape treatments are complementary approaches that serve different landscape goals (Figure 8). Combining these approaches at the appropriate scale and location will significantly increase our capacity to protect communities and 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.

Highlights from the white paper include:

- The main goal of a fuel break should be to enhance the effectiveness of potential control lines. The contribution of a fuel break to forest health is indirect; for example, by preparing a forest road to be utilized as a control line during a future prescribed fire or managed wildfire.
- Landscape scale, cross-boundary forest health treatments are more effective than fuel breaks at improving forest resilience and supporting wildfire operations.
- Without appropriate maintenance of fuel breaks, and adequate firefighting resources available during a wildland fire, fuel breaks are likely to fail in cases of extreme fire weather.
- Shaded fuel breaks should only be implemented along potential control lines of high value – areas with strong strategic value for fire operations and where a landscape treatment is not feasible or needed.
- The role of fuel breaks can be dynamic. Forest health goals and fire management goals are complementary if fuel breaks are utilized to both aid in effective. suppression when necessary and promote the use of prescribed and managed fire.
- Monitoring treatment effectiveness and building a stronger understanding of the relationships between fuel break spatial designs, silvicultural prescriptions and maintenance schedules, and effects on plants and animals is an area of further inquiry and research for DNR and our partners.



Fuel Break and Forest Resilience Partnership in Chelan County

Contributing Author: Patrick Haggerty (Cascadia Conservation District)

In 2021, Cascadia Conservation District, Chelan County Public Utility District (PUD), and Washington State Department of Natural Resources were awarded a $2.8 million grant through the Natural Resources Conservation Service Regional Conservation Partnership Program. The grant will support forest resilience and fuel breaks on private lands and that have been identified as high-priorities through the DNR landscape evaluation. Additionally, the project will target treatments along 140 miles of overhead power lines in the area, where Chelan PUD already spends more than $3 million each year to trim trees and clear vegetation. Project partners anticipate that more than 3,000 acres will be treated over the next five years as a result of the increased funding and partnership.

Figure 8. View of fuel breaks and landscape treatments.

Artwork by Gretchen Bracher.

Logging Systems and Economic Analysis

Contributing Authors: Kevin Ceder (Woodland Creek Consulting) and **Sean Jeronimo** (Resilient Forestry)

Goal 3 of the 20-Year Forest Health Strategic Plan is to enhance economic development through implementation of forest restoration and management strategies that maintain and attract private sector investments and employment in rural communities. In order to provide partners with an estimate of the wood product and revenue generated from landscape restoration associated with the plan, DNR has developed innovative logging systems and economic analysis tools. These tools can assist managers and partners with project planning by providing estimates of logging system types, volume outputs, costs, and revenues for a planning area. This information on operational feasibility and economics can be integrated with landscape treatment priorities to design successful restoration projects.

The logging systems tool generates a preliminary map of potential treatment units and assigns a logging system for each unit. Logging systems are determined using terrain profiles, road locations, and user-defined maximum skidding distances and slope thresholds. For example, if a location is within 2,000 feet of roads with slopes generally less than 35 percent, ground-based systems may be used. If slopes are too steep for ground-based systems, cable systems may be used if the location is within 1,200 feet of roads. If ground-based or cable systems cannot be used, helicopter systems may be used, or temporary roads may be needed, if the location is within one mile of a road. These distances and slope thresholds can be adjusted as needed. Locations are aggregated into potential treatment units by logging systems that are larger than a minimum operable area and potentially accessible from the existing road system. Ground logging system units are allowed to have a small percentage of cable systems to account for steep areas in broken terrain that could be treated with ground-based systems. Minimum unit sizes and the percentage of cable systems in ground-based units can be adjusted as needed.

Economic analysis tools calculate the potential harvest volumes and revenues for the preliminary treatment units using estimated standing volumes, stand structure classes, vegetation types, logging system-specific operating costs, hauling costs, and delivered log prices. Volume removal is estimated by removing a percentage of the standing volume, which is summarized from LiDAR-derived data. This percentage is set by the user based on structural condition and vegetation type. Local log prices along with logging and hauling costs are used to create a first-cut estimate of units where treatments may generate revenue, break even, or may require investments.

Figure 9. Inputs to logging systems tool (left) including terrain (slope) and roads (roads ML) are processed into potential treatment units by logging system type (right).

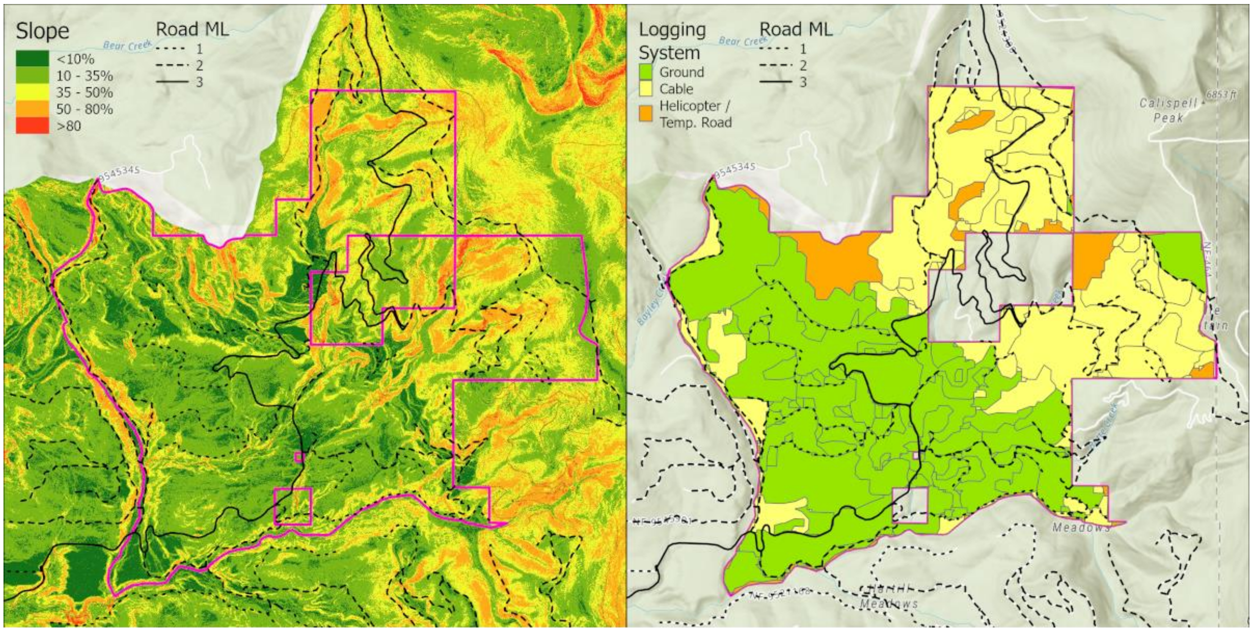
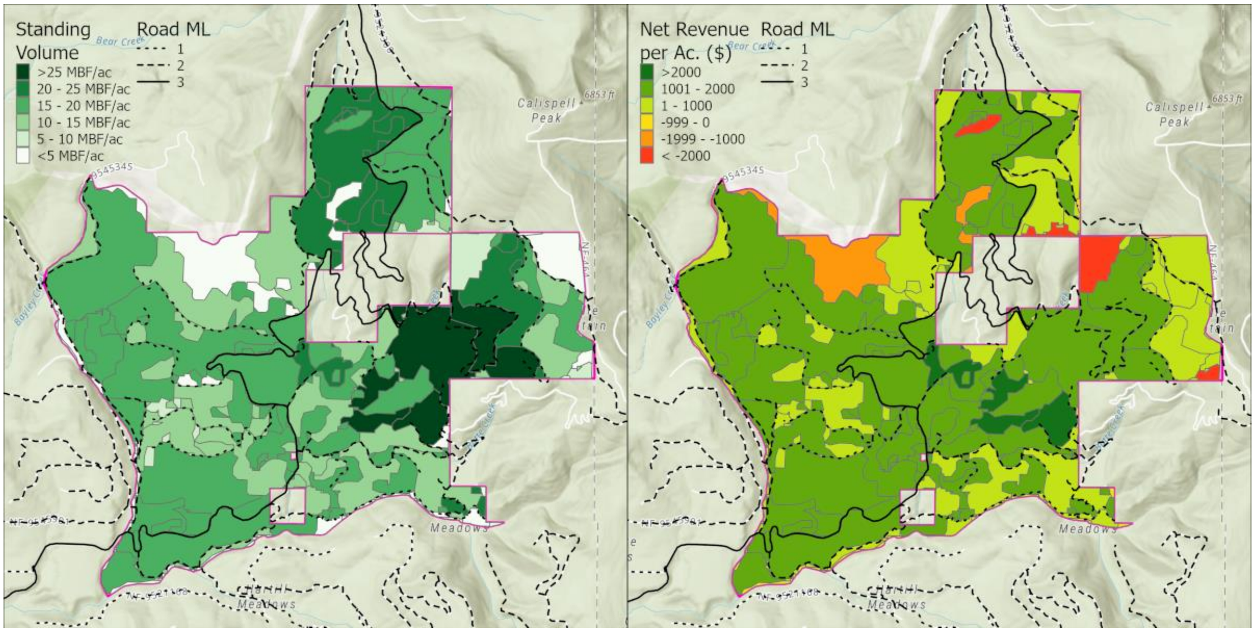


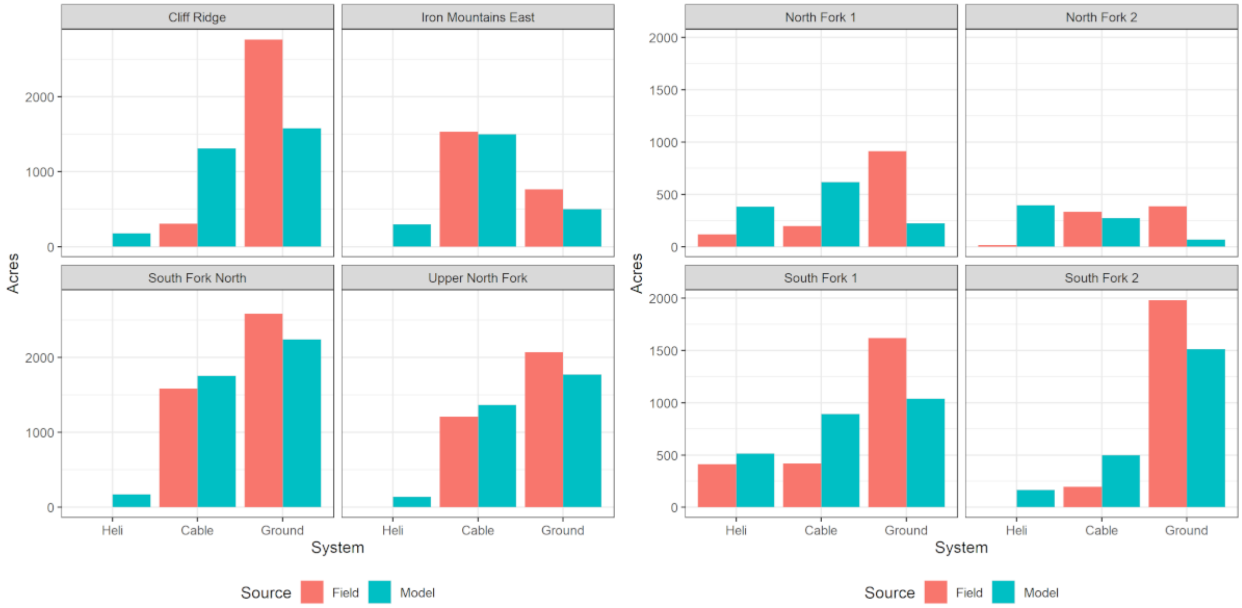
Figure 10: Standing volume for preliminary units (left) along with logging system and hauling cost are used to determine units that may generate revenue (shades of green)or require investments for restoration (oranges and red) (right).



Logging systems and economic analyses use the best information available at the time, including remotely sensed data, harvest system limitations, log prices, and logging and hauling costs. However, the tool is not intended to be a complete logging systems design and economic analysis for planning areas. Final treatment units, logging systems designs, and potential harvest volumes, revenues, and costs require field work, local knowledge, and landowner specific analysis and planning.

Preliminary versions of the tools were developed as a pilot project by Resilient Forestry in 2020. Updates and refinements were made in subsequent years based on validation, testing, and partner outreach. Initial analyses with these tools resulted in excessive areas assigned to cable logging systems, with costs likely more than the value of the harvested trees. Logging system classifications were compared with on-the-ground logging systems used in past harvest units or assigned during NEPA analyses in parts of the Mill Creek, Chewelah, and Twisp Projects managed by the Forest Service. Sensitivity analyses were used to assess the impacts of changing and refining logging system operability parameters to improve classification accuracy. Updated parameter values increased the acreage of ground-based systems assigned to areas where it was, or would be, used. Logging systems tool validation showed difficulty classifying ground-based systems in areas with occasional steep areas that would otherwise be operable.

Figure 11: Logging system acreages for field selected (red, NEPA or actual system used) compared to logging system model selections (blue) for watersheds in the Chewelah (left 4) and Mill Creek (right 4) planning areas.



The contractor will seek input and feedback from log purchasers, logging system experts, planners, and others that will use the tool outputs. Then they will finalize the validation and tool updates incorporating feedback from would be users of the tools and/or outputs. Tethered logging may be added.

DNR will first run the tools for 20-year Forest Health Strategic Plan priority planning areas where logging systems and economic outputs are requested. DNR will then run the tools for all priority landscapes in eastern Washington to support project planning. Other areas may also be run based on requests.

DNR State Lands timber harvest operation in Northeast Region. Photo by DNR.

Aquatic Restoration and Watershed Resilience

The 20-Year Forest Health Strategic Plan calls for an increase in the health and resilience of both forest and aquatic ecosystems for a changing climate. The health and function of our forests and watersheds are interrelated. Addressing forest and watershed resilience will aid in reducing risk of uncharacteristic wildfire, mitigate the impacts of future drought, and improve habitat for fish and wildlife species.

Drought Mitigation and Preparedness

For the majority of 2021, the U.S. Drought Monitor, published by the National Oceanic and Atmospheric Administration (NOAA), found that all of Washington State was abnormally dry. Almost the entire state experienced drought in 2021, and extreme drought conditions persisted in 47 percent of the state. Spring and summer in 2021 were some of the driest on record. In late June, a heat dome resulted in record breaking temperatures across the state. By the first week of July, the state had more than 630 wildfires, and conditions led to an emergency proclamation calling for a statewide burn ban. Shortly after, based on the recommendation of the State's Executive Water Emergency Committee, the Department of Ecology issued a drought declaration. The short-term effects of the 2021 drought were widespread, impacting agricultural production, salmon and cold-water fish species, and forest fuel moistures and wildfire risk.

DNR's Forest Health Highlights Report, published annually, describes impacts of forest insects and diseases across Washington. Following the 2014-2015 drought, DNR forest health scientists mapped more than 1.5 million acres impacted by wildfires and estimated that 3.4 million trees had been recently killed, largely as a result of drought-caused stress, insect outbreaks, and disease. The 2021 drought will impact forest ecosystems for years to come. DNR's 2021 Forest Health Highlights reported that the drought that year will likely increase tree susceptibility, and result in delayed mortality, due to stressed and weakened trees. Mitigating drought impacts will increase the resilience of our watersheds and help ensure forests continue to provide the ecosystem services Washingtonians depend on.

Forests, Roads and Water Quantity and Quality

Forests naturally filter water and regulate flow, providing clean and cold water for municipalities, farms, fish, and wildlife. Forest management, including the building of forest roads and changes in vegetation cover, have the potential to affect hydrologic and aquatic systems. Management and conservation efforts focused on increasing the pace of aquatic restoration are critical to addressing threats posed by climate change and drought, ensuring forests continue to provide clean water.

There is a long history of collaboration and partnership in Washington focused on maintaining and improving forest roads to protect fish habitat and water quality. The Road Maintenance and Abandonment Plan (RMAP), a result of the 1999 Salmon Recovery Act, requires state and private landowners to inventory roads and upgrade those that affect hydrologic and aquatic systems. Since 2000, more than 40 large forest landowners collectively invested more than $300 million in road improvements.

Investing in forest roads is critical to achieving the overall goals of landscape and aquatic resilience as described in the 20-Year Forest Health Strategic Plan. DNR continues to invest in forest roads on state, and in some cases federal lands, through our partnership with the Forest Service and use of Good Neighbor Authority.

Culvert replacement with a bridge on North Nanamkin Creek on the Colville Reservation. Photo by Confederated Tribes of the Colville Reservation.

The rest of this chapter provides an overview of our methodological approach for evaluating aquatic restoration needs in priority planning areas. The chapter also highlights recent aquatic restoration projects completed by partners in eastern Washington.

Assessing Aquatic Restoration Need

Contributing Authors: Hans Smith and Brandon Rogers (Yakama Nation Fisheries)

Assessing aquatic restoration needs in priority planning areas and implementing aquatic restoration treatments at a watershed scale are vital to achieve the goals of the 20-Year Forest Health Strategic Plan. Partners and landowners in Washington invest millions of dollars each year in water resources and fish habitat projects. In partnership with tribes, counties, state, and federal land managers, aquatic landscape evaluations provide a technical framework for prioritizing and implementing watershed restoration that compliments and enhances the benefits of landscape-scale forest restoration.

What is Aquatic Restoration?

Aquatic restoration generally refers to active management activities undertaken by resource managers to recreate or mitigate natural hydraulic and hydrologic processes that have been augmented or damaged by past management activities. Water bodies like streams, rivers, and lakes are distinctive and biologically complex areas on the landscape with unique disturbance and successional trajectories that are directly shaped and altered by the conditions of the surrounding watershed. In areas where aquatic evaluations indicate natural process impairments; practitioners use a suite of innovative treatment types to restore more natural hydraulic and hydrologic processes which maintain water quality and support critical aquatic habitats.

Elements considered in aquatic evaluations:

- Processes: What types of natural processes create and sustain water resources and aquatic habitats that support regional priorities like clean water and salmon runs?
- Species Distributions: What species occur in the landscape's aquatic environment? What are the distributions of these species across the landscape?
- Natural Function: Are natural processes functioning similar to historic conditions? If not, are changes to natural processes impairing conditions to priority aquatic resources like salmon rearing and spawning habitat?
- Project Identification: What actions or interventions can be reasonably taken to overcome aquatic resource impairments or to restore natural processes?

Many aquatic restoration actions target maintaining or improving conditions for aquatic life, such as fish and amphibians. Endangered and threatened salmon and steelhead habitat restoration receives attention because of the need to increase the capacity of aquatic habitats to support larger fish populations and increase population resilience from natural and human caused disturbance events. Salmon and steelhead habitat restoration typically involves instream and floodplain complexity treatments like installing woody debris, reconnecting side channels and working to incorporate ground water as a connected habitat feature. Many of these types of complex habitat features have been lost and degraded in eastern Washington streams and rivers, including the natural cycles that create and sustain these types of habitats.

Photo by Yakama Nation Fisheries and Inter-Fluve.

Types of Aquatic Restoration

- Instream wood roughness and complexity restoration
- Side channel creation and/or reconnection
- Stream bank bioengineering
- Floodplain reconnection
- Channel reconfiguration
- Culvert/bridge replacements for fish passage and stream simulation
- Irrigation diversion changes
- Riparian plantings and streamside vegetation management
- Wetland creation
- Levee and infrastructure removal
- Beaver restoration and beaver dam analogs
- Road decommissioning and obliteration
- Cold water refuge creation

Aquatic Evaluation Methods

Once a priority planning area has been selected, an assessment of both terrestrial and aquatic landscape conditions provides a holistic picture of the suite of treatments needed and potential sequencing of treatments to improve forest health and watershed function. Aquatic evaluations include the following steps:

- Identify Processes
- Collect and Analyze Data
- Link Processes and Conditions to Values
- Identify Projects at the Site Level

Identifying Processes

Aquatic systems are highly dynamic and responsive to disturbances, so it is important to think about the state of the system in terms of natural processes like flooding, sediment recruitment and transport, channel evolution, and riparian and floodplain interactions. Restoration practitioners use typical diagnostic indicators to track the status of natural processes operating in an aquatic landscape. In the Upper Columbia Basin, for example, practitioners use the following indicators when conducting an Aquatic Evaluation to support salmon habitat restoration planning.

Matrix of Diagnostic Pathways and Indicators*	
Watershed/Reach Conditions	**Habitat Quality**
Road Density/Locations	Substrate
Disturbance Regimes	Large Woody Debris
Land Use	Pools
Flow/Hydrology	Off-Channel Habitat
Change in Peak/Base Flows	Refugia
Increase in Drainage Network	Riparian Condition
Water Quality	Mechanical Injury
Temperature	Trophic Productivity
Sediment/Turbidity	Pathogens/Predation
Chemical Contamination/Nutrients	**Channel Conditions and Dynamics**
Habitat Access	Width/Depth Ratios
Physical Barriers	Bank stability/Channel migration
Flow/Hydrology	Vertical channel stability
	Floodplain connectivity

*Adapted from UCRTT

Collecting and Analyzing Data

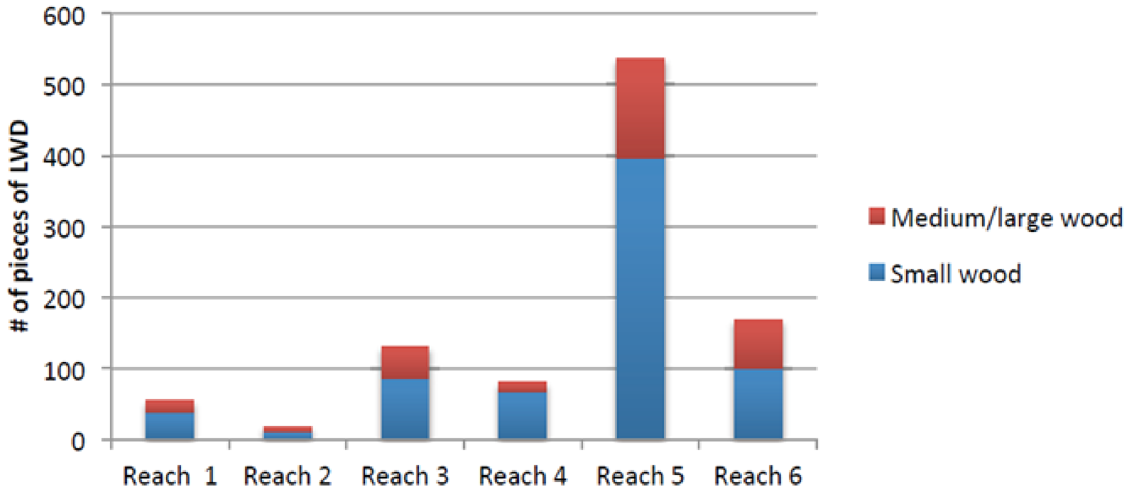
Recent and historic stream surveys provide valuable data needed to assess the functional ratings of diagnostic indicators. Within lands managed by USDA Forest Service, and in important salmon habitat tributaries, stream surveys using Forest Service Level II survey protocols provide detailed, geographically specific quantification of the number of pools present in a system, the amount of large wood loading, and the percentage of side channel systems present. LiDAR imaging, chrono-sequenced ortho-rectified aerial photography, drone imagery, and geomorphic surface maps provide other landscape scale datasets that are useful in quantifying existing aquatic conditions.

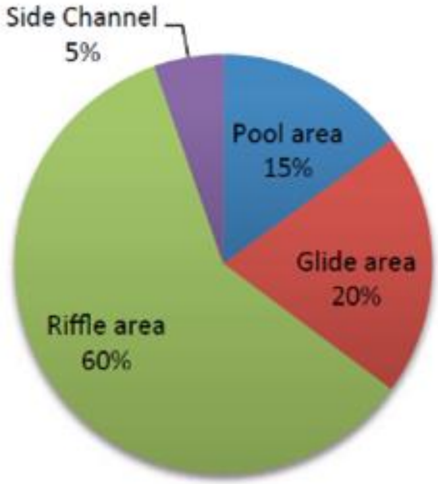
Once collected, data can be summarized by stream-reach specific units, which enable the comparison of indicator metrics to other analog conditions and between analysis ranges. Summarizing the collected data into these geographically distinct units allows land managers to see the aquatic system indicator conditions at both the reach and aggregate landscape scale, which informs treatments needs and the viability of different treatment types.

Photo by Yakama Nation Fisheries and Inter-Fluve.

Linking Processes and Conditions to Values

Functional rating criteria for typical diagnostic indicators have been developed that take into account how eastern Washington aquatic systems historically functioned prior to modern human disturbances and alterations. These criteria provide a starting point by which to compare the summarized indicator metrics with technically referenced target conditions. Outputs from this process indicate areas where specific process pathways and indicators are not functioning, or are at risk of being lost. Being able to determine functional conditions of each indicator at the reach and landscape scale helps practitioners identify specific locations to conduct restoration to improve aquatic system functions.





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Example Habitat Quality Functional Rating Criteria*

General Indicator	Specific Indicator	Adequate Conditions	At Risk Conditions	Unacceptable Conditions
Substrate	Substrate / Fine Sediment	Gravels or small cobbles make up >50% of the bed materials in spawning areas, embeddedness < 20%, ≤12%fines/sand (<2 mm) in spawning gravel.	Gravels or small cobbles make up 30-50% of the bed materials in spawning areas, embeddedness is 20-30%, 12-17% fines (<2 mm) in spawning gravel.	Gravels or small cobbles make up <30% of the bed materials in spawning areas, embeddedness > 30%, >17% fines (<2 mm) in spawning gravel.
Large Woody Material	Pieces per Mile at Bankfull	Large wood (diameter > 12 in, length > 35 ft) at a minimum: Wetted width: < 16.4 ft, 20 pieces/mile ≥ 16.4 ft, 70 pieces/mile Adequate rating also indicates there are sources of woody debris available for both long- and short-term recruitment within the reach.	Large wood (diameter > 12 in, length > 35 ft) ranges from: Wetted width: < 16.4 ft, >0 - 20 pieces/mile ≥ 16.4 ft, 17-70 pieces/mile Current levels are able to maintain the minimum requirements for an "adequate" rating, but potential sources for long-term woody debris recruitment, as determined by the Riparian Structure reach metrics, are lacking in order to maintain these current levels.	Large wood (diameter > 12 in, length > 35 ft) at a minimum: Wetted width: < 16.4 ft, 0 pieces/mile ≥ 16.4 ft, 0-17 pieces/mile Current levels are not meeting the minimum requirements for an “adequate” rating, and potential sources of woody debris for short- and/or long-term recruitment are lacking as well.
Pools	Pool Spacing (unconfined reaches only, where unconfined reach is >4 times the bankfull width)	Pool spacing: Channel widths (bankfull widths) per pool. Gradient <1%: ≤ 2 CW/P Gradient >1%: ≤ 3 CW/P	No criteria for At Risk Condition.	Pool spacing: Channel widths (bankfull widths) per pool. Gradient <1%: > 2 CW/P Gradient >1%: > 3 CW/P
Off-Channel Habitat and Refugia	Connectivity with Main Channel	Reach has many ponds, oxbows, backwaters, and other off-channel areas with cover, and side channels are low energy areas. No man-made barriers present along the mainstem that prevent access to off-channel areas.	Reach has some ponds, oxbows, backwaters, and other off-channel areas with cover, and side channels are generally high energy areas. Man-made barriers present that prevent access to off-channel habitat at some flows that are biologically significant.	Reach has few or no ponds, oxbows, backwaters, and other off-channel areas. Man-made barriers present that prevent access to off-channel habitat at multiple or all flows.

*Adapted from UCRTT

Aquatic Restoration Implementation

Aquatic evaluations provide clear and spatially specific information about where aquatic processes are not functioning. This data can be used by aquatic restoration practitioners to efficiently focus planning restoration actions in targeted areas to address the specific at-risk stretches. For this task, teams of biologists, hydrologists, Professional Engineers, and other technical professionals begin to focus site specific resources to develop discreet aquatic restoration actions. Actions are typically modeled and engineered so that project functionality and outcomes can be evaluated for meeting objectives and understanding risks. Because aquatic restoration occurs in sensitive dynamic environments, extensive environmental analysis is required for each proposed restoration action, requiring federal and state agency review and permits.

Photo Credit: Yakama Nation Fisheries and Inter-Fluve

Once implementation begins much of the work focuses on protective actions that isolate the restoration work from adjacent sensitive areas. Coffering in water bodies, silt fencing, turbid water control, and fish removal are major project elements that require skillful planning and execution. Many restoration projects require the use of heavy equipment to conduct targeted grading, excavation, wood and tree placement, culvert construction, and other engineered project tasks. Using construction equipment in the aquatic environment takes highly skilled operators that understand project permitting requirements and how to operate in a manner that minimizes unnecessary disturbance.

Photo by Yakama Nation Fisheries and Inter-Fluve.

Key Partnerships

Persistent water resource management issues in eastern Washington have galvanized cross-agency planning. Increased funding and technical support for aquatic resource assessments and restoration actions have contributed to the emergence of a watershed restoration community consisting of tribes, state land management agencies, federal land management agencies, local counties and jurisdictions, and many non-governmental organizations. Regional salmon recovery plans have also developed cooperative frameworks that build regional partnerships and help direct resources towards high priority aquatic restoration projects. Building on these partnerships, DNR aims to advance aquatic evaluations as a key component of the Forest Health Assessment and Treatment Framework across more priority planning areas in the future.

Achieving Forest Health and Aquatic Restoration Objectives in the Twisp River Watershed: Confederated Tribes of the Colville Reservation Large Wood Placement Project Summer 2022

In the summer of 2022, Colville Confederated Tribes staff worked with staff from the Okanogan-Wenatchee National Forest staff to complete 5.5 miles of aquatic restoration work in the Twisp River watershed. Goals of this project were to help restore natural river processes, and improve the quantity and quality of aquatic habitat for native and ESA-listed fish by adding large and small wood to the Twisp River and Little Bridge Creek. As part of that project, staff identified 20 acres on US Forest Service land in the Twisp River watershed that were overstocked and needed a prescribed thinning operation to improve forest health and resilience. Colville Confederated Tribes completed the forest health thinning and used the thinned trees for the aquatic restoration work. Over 4,000 whole trees were harvested, staged, picked up with a heavy lift helicopter, and flown into the nearby Twisp River and Little Bridge Creek to supplement large and small wood and create complex aquatic habitat that will benefit ESA-listed fish species.

20 acres of US Forest Service land in the Twisp River watershed was thinned by Colville Confederated Tribes to improve forest health and provide trees for placement in Little Bridge Creek and the Twisp River (top left and top center photos). Over 4,000 whole trees were harvested, staged, picked up with a heavy lift helicopter, and flown into the nearby Twisp River and Little Bridge Creek to supplement large and small wood and create complex aquatic habitat that will benefit ESA-listed fish species (top right, bottom left and bottom right photos). Photo by Matt Young, Confederated Tribes of the Colville Reservation.

Creating Watershed Resilience in the Upper Columbia Basin through Partnerships and the help of beavers

The Upper Columbia Basin is highly vulnerable to drought with water shortages raising concerns for the economy, forests, native fish, and the way of life. The 20-Year Forest Health Strategic Plan commits to improve both forest health and watershed resilience, and DNR is investing in drought mitigation strategies to address both of those objectives by trying to hold water naturally on the landscape longer. One of these strategies is relying on collaboration with partners, both human and animal.

In Fiscal Year 2022, DNR's Forest Resilience Division utilized funds from House Bill 1168 to continue a partnership started in the previous biennium with the Confederated Tribes of the Colville Reservation and Trout Unlimited to construct and maintain beaver dam analogs. The project also included community outreach, native planting, and beaver re-location onto federal lands. Beavers are known as landscape engineers. The dams they create with logs and debris can rebuild eroded streams and restore wetland habitat. Additionally, the dams create ponds that store water on the landscape. So, in taking a page from the beavers' book – we're imitating their work by building what are known as beaver dam analogs, or BDAs. Basically, wooden posts pounded into a stream, then woven through with tree branches.

Photo Credit: Colville Confederated Tribes and Trout Unlimited

While BDAs provide crucial water basin wide benefits, Crystal Elliott of Trout Unlimited noted that beavers and our native fish evolved together. *"It's not a coincidence that we have a decimated population of beaver across the West... and the same population status for salmon and steelhead. These species co-evolved and having beaver on the landscape created habitat for salmon and steelhead that, in many cases, is no longer there."*

Last year, partners in eastern Washington built 34 beaver dam analogs in Okanogan and Chelan Counties in priority planning areas, planted 700 native plants, and re-located 15 beavers. One location along South Fork Beaver Creek in the Methow Valley was in poor condition from historic impacts of beaver removal and heavy grazing. As a result, the creek incised into the wetland meadow draining the wetland and lowering the water table. To improve wetland function, 14 relic beaver dams on site were restored with newly installed BDAs. According to Matt Young, fish biologist with Colville Tribes Fish and Wildlife, *"It may take many years, and the help of a beaver family, to fully restore South Fork Beaver Meadows but the positive impacts are already being seen. The new BDAs have been successful in retaining additional surface water and the incised channel has begun to return to natural levels."*

Forest Health Partnerships

Implementing RCW 76.06.200 while developing durable and actionable strategic plans requires cooperative partnerships. The 20-Year Forest Health Strategic Plan and State Forest Action Plan were crafted with input from Tribes, conservation groups, timber industry representatives, county governments, federal agencies, and our sister state agencies. This collaborative approach remains a signature theme of DNR's forest health and resilience work. Collaborating is predicated on the idea that wildfire knows no boundaries, thus we must work with our neighbors in order to reduce risk.

Implementing partners and stakeholders remain involved at every level of the process – from the statewide Forest Health Advisory Committee, to stand-level monitoring occurring in recently treated forests. Collaboration is also being facilitated through critical investments like the Building Forest Partnerships Grant Program, which supports diverse interests working together towards shared forest health goals. Partnerships and collaboration have led to burgeoning success and they remain a key part of our strategy moving forward.

This section of the report highlights investments and case studies made through partnerships across all land ownerships to increase forest health and watershed resilience in Washington.

Yakama Nation Fisheries aquatic restoration project in the Entiat River. Photo by Yakama Nation Fisheries and Inter-Fluve.

Shared Stewardship: State and Federal Partnerships

Washington State Shared Stewardship Investment Strategy

In May 2019, Commissioner of Public Lands Hilary Franz, Washington Department of Fish and Wildlife (WDFW) Director Kelly Susewind, Forest Service Chief Vicki Christiansen, and Regional Forester Glenn Casamassa signed a "Shared Stewardship" Memorandum of Understanding (MOU). At the time, the MOU was the second of its kind in the nation and established clear commitments among public agency partners in Washington. The core elements of the MOU direct signees to work together to determine management needs and prioritize stewardship decisions, use all existing tools to conduct the right work at the right places at the right scale, and to conduct the work with partners and stakeholders.

The purpose of the Shared Stewardship Strategy is to address critical issues facing natural resources, managers, and communities. The overarching goal is to establish a foundation for future collaboration. The 2020 Forest Action Plan operationalizes shared goals into concrete steps and priority actions to help focus the department's work and partnerships with WDFW, Forest Service, and others. The primary goals and desired outcomes are focused on ecological restoration, healthy communities, sustainable recreation, sustainable infrastructure, and conservation and protection of fish and wildlife.

Washington's Shared Stewardship Principles:

- Use the best available science to inform decisions.
- Use all authorities, programs, and tools to improve efficacy.
- Establish models to prioritize decision-making and identifying priority landscapes and projects.
- Use existing strategies and plans to guide work.
- Target investments to achieve scale and effectiveness.
- Foster strong working relationships and partnerships.
- Innovate, be willing to take measured risks and seize new opportunities with partners and keep in mind the "customer."

Washington State Department of Fish and Wildlife's Role in Shared Stewardship

Contributing Authors: **Mike Kuttel Jr., Matt Eberlein, Cynthia Wilkerson** (WDFW)

Collectively, USFS, DNR, and WDFW manage over 10 million acres of forests in Washington. Shared stewardship of these forests provides an opportunity to conserve fish and wildlife habitat at landscape scales, reduce wildfire risk and improve forest resilience to climate change, wildfires, insects, and disease, and provide benefits to communities including clean air and water, economic benefits, recreational, and commercial opportunities.

Each agency brings unique authorities, skills, capacity, and priorities to shared stewardship. WDFW focuses on projects that provide fish and wildlife benefits including correcting fish passage barriers, improving instream and riparian habitats, restoring watershed hydrology, addressing deferred maintenance of forest roads and trails, conserving wildlife migration corridors, improving habitat for terrestrial species, and forest health and fuels reduction treatments to build resilience to climate change, reduce wildfire risk, and improve fish and wildlife habitat. WDFW has been working on forest health and fuels reduction treatments for years to improve fish and wildlife habitat on State Wildlife Areas.

Since 2014, WDFW has thinned over 14,940 acres, treated 7,463 acres with prescribed fire, and planted trees on 384 acres. In many cases WDFW lands are between private lands in the wildland urban interface (WUI) and USFS lands at higher elevations. Forest health and fuels reduction treatments on WDFW lands make important contributions to reducing the risk of wildfires moving between the WUI and USFS lands and vice versa. In addition, WDFW has partnered with USFS, Bureau of Land Management, DNR, State Parks, and other partners on cross-boundary thinning and prescribed fire projects.

WDFW and DNR plan to work together on projects on USFS lands under Good Neighbor Authority (GNA) with DNR taking the lead on forestry work and WDFW taking the lead on fish and wildlife conservation projects. An example partnership could include DNR managing a timber sale under GNA and WDFW using revenue from the timber sale to complete fish and wildlife habitat projects in the same watershed. Case studies featuring recent WDFW forest health treatments are featured in the Partnerships and Planning Section of this report.

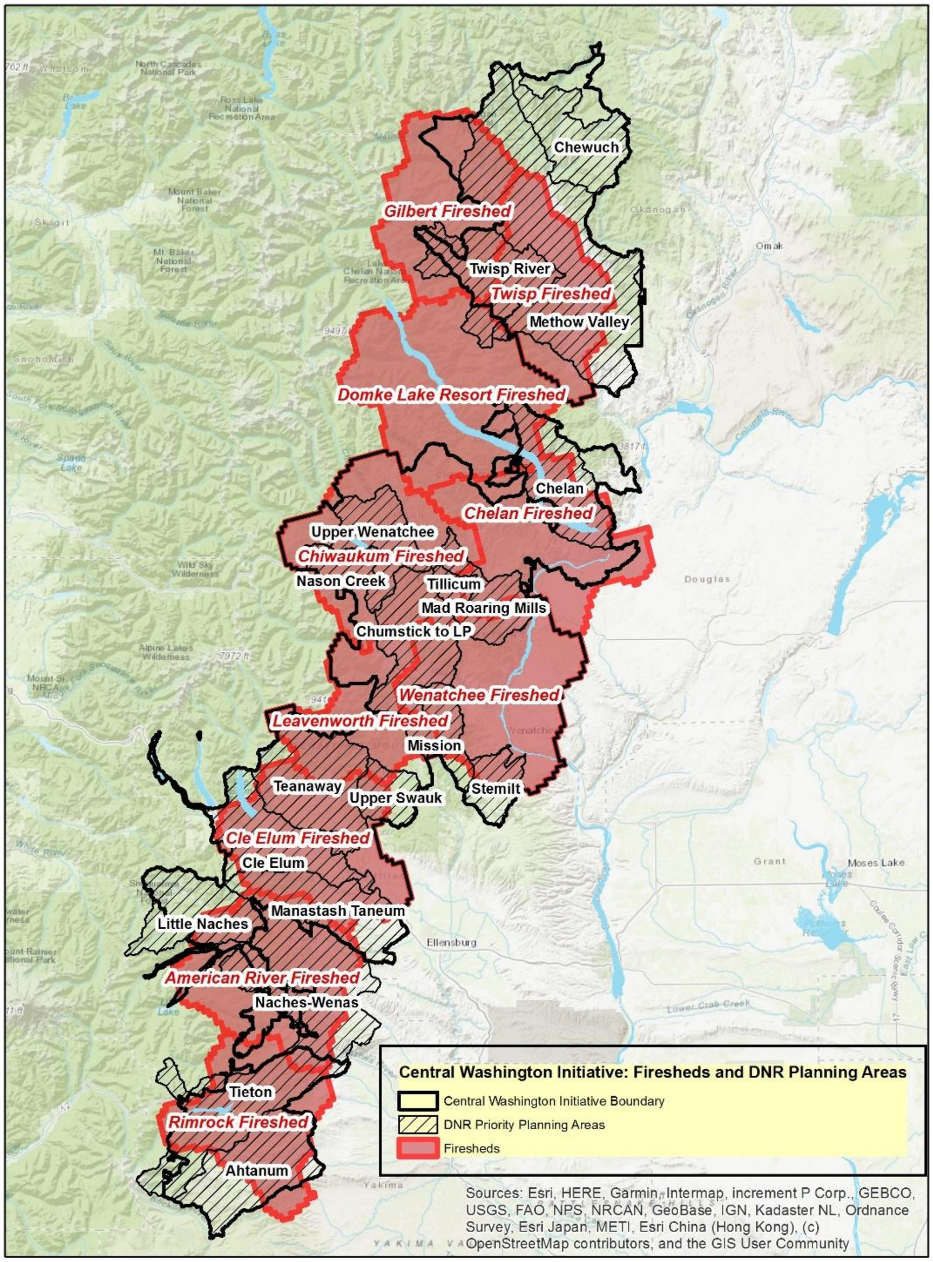
Confronting the Wildfire Crisis: A Strategy for Protecting Communities and Improving Resilience in America's Forests

In 2022, USDA Forest Service released a 10-year strategy focused on addressing the increasing risk posed by wildfire. The plan seeks to increase the scale of forest health treatments across the western United States, including mechanical fuels treatments and prescribed burning. The Forest Service reports that "overgrown forests, a warming climate, and a growing number of homes in the wildland urban interface, following more than a century of rigorous fire suppression, have all contributed to what is now a full-blown wildfire and forest health crisis."

The plan calls for treating 20 million acres of National Forest System lands in the next decade, as well as an additional 30 million acres of other Federal, State, Tribal, and private lands. As part of the Bipartisan Infrastructure Law passed by the 117th Congress and signed by President Biden, the federal government will invest more than $3.3 billion from 2022-2026 into the implementation of the plan and wildfire risk reduction activities.

In Washington State, the release of this new strategic plan, combined with the historic funding for forest health and wildfire through the Bipartisan Infrastructure Law, is leading to significant increases in funding for hazardous fuels treatments. In April, the USDA Forest Service announced the launch of the [Central Washington Initiative]() that focuses on 2.45 million acres of federal, state, county, private, and tribal lands in Okanogan, Chelan, Kittitas, and Yakima counties. This aligns with multiple DNR priority planning areas, and in June, DNR signed an MOU committing to leverage resources toward shared goals in the initiative landscape over the next 10 years.

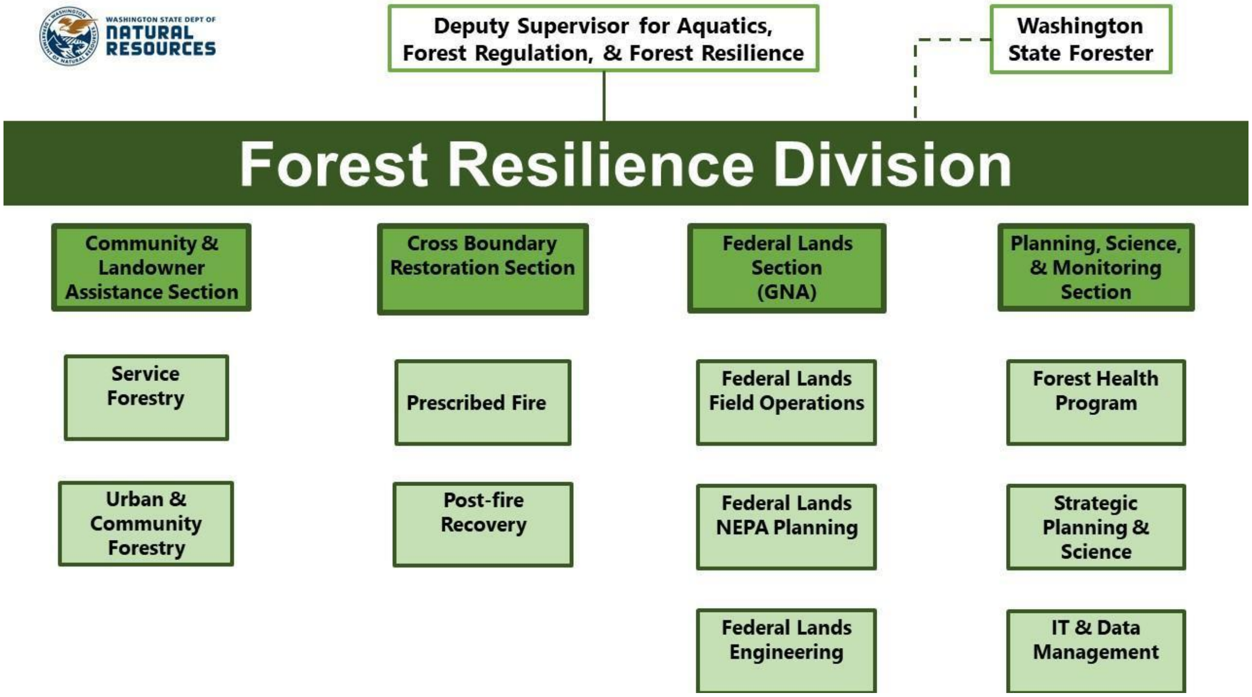
Figure 12. Central Washington Initiative Landscape and DNR Priority Planning Areas



Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

Washington DNR Forest Resilience Division Organizational Structure

In 2019, the agency established the Forest Resilience Division to work across all lands and in the interest of all Washingtonians to sustain and increase the health and resilience of our forests and local communities. The Division is a combination of previously existing agency programs focused on forest health insect and disease monitoring, landowner assistance and wildfire preparedness, urban forestry, and forest stewardship, as well as new programs focused on prescribed fire, federal lands restoration, forest planning, and landscape ecology. The division consists of staff based in Olympia as well as place-based and regional staff. The Division's work is delivered by programs within four sections: Community and Landowner Assistance, Cross-Boundary Restoration, Federal Lands (GNA), and Planning, Science, and Monitoring.



Planning, Science, and Monitoring

This section provides forest health insect and disease monitoring, including aerial surveys of forest health conditions that result in the annual Forest Health Highlights report. This team of forest pathologists, forest entomologists, and forest health specialists also provide technical assistance to forest landowners. Our scientists and planners lead the development and revision of forest resilience strategic plans, including the 20-Year Forest Health Strategic Plan: Eastern Washington and the state's Forest Action Plan. They work with partners across all lands to plan, implement, and monitor related activities while supporting the agency's climate change mitigation and preparedness work. This section oversees coordination of the Forest Health Advisory Committee, All-Lands Direct Investments, Building Forest Partnerships grant program, and stewardship of forest health data and information technology tools, including the Forest Health Tracker, to support the Division’s work.

Community and Landowner Assistance

This section combines three long-time DNR programs: Urban and Community Forestry, Landowner Assistance and Forest Stewardship. The Urban and Community Forestry Program works to educate citizens and decision makers about economic, environmental, psychological, and aesthetic benefits of trees. Staff members assist local governments, citizen groups and volunteers that plant and sustain healthy trees and vegetation where hpeople live, work and play. This section supports the shared mission to provide leadership to create self-sustaining urban and community forestry programs that preserve, plant and manage forests and trees for public benefits and quality of life.

The newly established statewide Service Forestry Program integrates the agency’s private landowner assistance programs into a single, statewide program to provide technical assistance, access to financial incentives, and forest health management planning to private landowners. This program is an integral part of direct delivery of technical assistance and educational services supporting proactive management of Washington’s non-industrial private forests. It provides land management advice to non-industrial private landowners and helps to assess resource conditions and forest health, identify potential problems and opportunities, determine cost-share eligibility, assist with treatment implementation, and recommend management practices to help achieve objectives. The program educates landowners and assists with development and implementation of management plans to guide current and future management actions.

Federal Lands

The Federal Lands Program focuses on using state expertise, resources and mechanisms to increase work on federal land throughout the state, primarily on National Forest System land through the use of DNR’s Good Neighbor Authority Agreement (GNA) with the federal government. This section works directly with USFS personnel to implement a variety of restoration projects, such as decreasing stream barriers for fish and other aquatic organisms, addressing forest road issues, timber sales, wildlife habitat enhancement and more. In addition to forest health treatment implementation through GNA, this program provides capacity and expertise to support National Environmental Policy Act planning. The program is funded through a variety of funding sources, including state and federally appropriated funds, and revenue derived from restoration projects with commercial timber as a component. The program has active projects on the five major national forests in Washington.

Cross-Boundary Restoration

The Cross-Boundary Restoration Section encompasses newly established programs that cut across land ownerships to deliver forest resilience outcomes. These include the prescribed fire program, post-fire recovery program, and the implementation strike team. The new prescribed fire program focuses on increasing safe and effective prescribed fire in Washington to restore forests and other ecosystems. The program focuses on prescribed fire training, funding prescribed burns, working with partners to promote and implement prescribed fire, and monitoring the effects of prescribed fire and wildfire. The section is standing up new programs to provide leadership and support for all-lands ecosystem function recovery post-wildfire, and additional capacity to increase the pace and scale of forest health treatments in the right place, at the right scale.

Significant work accomplished by DNR related to Forest Resilience occurs through its partnership with the U.S. Forest Service and other private and government entities implementing cooperative forestry, state, and private Forestry programs. DNR may continue to update and refine its organizational structure to reflect the needs of communities and our partners over time.

DNR Federal Lands Program Accomplishments

More than 12 million acres of Washington's land base is managed by the federal government. It is in the state's interest to ensure that forested acres within this land base managed by the Bureau of Land Management, US Fish and Wildlife Service, U.S. Forest Service, and Department of Defense are healthy and resilient. This biennium, DNR's Federal Lands Program received $8.7 million from the legislature to implement 2SHB 1168. The funds, and use of Good Neighbor Authority (GNA), enabled forest restoration work while enhancing workforce development.

Implementation of restoration projects including hazardous fuels reduction projects, commercial timber sales, aquatic and forest road infrastructure improvement projects and completing deferred road maintenance, makeup the diverse work portfolio of the program. In addition to implementing projects, the program also accelerates planning and supports compliance with the National Environmental Planning Act (NEPA). NEPA is required to conduct restoration projects on federal lands, and DNR is providing support through in-kind technical assistance and contracted services.

Tillicum Hazardous Fuels Reduction Project. This 4000-acre thinning project was administered by the DNR Federal Lands Program on the Okanogan-Wenatchee National Forest. Photos show before thinning (left) and after thinning (right) in Unit 28 of the project area. Photos by John Marshall.

Statewide, the program has sold approximately 73 million board feet (MMBF) through commercial restoration projects, which will generate up to $13 million dollars in program revenue. Program revenue will be reinvested in forest restoration and management activities on federal lands in Washington. Projects will include vegetation management as well as habitat restoration, improved forest roads and recreation access, and aquatic restoration. In total, the program has committed to 80 projects with 14 complete, 16 in implementation, and 50 planned.

Table 7: DNR Federal Lands Program Good Neighbor Authority Project Accomplishments 2018-2022 (State Fiscal Year)

Federal Lands Program GNA Accomplishments 2018-2022	**Commercial Acres**	**Non-Commercial Acres**	**Aquatic Improvement Projects (Count)**	**Deferred Maintenance (Miles)**	**Decommissioning (Miles)**	**NEPA Projects Completed**
2018-2020 eastern Washington	2135	967		24	3	
2018-2020 western Washington	1439	0	24	27	11	0
Total 2018-2020	**3574**	**967**	**24**	**51**	**14**	**0**
2021 eastern Washington	1354	1225	1	18	2	1
2021 western Washington	739	0	4	24	2	1
Total 2021	**2093**	**1225**	**5**	**42**	**4**	**2**
2022 eastern Washington	308	4882	0	0	0	3
2022 western Washington	659	0	5	66	4	1
Total 2022 to date	**967**	**4882**	**5**	**66**	**4**	**4**
Total 2018-2022 to date	**6634**	**7074**	**34**	**159**	**22**	**6**

Good Neighbor Authority Project Highlight: Tillicum Hazardous Fuels Reduction Project

In partnership with the Okanagan-Wenatchee National Forest, the DNR Federal Lands Program is conducting one of the largest non-commercial fuels reduction projects in recent history. The Tillicum Hazardous Fuels Reduction (HFR) project represents a formative step in the progression of the 20-Year Forest Health Strategic Plan by making a $3.3 million investment with funds provided by 2SHB 1168. The project includes landscape scale fuels reduction on more than 4,000 acres under a single contract.

DNR completed all the associated field work and contract design, competitively bid the project, and conducted all subsequent contract compliance. This project includes hand pruning, limbing, and piling overly dense vegetation under 8 inches across a vast area on slope inclines ranging from 30-80%. At times, over 70 contractors with chainsaws were working to complete this project and compliance was conducted with three DNR Federal Lands Program staff to effectively manage a contract at this scale.

Hand-thinning crew that implemented the Tillicum GNA Project. Photo Credit: John Marshall

The project is within the Tillicum priority planning area. Combined with prior DNR funded treatments and US Forest Service implementation, over 70% of the landscape evaluation's identified mechanical treatment need on operable acres will be have been treated within a 4-year window. Critical prescribed fire and treatment of fuel piles will follow. This will be one of the first priority planning areas to reach a point that the forest condition has changed at-scale due to proactive treatments. This priority planning area effectively acts as proof of concept. The next phase of work in the Tillicum priority landscape will be to conduct the post-treatment monitoring work to confirm if the treatment objectives were met.

State Agency Partnerships: Implementation of Forest Health Treatments in Priority Planning Areas

Washington Department of Fish and Wildlife

Contributing Authors: **Mike Kuttle Jr., Richard Tveten**, **Matt Eberlein**, **Paul Dahmer**, **Cynthia Wilkerson** (WDFW)

Washington Department of Fish and Wildlife's mission is "to preserve, protect and perpetuate fish, wildlife and ecosystems while providing sustainable fish and wildlife recreational and commercial opportunities." There are 33 wildlife areas owned or managed by WDFW, and each maintains a management plan that guides agency decision-making.

This section of the report highlights two recent forest health projects completed by WDFW in wildlife areas in eastern Washington, Ramsey and Burch Mountain, both of which are within DNR priority landscapes.

Ramsey Unit - Methow Wildlife Area (WLA)

In 2019 WDFW thinned the Ramsey unit of the Methow WLA to improve wildlife habitat, restore forest health and reduce wildfire risk. The below photos show how thinning restored the general structure of the forest.

Unthinned stand (left) and thinned stand (right) at the Methow Wildlife Area. Photo by WDFW.

Due to COVID 19, WDFW was not able to conduct the prescribed burning as planned in the spring of 2020. Thus, slash and deep duff were still present when the Cub Creek 2 wildfire burned through part of the unit in late summer 2022. While thinning alone did aid in fire suppression and response, and thinning was able to reduce wildfire impacts in some parts of the unit, the fire killed large trees and about one quarter of the area burned.

Thinned areas with high and low tree survival in the Cub Creek 2 wildfire. Photo by WDFW.

In the fall of 2021 WDFW conducted a prescribed burn on the remaining portions of the Ramsey unit of the Methow WLA. The main goal of the burn was to follow up after the commercial harvest from 2018 to reduce harvest debris, enhance forage for wildlife, and prepare the site for native grass seeding directly after the burn. This burn was unique, it was conducted just several months after the devastating Cub Creek 2 fire that burned portions of the Methow WLA and a section of the planned burn site.

> *"This situation created a learning opportunity for the community and visitors of the Methow Valley. WDFW wanted to show the difference between planned and unplanned fires and their effects,"* said Matt Eberlein, WDFW prescribed fire program lead. *"We were very careful in our planning efforts and did a considerable amount of public outreach months prior to the burn. Public media and community groups were invited to visit the site to view what the Cub Creek fire had done and what we were planning to do prior to the fire."*

On June 23, 2022, Methow Valley community members, conservation groups, and local public officials were invited to return to the site seven months after the burn was completed. Participants were able to view the effects of the Ramsey unit prescribed burn and the Cub Creek wildfire. Several sites provide a stark visual contrast between the different effects a crown fire has versus a planned, low-severity prescribed fire. Other topics discussed were smoke management and the great care and planning that goes into a prescribed burn, such as burn plans, smoke management, and burn windows.

Prescribed fire in a thinned unit (left) and an image of the post-fire condition the day after the prescribed burn on the Methow WLA. Photos by WDFW.

Burch Mountain – Swakane Wildlife Area Unit

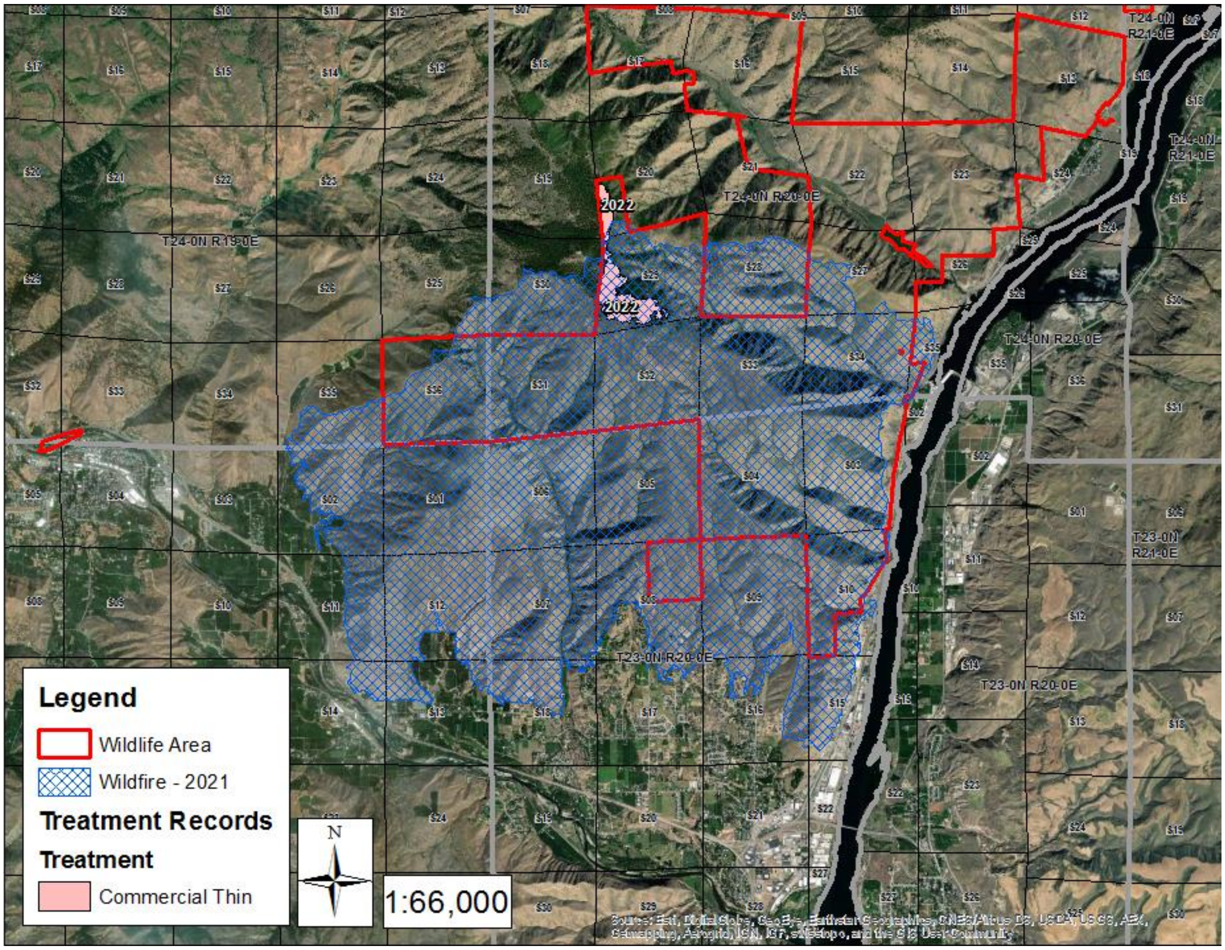
Portions of the Burch Mountain unit are characterized by overstocked forests in historically open, ponderosa pine and mixed pine and Douglas fir woodlands. Wildlife area managers planned a forest health treatment to be implemented in 2021. Unfortunately, just as WDFW was working to secure a contractor to implement the project, the 2021 Red Apple wildfire burned through the area. Approximately 20 percent of the proposed project had to be dropped from treatment as a result of high levels of tree mortality in the stand.

In 2021, WDFW commercially thinned 90 acres on the site. The treatment reduced fuel loads, removed fuel ladders, increased resources for remaining dominant trees, shifted species composition toward fire and drought tolerant species, and reinvigorated browse vegetation for mule deer within thinned areas. On average, WDFW estimates that 1,800 tons or approximately 20 tons per acre of biomass were removed from the site.

Untreated (left) and treated (right) stand at Burch Mountain. Photo by WDFW.

WDFW plans to burn slash piles and pre-commercially thin over dense thickets of small trees in 2023. The long-term objective of forest management on the site is to further reduce fuels with prescribed fire and periodically thin as necessary.

Figure 13. Map of Swakane Wildlife Area and the 2021 Red Apple Fire



Washington State Parks

Contributing Authors: **David Cass, Zach St Amand** (Washington State Parks)

Washington State Parks is nationally recognized as one of the best state park systems in the country. State Parks features 124 parks, 13 interpretive centers, 770 historic structures, and 500 miles of long-distance trail. In 2019, State Parks hosted 37 million visitors contributing about $1.4 billion to the state's economy.

The mission of Washington State Parks is "to care for Washington's most treasured lands, waters, and historic places." Parks and public lands connect all Washingtonians to their diverse natural and cultural heritage and provide memorable recreational and educational experiences that enhance their lives. State Park's stewardship program is tasked with helping care for these lands as subject matter experts in natural resources, archeology, and historic preservation.

Stewardship highlights include:

- State Parks include 122,000 acres of uplands of which about 85,000 acres are forested;
- >10% of our acres contain ecosystems that provide habitat for rare plants or animals or both.
- >40% of our acres support ecosystems that are at moderate to severe risk of extirpation at the state or global level;
- State Parks manages most of the remaining low-elevation old-growth forest in the state.

Log deck from the Bullfrog forest health project on State Park land near Cle Elum. Photo by DNR.

State Parks and Wildfire

- There are fires in State Parks every year. Many of our rangers are trained wildland firefighters that conduct initial response to wildfires in parks.
- Parks have a high potential rate of ignition as a result of lots of people, campfires, and fireworks; though most fires that occur in State Parks start outside of park boundaries.
- Parks have a lot of facilities, visitors, and are often near development meaning wildfires in parks pose risk to life and property.
- Parks have a lot of fuels. Most undeveloped lands are passively managed, so in fire adapted ecosystems they have accumulated heavy fuels during the fire suppression era. When you look at a satellite photo that includes state park lands, they are often the

darkest green block of land in the general area.

- State Parks are in a position on the landscape to be of critical importance and critically at risk in managing wildfires. Compared to other public lands in Washington, State Parks has the highest proportion of lands that are in the Wildland Urban Interface (WUI).

Trautman Forest Health Project

Riverside State Park encompasses 9,185 acres within the City of Spokane and Spokane County. The park is characterized by dry ponderosa pine forest. Most of the acreage of the park is in the WUI and most of the boundary abuts private landowners, primarily residential properties.

In fall 2021 through spring 2022, State Parks completed a 288 acre non-commercial forest health thinning on the Trautman Conservation Ranch, a Spokane County owned property managed by State Parks through a long-term lease agreement. In 2018, Parks conducted a wildfire risk assessment. The assessment identified portions of Riverside as having very high surface fire and crown fire potential.

State Park's forest health goals go beyond reducing wildfire risk. Management goals include removing diseased and low-vigor trees and contributing to overall forest and non-timber plant health, while maintaining valuable wildlife habitat. Along the roadways State Parks completed shaded fuel break treatments. On the interior the agency removed many of the stems, but left skips and untreated patches as wildlife cover to promote a mosaic and heterogeneous landscape. State Parks is also finding old growth trees and thinning around them to promote vigor and reduce ladder fuels.

Before treatment (left) and post-treatment photo (right) from the Trautman forest health project. Photos by Washington State Parks.

In the next year, State Parks plans to burn piles created during the thinning and conduct noxious weed control where needed. Then, if practicable and safe, State Parks will prescribe burn treated areas to further reduce activity fuels and reintroduce low-severity fire. There may be additional commercial and non-commercial thinning operations planned in the future to maintain the desired stand structure and diversity.

The thinning work in 2021-22 was conducted by DNR Heights Crews and funded in part through state legislative funds provided to DNR through 2SHB1168.

Bullfrog forest health project on State Park land near Cle Elum. Photo by DNR.

Partnerships with Private Landowners

Department of Natural Resources Service Forestry Program

Approximately 15 percent of Washington's forested acres are owned by small forest landowners. Although forest acres across Washington declined by 2 percent between 2007 and 2019, the number of small forest landowners increased over that same time period by 8.5 percent, or 17,000 new small forest landowners. More than 75 percent of these landowners own less than 20 acres.

The DNR Service Forestry Program aims to be the primary point of contact for small forest landowners who may have questions about their forest. The Service Forestry Program officially got up and running in 2022; however, the program is far from new – Service Forestry combines two programs, the Stewardship Forestry Program and the Landowner Assistance Program, into one and. Along with the programs administered by the Small Forest Landowner Office, it provides a one-stop-shop for landowners across Washington.

Photos of forest health thinning and defensible space work conducted on small private forest landowner parcels by the DNR Service Forestry Program and Cascadia Conservation District. Photos by DNR and Cascadia Conservation District.

Service forestry helps reduce the need for landowners to visit with multiple specialists. Service foresters are trained and able to speak intelligently on a wide range of topics, from common forest pathogens to fire-resilient land management, timber harvesting, and wildlife habitat.

After a visit with a service forester, landowners should come away with a holistic view of their property's health, options for management, as well as programs and services that can help assist them meet their management goals. In addition to being educated on a variety of subjects related to forest health, all service foresters are well versed in the different programs (both those offered through DNR and through partner agencies), and are able to recognize when landowners are eligible for these programs.

Coupled with its expanding roles, the Service Forestry Program also significantly widened its geographic coverage and staff depth. The Program now includes the following positions:

- 1 program manager
- 6 program coordinators
- 3 financial assistance program administrators
- 6 district managers
- 1 wildlife biologist
- 30 foresters

This expansion significantly increases capacity for the Service Forestry Program to serve the entire state. All service forester consultations are offered free of charge – landowners just need to sign up by contacting their local DNR office, or filling out the online consultation form.

From Oct. 1, 2020 to Sept. 30, 2022, DNR approved 392 new stewardship plans covering 71,846 acres. During the same time period there were 820 forest stewardship plans covering 126,066 acres across the state.

The expansion of the program also comes with the expansion of the financial assistance program into western Washington. Prior to Aug. 1, 2022, the financial assistance program was only available to landowners in eastern Washington. Originally part of the landowner assistance program, this program pays a portion of the costs for landowner implementation of forest health, wildfire resilience, wildlife habitat, or other related treatment activities. Landowners with 5,000 acres or less of forestland are eligible for financial assistance.

Before (left) and after (right) photos of a private landowner forest health cost-share treatment administered by DNR Service Forestry Program. Photo by DNR Southeast Region Service Forestry.

In the 2021-2023 biennium, DNR's Service Forestry program committed to implement 13,100 acres of cost-share projects with willing landowners. As of fall 2022, 10,773 acres of forest health treatments have been completed through financial cost-share with small forest landowners for the 21-23 Biennium in eastern Washington using state funds and leveraged federal resources.

To increase accessibility of the program's services to small forest landowners, this year DNR developed and launched the Landowner Assistance Portal, a one-stop shop for a small forest landowners information needs which includes a new Find Your Forester online map tool.

Washington State Conservation Commission

Contributing Author: **Shana Joy** (Washington State Conservation Commission)

Throughout the state, conservation districts (CD's) and the Washington Department of Natural Resources (DNR) are often working collaboratively on a number of different projects. Conservation districts are experts in their service to landowners in a variety of areas, from soil restoration to riparian work to food system assistance. In many areas, conservation districts are also leading efforts in community resilience planning, home hardening work, and forest health work oriented at the individual and community level.

Due to many of the conservation districts filling niches in natural resource services that, in some geographic areas, DNR may fill, there have been historic challenges with getting funds for conservation districts to do this work. Funds from 2SHB 1168 have started to change this. For the 2022 fiscal year, DNR and the State Conservation Commission – which heads all of the state's conservation districts – developed an agreement that covered Ferry, Okanogan, Cascadia, Kittitas County, North Yakima, Underwood, Mason, Snohomish, Skagit, Whatcom, Pierce, and Whidbey Island Conservation Districts to do forest and community resilience projects. $368,000 were spent on projects ranging from home wildfire risk assessments, community wood chipping events, tree thinning, community workshops and events, and preparing and distributing informational newsletters.

Highlights of the work completed in the agreement (February to June, 2022) include:

- 106 wildfire home risk assessments
- 28 fuels related chipping days that helped 28 communities across Whatcom, Mason, Yakima, Kittitas, Snohomish, Okanogan and Klickitat counties.
- 4 Community Wildfire Protection Plans initiated and/or engaged in development
- 80,000 households reached with postcards, newsletters and locally published articles about wildfire resilience and community preparedness.

Defensible space thinning around a home in Chelan County. The project was administered by Cascadia Conservation District. Photo by Cascadia Conservation District.

The State Conservation Commission and DNR agreement benefits participating Conservation Districts and reduces the administrative burden on agency staff and partners. Due to the success of the past agreement, the State Conservation Commission and DNR have a new agreement for fiscal year 2023.

All-Lands, All-Hands Cross-Boundary Partnerships

This biennium, DNR established an All-Lands Direct Investments program funded by state dollars to implement House Bill 1168. Project funding was directed towards planning and implementation of forest health treatments in priority planning areas. More than $2.5 million of investments have been made or committed in contract to date, resulting in over 3,300 acres of forest health treatments completed.

Table 8. 2021-2023 All Lands Direct Investments

Land Ownership Impacted	Deliverables completed FY22 and under contract for implementation in FY23	Implementing Organizations Funded to Lead Forest Health Activities
Tribal	503 treated acres	Kalispel Tribe of Indians, Umatilla Tribes
State	1,152 treated acres	WA State Parks, WA DNR
Federal	1,220 treated acres, 3000 acres prepped and laid out, 34 Beaver Dam Analogs (BDAs) constructed, 700 native plants installed, 15 beavers re-located, 1.5 miles of road maintained, over 1000 tons of aggregate purchased and delivered to spread on national forest system roads and reduce resource impacts.	A&E LLC, Cadman Heidelberg Cement Group, Cascade H & A, Columbia Gorge Scenic Area, Colville Confederated Tribes, Mount Adams Resource Stewards, Mount Baker Snoqualmie National Forest, Okanogan-Wenatchee National Forest, Olympic National Forest, Resilient Forestry, Snohomish County, Umatilla National Forest
Local	200 lbs of native seed mix for the City of Roslyn's Urban Forest	Benson Native Seed
Private	464 acres treated	American Forest Management, Cascadia Conservation District, San Juan Conservation District, The Nature Conservancy
Total	3,339 acres treated 3,000 acres prepped and laid out 1.5 miles of road maintained 34 BDA's installed, 700 native plants installed, 200 lbs of native seed distributed, and 15 beavers re-located	Funds distributed to 20 organizations

Building Forest Partnerships Program

Collaboration across boundaries depends on people and relationships. DNR awarded $476,000 this biennium to help forest collaboratives engage their communities, grow partnerships to contribute towards implementation of RCW 76.06.200, and deliver on our strategic plan goals. Funding helped ensure Washington's forest collaboratives have access to professional facilitation and meeting coordination, enabling forward momentum in collaborative efforts and projects.

The dollars have facilitated positive strides toward community engagement with local stakeholders related to forest health issues, supported planning and implementation of critical survey work needed to conduct forest health related management activities, as well as empowered members to lead and engage shared stewardship strategy conversations to get important treatments done. The Building Forest Partnerships program supported more than 500,000 acres of forest health project planning in priority landscapes from 2021-2023.

Upper Wenatchee monitoring plan field tour hosted by the North Central Washington Forest Health Collaborative. Photo by Cascadia Conservation District.

Table 9. Building Forest Partnerships Program Investments 2017-2023

Funding Recipient	Counties	2017-2019 Biennium	2019-2021 Biennium	2021-2023 Biennium
Chumstick Wildfire Stewardship Coalition	Chelan	$25,000	$40,000	$50,000
Darrington Collaborative	Pierce, King, Snohomish, Skagit, Whatcom	$25,000	$40,000	$50,000
North Central Washington Forest Health Collaborative	Okanogan, Chelan, Douglas	$25,000	$40,000	$50,000
Northeast Washington Forestry Coalition	Ferry, Stevens, Pend Oreille	$25,000	$40,000	$50,000
Olympic Forest Collaborative	Clallam, Jefferson, Grays Harbor, Mason	$25,000	$40,000	$50,000
Pinchot Partners	Skamania, Thuston, Lewis, Pierce	$25,000	$40,000	$50,000
San Juan Islands Forest Health Collaborative	San Juan	N/A	N/A	$50,000
South Gifford Pinchot Collaborative Group	Skamania, Cowlitz, Clark, Klickitat, Yakima	$25,000	$40,000	$50,000
Stemilt Partnership	Chelan	$7,000	$28,000	$26,000
Tapash Sustainable Forest Collaborative	Klickitat, Yakima, Kittitas, Chelan	$25,000	$40,000	$50,000
Total Forest Collaborative Building Forest Partnership Funding		**$207,000**	**$348,000**	**$476,000**

Prescribed Fire Program

Prescribed fire is a critical tool for improving forest health and resilience across all-lands. Dry-forest ecosystems in central and eastern Washington evolved with frequent fire. These types of forests, dominated by species such as ponderosa pines and other fire-adapted plants, historically had low-intensity fires burn in the understory at least once every decade. Low-severity fires reduced the amount of ladder fuels capable of taking fires up into tree canopies and removed continuous surface fuel, creating natural firebreaks and diverse vegetation mosaics. Reintroducing fire to the landscape is meant to mimic the benefits of historic frequent, low-severity fires.

DNR launched a Prescribed Fire Program in the fall of 2021. The program intends to identify and address the overarching and systematic challenges that practitioners and land managers face when planning and implementing prescribed fire projects. Specifically, the program is working with partners to address prescribed fire policies, regulatory requirements, funding, training, and planning support.

Prescribed burn in October 2022 at Camas Meadow Natural Area. Photo by DNR.

Prescribed fire treatments are typically described as either pile burning or broadcast burning. Experienced land managers follow a burn plan guided by state and federal regulations with site-specific environmental objectives and limitations. Safety is the number one priority of DNR's prescribed fire policy – if the weather and fuels conditions do not meet predetermined standards, burning will not be conducted on that day.

This past year, skilled professionals within the agency conducted prescribed fire operations on DNR-managed lands and assisted partner agencies with prescribed burning on land they manage. In addition to support towards several successful burns on DNR State Trust Lands, in fiscal year 2022 DNR staff and resources directly supported delivery of over 1,613 acres of Rx burns and 775 piles burned on Colville Confederated Tribes Reservation lands, federal, local, and private lands. Other metrics of success include:

- DNR fire staff assisted the Confederated Tribes of the Colville Reservation for 939 acres of prescribed burning in Spring 2022 and 2,028 acres in Fall 2022.
- DNR staff attended three (3) Prescribed Fire Training Exchange (TREX) events in the western US to work on firing and burn boss qualifications.
- Invested over $300,000 in cooperative burn training and community-organized operations.

This biennium, DNR developed a Certified Prescribed Burn Manager (CPBM) Program to bolster the capacity of prescribed burners in the state, while ensuring that all land managers leading prescribed burns have a consistent set of skills and knowledge to achieve safe outcomes on the ground. The CPBM Program is not intended as a "learn to burn" class, but provides experienced fire practitioners an overview of burn planning expectations and the state-specific regulatory processes they're required to follow.

Those who complete the Certified Burner classroom portion of the course must also lead a burn operation under observation of a certified evaluator in order to complete their certification process, allowing them to benefit from increased liability protections.

DNR hosted the first CPBM course for members of the public in early 2022. The DNR certified burn program manager, along with other DNR personnel, led the multi-day class, which included more than 20 participants representing a variety of organizations, including Cascadia Conservation District, Center for Natural Lands Management, Chewack Wildfire, Ekone Organization, Kalispel Tribe, Kittitas County Fire District, Lionberger Fire and Forestry, Methow Valley Citizens Council, Mount Adams Resource Stewards, Rayonier Forestry, South Puget Wildland Team, Spokane County Fire District, Washington DNR, Washington Prescribed Fire Council, and private landowners. The course included information about legal requirements, safety, weather, fire behavior, smoke management, prescribed fire techniques, public relations, planning, and contingencies (as described in RCW 76.04.183).

"Going in and evaluating how things burned and how it consumed fuels is going to be a big learning curve for a lot of us. I haven't written a burn plan before. I've done a lot of prescribed fire, but I don't think about the idea of it by looking at a component in the forest and thinking about what I'm going to get rid of. I think of it more from the wildland fire component, like what's going to create a really good holding line for a town like Roslyn. How we are going to defend that space when wildfire comes next to the town." - Eric Kiehn, Captain of Kittitas County Fire District 1

The first participant to become certified through the new program was Lucas King, Stewardship Crew Program Lead at Mount Adams Resource Stewards (MARS) in Glenwood, Washington.

"This program will continue to improve and grow state-wide capacity to implement safe and effective prescribed fire on private lands to reduce the risk of catastrophic fire and improve overall forest and watershed health. Washington DNR staff were helpful, supportive, and communicative through this initial rollout of the program. DNR went out of their way on short notice to help facilitate multiple prescribed burns this spring including the prescribed fire on June 1, 2022 that was my evaluation burn on the Mt. Adams Community Forest." – Lucas King, Mount Adams Resource Stewards

Ignition team on the Mount Adams Resource Stewards led 2022 Pine Flats RX Burn.
Photo by Mount Adams Resource Stewards.

Table 10. Summary of Washington State Prescribed Fire Activity*

Year	# of RX Fires	RX Acres
2021	117	12,530
2022**	76	9,585

*Based on Regional SIT reporting system; does not include all-lands, such as acres burned on private land.
**Statistics current as of November 3, 2022

Prescribed fire on the Mount Adams Community Forest on June 1, 2022. Photo by Mount Adams Resource Stewards.

State and federal partners collaborate on prescribed burn in Okanogan County to improve forest health and decrease wildfire severity

The Washington State Department of Natural Resources (DNR), Washington Department of Fish and Wildlife (WDFW) and U.S. Bureau of Land Management (BLM) partnered in 2022 to implement a cross-boundary prescribed burn. The three agencies worked together to conduct a cooperative, cross-boundary prescribed fire operation on 127 acres of a 250-acre project area about three miles south of Loomis in northern Okanogan County.

Each of the three units mapped as part of the burn plan include land under the jurisdiction of at least two of the partnering agencies. The full project area will treat approximately 140 acres of land managed by DNR, about 80 acres of the Sinlahekin Wildlife Area Sinlahekin Wildlife Area managed by WDFW, and about 40 acres managed by BLM. Planning and implementing the burn in coordination with adjacent landowners enabled all agencies to treat more acres and reduce overall wildfire risk across ownership boundaries.

The tri-agency project is an example of cross-boundary collaboration to improve forest health in Washington. The 20-Year Forest Health Strategic Plan released in 2017 by DNR places an emphasis on the all lands, all hands approach to forest health.

"This partnership between three public land management agencies highlights the impact that cross-boundary prescribed fire operations can have on our efforts to make our forests healthier and more resilient against wildfire," Washington Prescribed Fire Council President Chris Martin said. *"Prescribed fire is a cost-effective tool with a high rate of success for accomplishing the goals we all share for Washington forestlands. We are grateful for Commissioner Franz's leadership in bringing prescribed fire back to state lands."*

Prescribed burn on DNR State Trust Lands in 2022. Photo by DNR.

Prescribed fires reduce fuels that contribute to high-severity wildfires, boost the health of older trees by thinning overcrowded stands competing for limited water and sunlight, support new wildlife habitats by creating open spaces and snags, and enhance soil conditions by recycling nutrients into the ground.

“The Northeast Region of DNR is thrilled to implement this cross-boundary prescribed burn in the spirit of cooperation with our land management partners at WDFW and BLM,” said Northeast Region Assistant Manager for State Lands Pat Ryan. “Wildfire knows no boundaries, so this proactive prescribed burn will reduce the impacts to the resources and lands we manage before the next wildfire hits.”

Northeast Washington Prescribed Fire Training Exchange

The 2021 Northeast Washington Prescribed Fire Training Exchange (NE TREX) was hosted that spring in the northeast corner of Washington, primarily in Stevens, Pend Oreille, Ferry, and Spokane Counties. The spring 2021 NE TREX was highly successful, with 24 participants supporting four prescribed fire projects over seven days and assisting with activities including unit preparation, ignitions, and mop-up.

The TREX planning team coordinated with Tribal, federal, and state agencies to host trainees and to support prescribed fire operations for a total of 246 completed acres. In addition to training and burning, the NE TREX planning team coordinated with multiple private landowners to take significant steps towards ultimately conducting prescribed burns on their lands. The TREX team worked with partners to identify potential landowners, conduct site visits, and begin developing prescribed burn plans on four properties with an additional prescribed burn plan developed with the Kalispel Tribe.

As a result, the Kalispel Tribe was able to take advantage of this groundwork laid in 2021 and successfully complete additional units in October 2022 in collaboration with TREX. By using qualified TREX planning staff, the tribal fire program manager was able to complete tasks for his National Wildfire Coordinating Group (NWCG) Burn Boss qualification and meet the requirement to lead a burn as part of their Certified Prescribed Burn Manager certification. By focusing on local participants and by bringing TREX to new locations in the state, the program intends to develop capacity, expertise, interest, and leadership to support long-term stewardship and locally led burning.

Northeast Washington Prescribed Fire Training Exchange (TREX) Fall 2022. Photo by Rob Lionberger.

20-Year Forest Health Strategic Plan Monitoring Framework

One of the five overarching goals of the 20-Year Plan is to "develop and implement a forest health resilience monitoring program that establishes criteria, tools, and processes to monitor forest and watershed conditions, assess progress, and reassess strategies over time".

During the 2018-2020 biennium, DNR science staff worked with a wide range of partners to develop a monitoring framework based on this goal. The monitoring framework, which was included in the 2020 legislative report, defines a set of specific questions to guide monitoring, describes methods and datasets, and defines roles of DNR staff and partners to accomplish the work at three different levels: eastern Washington region, planning areas, and treatment units. The framework is centered on two overarching questions:

1. How are forest conditions and associated forest health indicators changing over time? We quantify numerous indicators, including wildfire risk, vulnerability to drought and insect outbreaks, wildfire habitat conditions, departure from resilient landscape conditions, as well as social and economic indicators.

2. What are the outcomes of forest health treatments? We assess outcomes by tracking and mapping treatments, and assessing how they are changing vegetation conditions and affecting associated forest health indicators.

Over the course of the 2021-23 biennium, DNR staff have devoted extensive efforts to put the monitoring framework into practice in order to address these questions. Working with many partners from research institutions, land management agencies, NGOs, consulting firms, local government agencies, and other organizations, DNR staff have built out the core components (data collection, methodologies/tools, and reporting) described in the framework.

DNR staff have actively engaged partners through several key mechanisms. These include the monitoring subcommittee of the Forest Health Advisory Committee, establishing a working group with key Forest Service regional and forest-level staff to coordinate monitoring efforts, and assisting planning area monitoring efforts that are being led by the Forest Service or other partners.

Monitoring Updates: 2021-2023 Biennium

DNR is excited to report on the progress that has been made in developing and implementing the monitoring framework of the 20-Year Forest Health Strategic Plan. In coordination with many partners, DNR staff have built datasets and tools to begin answering key monitoring questions and to inform adaptive management. These include: tools to comprehensively track and report progress related to treatment targets and implementation; datasets and methods to quantify changes in conditions from treatments, wildfires, and insects; and approaches to understanding how these changes affect forest health indicators. Tools also include a treatment unit monitoring system to facilitate field data collection and long-term data storage that partners can adapt to meet their needs.

We now have the datasets and tools to begin answering the two overarching questions listed above in priority landscapes, as well as in other parts of eastern Washington. While we are still developing some of these components, DNR and our partners have produced monitoring results at all three levels (regional, planning area, and treatment unit) that are beginning to inform implementation of the 20-Year Forest Health Strategic Plan.

In this chapter, the components of the monitoring framework are described as they were developed over the last two years at the regional, planning area and treatment unit level. This chapter of the legislative report also highlights key results and describes the implications of these results for DNR and our partners. Major components include:

Regional and Planning Area Monitoring

- **Forest Health Treatment Tracking:** DNR collects forest treatment data reported by land owners and managers. The report quantifies treatment acres, describes the types of treatments, and their spatial locations on a semi-annual basis. Forest Health Tracker is a publicly available online tool.

- **Change Detection:** Utilizing satellite and photogrammetric (aerial imagery) datasets, DNR science staff developed methods to (1) map disturbances including treatments, insects, and wildfires, (2) assess forest structural changes. These datasets are used, in combination with treatment tracking data, to quantify change in priority landscapes and across eastern Washington.

  Within priority planning areas, data on forest structural changes is used to determine progress towards landscape-level treatment and restoration targets from landscape evaluations. Forest structure data is based on NAIP imagery and covers most of eastern Washington between 2015 and 2021. These datasets were developed in partnership with DNR State Lands, University of Washington, and the USFS.

- **Evaluating the Work of Wildfires:** Wildfires are the largest disturbance agent in eastern Washington by several orders of magnitude. Over 460,000 acres of forest burned in 2021 alone. DNR staff conducted a comprehensive analysis and report on how the 2021 fires moved landscapes towards or away from desired conditions and treatment targets. DNR developed tools for rapid mapping of burn severity and post-fire treatment needs.

- **Wildfire Emissions:** Wildfires are a major source of carbon emissions in the western United States. To better understand how these emissions fit with the overall carbon budget for the state of Washington, DNR scientists analyzed wildfire emissions between 2014 and 2021 using the best available methods.

- **Social Science Monitoring:** 2022 marks the fifth year since the 20-Year Forest Health Strategic Plan was released. DNR hired an outside social science research firm to survey and interview highly-engaged stakeholders and partners to assess plan implementation. The assessment identified key areas of progress, perceived needs, and opportunities to enhance partner engagement, external communication, and cross-boundary planning and implementation.

- **Economic Analysis of the 20-Year Forest Health Strategic Plan:** DNR partnered with RTI International to evaluate the economic impacts of implementing forest health treatments across all-lands as well as the economic impacts of DNR State Lands treatments in eastern Washington.

- **Modeling Landscape-Scale Treatment Effects on Snowpack and Streamflow in the Nason Creek Watershed:** Through a partnership with the Pacific Northwest Research Station and the Pacific Northwest National Laboratory, we modeled the impacts of landscape-scale restoration treatments on snowpack and streamflow in the Nason Creek Planning Area. We are expanding this work to broadly model the impacts of the 20-Year Plan treatments on snow and streamflow, determining landscape locations where treatments and wildfires can have the biggest impacts.

- **Cle Elum Snowpack Study:** The net effect of forest management actions on extending or curtailing snow storage varies with climate, topography, and forest characteristics. Considerable uncertainty exists in some climate zones where forest management is most active. The eastern Cascades encompass one such zone that is particularly vulnerable to wildfire risk and water scarcity, yet there is no empirical data observing the relationship between forest canopy, snowpack, and topographic position. In order to fill this data gap, project partners collected three years of field observations of snow depth and duration across a range of forest and climate conditions, and across topographic positions.

- **Upper Wenatchee Pilot Project Monitoring Plan:** In 2017, the Okanogan-Wenatchee National Forest (OWNF) initiated planning on approximately 60,000 acres in close coordination with the North Central Washington Forest Health Collaborative (NCWFHC). The project area, known as the Upper Wenatchee Pilot Project (UWPP), completed the initial phase of environmental review in 2020. Collaborative partners recognized the importance of monitoring and initiated a taskforce to develop a monitoring strategy in

2021. The UWPP monitoring plan represents an excellent example of a planning area monitoring plan in Washington.

Treatment Unit and Stand-Level Monitoring

- **Treatment Unit Monitoring:** In 2020, DNR staff worked with partners to develop a protocol, field data entry and storage platform for monitoring forest health treatment units. Over the last two years, we refined and utilized the protocol and developed a common format to report treatment results. We include an in-depth monitoring report for a recent forest health completed by WA State Parks on the Bullfrog property within the Palouse to Cascades State Park Trail near Cle Elum, WA. The project combines field plot data with remote data from drone-based imagery and LiDAR.

  This project was led by WA DNR and developed in close partnership with WA State Parks and WDFW. A similar project was conducted in partnership with DNR State Lands for the Virginia Ridge timber sale and is included in the appendix.

- **Stemilt Prescribed Fire Monitoring in Chelan County:** Chelan County Natural Resource Department, in partnership with the DNR, local landowners, and land management agencies, is working to restore forest health and resiliency in the Stemilt and nearby 20-Year Forest Health Strategic Plan priority planning areas. Through implementation of commercial and non-commercial mechanical thinning and prescribed fire, a significant portion of the Stemilt priority planning area across multiple ownerships has been shifted to a more resilient condition. The DNR Forest Health Treatment Effectiveness Survey (Survey 1, 2, 3) was used to evaluate the success of a prescribed burn on county land near Upper Wheeler Reservoir in the Stemilt Basin.

- **USDA Forest Service Fuel Treatment Effectiveness Monitoring:** Starting in the 2017 fire season, USDA Forest Service (USFS) Region 6 staff brought together a team that conducted post-fire data collection throughout the region on many of the major wildfires of that year, recording fire outcomes in the field and then coordinating and cross referencing these results with past fuel treatment projects. The goal of the project is to evaluate which treatment types and return treatment intervals are most successful in slowing, managing, or stopping the spread of wildfires.

- **Treatment Longevity Study:** The longevity of treatments and resulting timeframe in which areas need retreatment is a major driver of long-term treatment need. However, scientific information on treatment longevity is sparse. During the 2019-2021 biennium, DNR funded a team at the University of Washington (UW) to investigate treatment longevity and future treatment needs using literature review, dataset compilation, and field data collection.

In addition to the major components listed above, DNR initiated and will be working on the following components of the monitoring framework over the 2023-25 biennium:

- **Modeling effects of Landscape-level Treatments on Wildfires**: The 3P project will pilot a process for the collaborative prioritization of landscape-scale forest and fuel treatment projects in three multi-ownership areas of eastern Washington. The selected areas will be based on the landscape priorities identified in DNR's 20-Year Forest Health Strategic Plan: Eastern Washington and the Confronting the Wildfire Crisis 10-year plan from the U.S. Forest Service. The 3P project will conduct prioritizations for each pilot area to explore how varying local priorities and constraints affect the placement and effectiveness of treatments.

- **Evaluating Interactions between Wildfires and Treatments**: A major next step that emerged from the 2021 Work of Wildfires assessment is to develop datasets on past treatments and analytical methods to evaluate how treatments affect wildfire severity under different weather conditions, and how fire managers utilize treatments during fires. We have developed a methodology to obtain key information from fire managers on how treatments were used. We have also initiated a research project with University of Washington Researchers and the Forest Service to analyze how extensive treatments affected the 2021 Schneider Springs Fire.

- **Mapping Insect Activity**: Working with remote sensing experts at Oregon State University, we are developing new methods to map and quantify the insect impacts on forest composition and structure. This monitoring project builds on the aerial detection survey program administered by the Forest Service, DNR, and Oregon Department of Forestry. The new maps leverage aerial surveys, Landsat time series, and new advances in disturbance attribution and interpretation to assess insect-induced tree mortality and defoliation across eastern Washington.

- **Mapping Species Composition:** Tree species composition affects drought vulnerability, insect and fire resistance, and wildlife habitat. Yet current mapping methods for tree species composition are not sufficiently accurate to use for landscape evaluations, climate vulnerability assessments, and monitoring. DNR is partnering with researchers at the Forest Service's Pacific Northwest Research Station and Oregon State University to develop improved methods for this critical aspect of resilience.

The rest of this monitoring chapter is divided into two sections: regional and planning area monitoring, and treatment unit and stand level monitoring. Each subsection will describe in more detail some of the monitoring components listed above.

Regional & Planning Area Monitoring

Forest Health Treatment Tracking

RCW 76.06.200 requires DNR "to proactively and systematically address forest health issues" and to assess, treat, and track progress. DNR has developed a forest health treatment database to collect treatment information for all DNR owned lands and forest health programs, as well as information from other public, private, and Tribal landowners willing to share data. The Forest Health Tracker is the primary method DNR and partners are utilizing to track progress in meeting the requirements of the legislation.

RCW 79.10.520 defines a forest health treatment as actions taken by DNR to restore forest health including, but not limited to landscape assessment and project planning, site preparation, reforestation, mechanical treatments including timber harvests, road realignment for fire protection and aquatic improvements, and prescribed burning. For the purposes of forest health treatment tracking across all land ownerships, DNR has defined a forest health treatment as an action taken in a forest ecosystem aimed to improve forest health and resiliency.

A treatment can be a standalone, one-time project or a component of a longer-term landscape scale forest health project. The responsible person, agency, or organization leading a forest health treatment submits their information to DNR for tracking purposes.

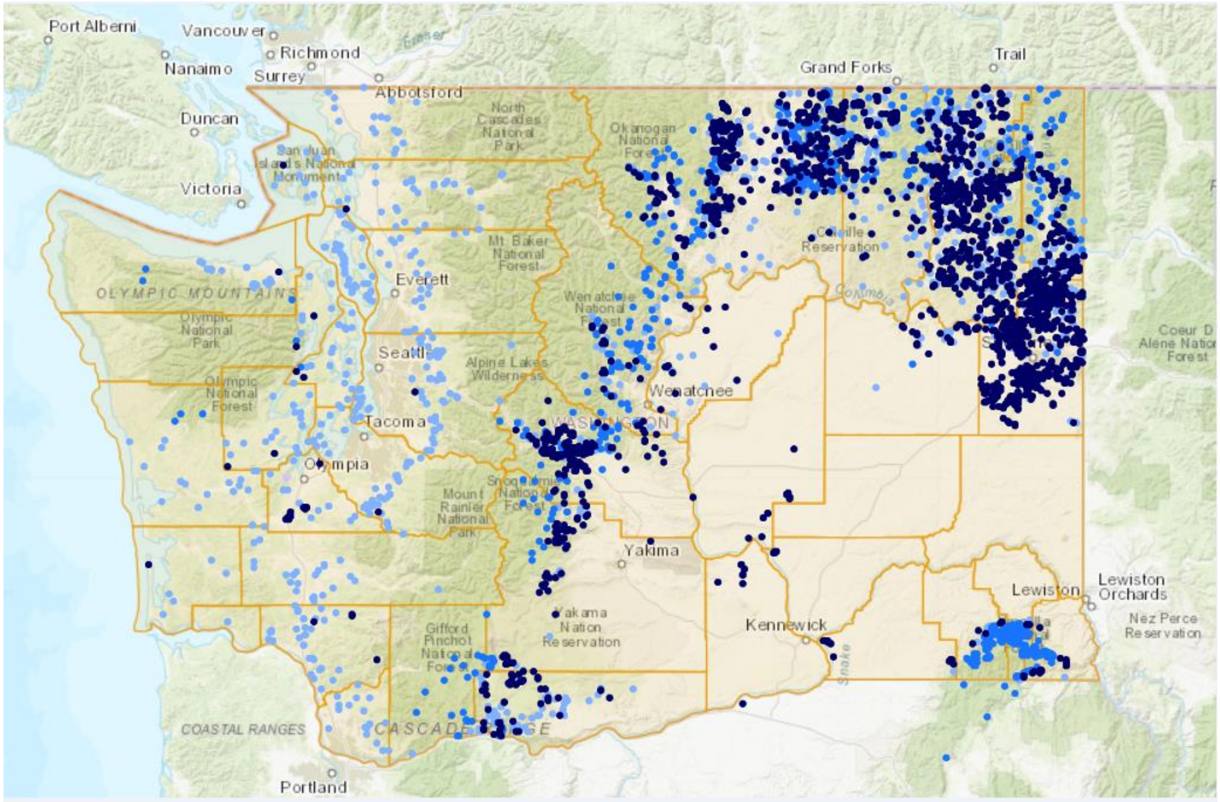
The party submitting forest health treatment information is responsible for reviewing the DNR definition of forest health and determining whether the treatment was motivated and implemented with the intent to improve forest health and resilience. In other words, landowners determine whether or not the objective of a given treatment is to support forest health and resilience. Reporting is voluntary and based on the judgment and management goals of partners and landowners in the state.

The current scope of DNR's all-lands, forest health treatment tracking is statewide, though it is more robust in eastern Washington, where the 20-Year Forest Health Strategic Plan and landscape evaluations establish treatment needs by priority planning area.

Forest Health Tracker

DNR developed a collaborative, online tool to compile and present forest health treatments and related activities across all-lands. This online tool, referred to as the Forest Health Tracker, is a platform to increase DNRs ability to identify the location of forest health activities that are proposed, planned, and completed across the state. Forest Health Tracker functions as a dashboard that visually displays and connects data in various forms from multiple landowners and implementing partners. Forest Health Tracker provides details for individual projects in order to foster more consistent reporting and transparency.

Figure 14. Project map in Forest Health Tracker with simple locations of forest health projects overlaid with county boundaries.



Many terms are used to communicate actions necessary to improve forest health and resilience in Washington. While different organizations and individuals may have slight variations in how they define specific forest health terms, the Forest Health Tracker website includes a glossary of definitions to guide both data entry and interpretation of information provided on the site.

In addition to project information, Forest Health Tracker connects users to information that can inform and facilitate cross-boundary planning. This includes an interactive Find Your Forester map to find contact information for technical assistance services and natural resource professionals. The site also includes the ability to view landscape evaluation results for priority planning areas, which allows the user to compare needed treatment results against proposed, planned, and completed forest health projects.

It is important to note, however, that the treatment data available on the website is not comprehensive. Not all forest health project information can be displayed through this online tool, such as information about private landowner treatments, due to privacy restrictions. Therefore, in addition to this online tool, DNR maintains a comprehensive forest health treatment tracking database that is utilized for routine progress reporting on forest health strategic plan goals. The database includes all data with privacy restrictions, but masks sensitive information to protect the confidentiality of private landowners and other land managers.

Eastern Washington Forest Health Treatment Tracking

RCW 76.06.200 directs that the forest health assessment and treatment framework "must endeavor to achieve an initial goal of assessing and treating one million acres of land by 2033". The 20 Year Forest Health Strategic Plan expands on this goal, aiming to implement 1.25 million acres by 2037.

Forest health treatment tracking and reporting is calculated and displayed in two ways:

- Total forest health treatment acres based on all activities conducted, including those that occurred in sequence on the same acre over time. For example, a commercial thinning may have been conducted on an acre prior to a prescribed burn. The total number of acres treated in this case would include the number of acres commercially thinned and the number of acres prescribed burned, even if these treatments occurred within the same footprint.
- Footprint acres are calculated through a spatial analysis of forest health treatment data. The data reflect every acre that received at least one forest health treatment since 2017. Total treatment acres allow us to track individual actions invested in and implemented at a point in time, while footprint acres allow us to track the scale of impact over time.

Between January 2017 and October 31, 2022, 493,460 acres of completed forest health treatments in eastern Washington have been reported by landowners and managers to DNR, impacting 309,556 footprint acres.

The tables below summarize treatment tracking of completed forest health vegetation treatments into three categories: non-commercial treatment, commercial treatment, and prescribed fire treatment. The tables also include a summary of treatment acres across eastern Washington, and within priority planning areas in comparison to the treatment need identified by the landscape evaluations. Figure 14a is a map of forest health treatments from 2017-2022.

Table 11. Total forest health treatment acres (not footprint acres), by calendar year, from January 1, 2017 through October 31, 2022 across eastern Washington.

	EASTERN WASHINGTON TREATMENT ACRES						
	2017	2018	2019	2020	2021	2022	Grand Total
DNR State Trust Lands	**18,025**	**24,096**	**16,995**	**26,822**	**23,180**	**14,827**	**123,944**
Commercial Vegetation	7,951	5,832	7,444	8,600	6,489	6,106	42,422
Non-Commercial Vegetation	9,232	16,091	7,009	16,728	13,987	8,443	71,488
Prescribed Fire	842	2,173	2,542	1,494	2,704	279	10,034
DNR Service Forestry	**2,724**	**3,175**	**4,252**	**5,434**	**4,577**	**1,812**	**21,973**
Non-Commercial Vegetation	2,724	3,175	4,252	5,434	4,577	1,798	21,958
Prescribed Fire						14	14
DNR Natural Areas						**339**	**339**
Commercial Vegetation						232	232
Non-Commercial Vegetation						96	96
Prescribed Fire						11	11
State Parks	**71**	**248**	**1,461**	**446**	**170**	**742**	**3,137**
Commercial Vegetation	62	92				415	569
Non-Commercial Vegetation	9	156	1,461	446	170	327	2,569
WDFW	**5,170**	**4,331**	**4,857**	**1,424**	**1,128**	**1,979**	**18,889**
Commercial Vegetation	1,931	1,538	521	394	143	1,426	5,954
Non-Commercial Vegetation	466	408	3,617	1,001	430	548	6,469
Prescribed Fire	2,773	2,385	718	29	555	5	6,466
USFS	**38,384**	**55,814**	**50,142**	**46,977**	**41,902**	**5,343**	**238,562**
Commercial Vegetation	6,285	6,100	6,773	7,739	5,216	978	33,091
Non-Commercial Vegetation	15,142	18,390	19,690	28,485	19,625	3,291	104,623
Prescribed Fire	16,957	31,324	23,679	10,753	17,061	1,074	100,848
USFWS	**549**	**779**	**1,041**	**2,344**	**1,336**	**1,206**	**7,258**
Commercial Vegetation			493	572			1,065
Non-Commercial Vegetation		26	105	1,090	730	375	2,327
Prescribed Fire	549	753	444	682	606	831	3,866
NRCS	**4,285**	**5,491**	**5,671**	**6,372**	**2,827**	**11,522**	**36,168**
Non-Commercial Vegetation	4,285	5,491	5,671	6,372	2,827	11,522	36,168
The Nature Conservancy	**207**	**109**		**123**			**439**
Commercial Vegetation	207	109					315
Non-Commercial Vegetation				123			123
Kalispel Tribe of Indians	**82**	**97**	**103**	**116**	**166**	**173**	**737**
Commercial Vegetation	82	97	103	116	119		517
Non-Commercial Vegetation					47	173	220
Colville Confederated Tribes	**7,191**	**8,231**	**7,030**	**4,113**	**9,881**	**4,976**	**41,422**
Commercial Vegetation	178	1,089	790	177	1,622		3,855
Non-Commercial Vegetation	7,013	7,143	6,240	3,935	8,259	4,976	37,567
BLM					**223**	**369**	**592**
Commercial Vegetation					223	369	592
Grand Total	**76,688**	**102,371**	**91,552**	**94,171**	**85,390**	**43,288**	**493,460**

** DNR Natural Areas and NRCS data was provided in tabular format only for this data update*

*** USFS provided a new data source, which updated their annual forest health treatment acres from 2017 – present*

Table 12. Acres of forest health treatment needed, completed treatments, and additional factors affecting the landscape by calendar year (January 2017 – October 31, 2022) by priority planning area.

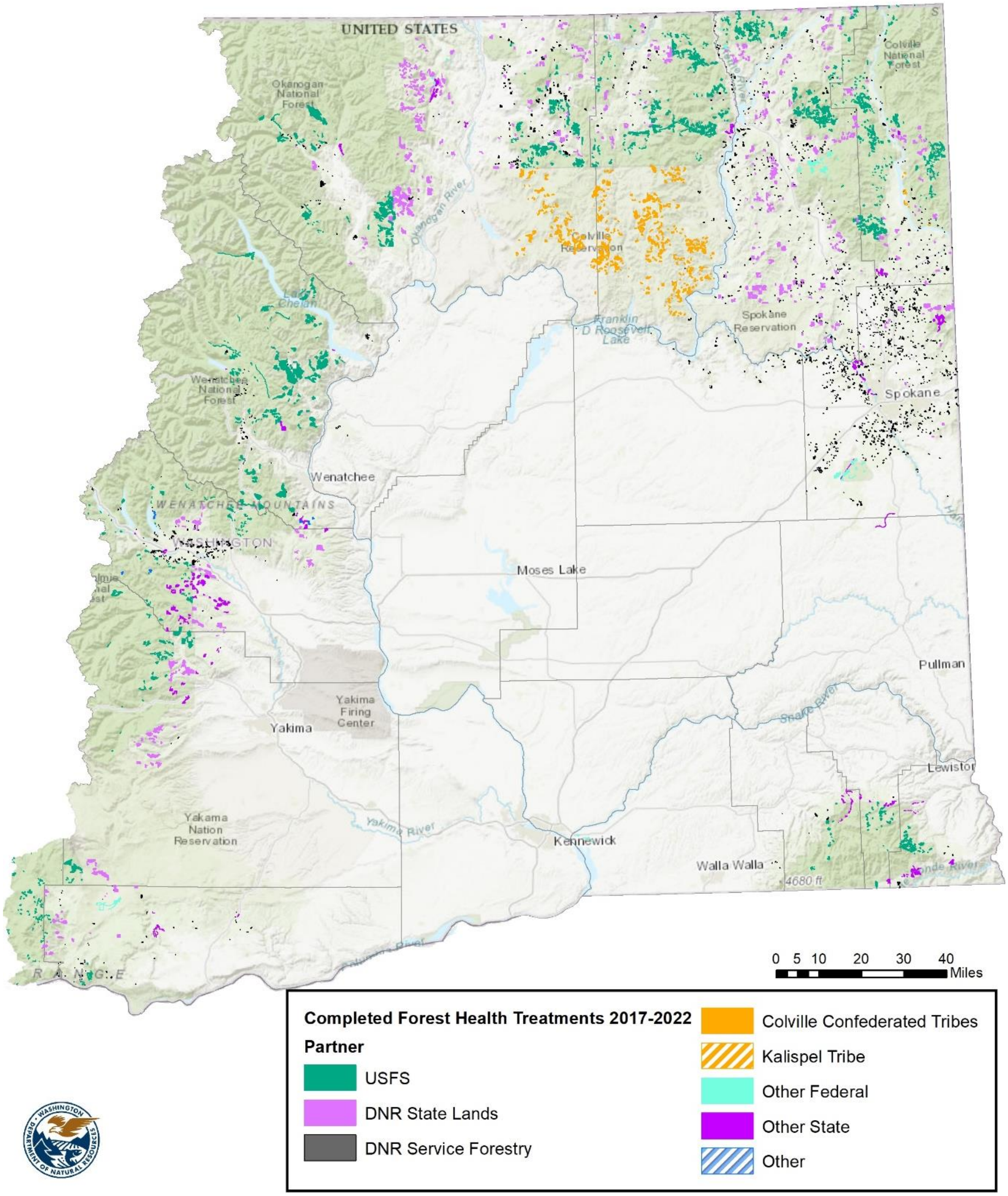
				Completed Forest Health		Other Factors Affecting	
Priority Landscape	**Total Acres**	**Forested Acres**	**Assessed Treatment Need** (Footprint acres)	Completed Total Treatment Acres	Completed Footprint Acres	Acres of low-mixed severity wildfire (2017-2022)	Acres of Forest Practice Applications approved
Ahtanum	120,477	89,217	19,000-29,000	3,948	3,761	0	12,494
Asotin	149,152	93,329	Analysis in 2024	9,826	5,122	36,897	12,543
Chelan	98,004	31,342	7,500 - 12,500	504	156	259	0
Chewelah	195,408	158,352	59,000 - 80,000	13,443	6,407	10	34,752
Chewuch	94,250	83,846	Analysis in 2022	427	202	17,836	189
Chumstick to LP	115,333	84,216	36,500 - 53,000	6,985	3,184	268	5,991
Cle Elum	109,396	80,300	22,000 - 35,500	4,721	3,229	1,646	19,820
Deer Park	181,171	90,497	36,000 - 49,000	4,533	2,981	1,530	28,859
Dollar	61,238	50,767	18,600 - 27,700	269	269	0	3,340
Gifford			Analyze in 2024	898	404	465	19,449
Glenwood	104,501	83,758	23,500 - 32,000	4,683	3,690	45	18,368
Highway 97	60,398	37,415	11,000 - 16,500	88	88	0	32,939
Inchelum			Analysis in 2024	1,837	1,841	20,858	3,922
Ione	44,248	41,784	16,500 - 21,000	1,163	1,142	0	1,608
Klickitat	149,649	103,274	43,000 - 55,000	1,248	814	74	31,518
Little Naches	95,331	92,914	25,500 - 43,000	1,942	1,025	4,929	0
Little Pend Oreille	92,986	81,145	30,250 - 43,500	7,821	5,225	51	18,734
Little White	95,750	84,705	17,750 - 27,500	645	645	158	2,922
Long Lake	103,291	41,253	14,000 - 20,000	3,391	3,570	1,848	15,698
Loomis			Analysis in 2024	13,758	9,315	4,301	5,789
Mad Roaring Mills	65,008	33,325	13,500 - 20,000	3,763	3,201	4,226	95
Manastash Taneum	104,072	65,833	16,500 - 29,500	8,700	5,126	73	4,579
Meaadow			Analyze in 2024	2,364	2,093	0	2,827
Methow Valley	338,246	182,937	49,500 - 75,000	20,626	15,361	31,376	3,140
Mica			Analysis in 2024	1,588	964	1	14,168
Mill Creek	186,306	162,060	57,000 - 80,000	22,366	11,378	185	33,312
Mission	49,121	32,743	10,406	6,153	2,143	121	8,522
Mt Hull	105,431	34,809	12,000 - 18,500	1,532	953	0	4,076
Mt Spokane	121,767	95,814	29,000 - 42,000	6,613	4,644	0	31,714
Naches - Wenas			Analysis in 2024	10,765	8,867	11,477	4,852
Nason Creek	31,679	29,243	6,750 - 11,500	748	320	0	1,857
Republic	180,553	144,350	46,500 - 64,000	15,643	8,271	28	62,727
Slate			Analysis in 2024	583	423	0	1,441
Stemilt	38,961	22,613	9,200 - 13,600	2,578	2,009	0	7,975
Stranger	89,904	72,061	30,000 - 38,000	4,840	3,047	1	34,205
Teanaway	132,120	111,696	38,500 - 60,000	3,183	2,841	18,904	2,392
Tieton	148,634	117,781	38,000 - 60,500	1,454	1,380	422	805
Tillicum	14,326	11,241	7,614	5,040	1,489	49	2,392
Toroda-Tonata	153,611	117,345	51,000 - 66,000	3,405	2,438	74	10,165
Touchet-Mill	203,750	92,785	22,000 - 27,500	1,582	642	11	13,829
Trail	105,242	94,948	35,200 - 44,000	4,584	3,465	7	15,723
Trout Lake	117,153	105,015	18,500 - 33,000	5,853	5,041	0	11,258
Tucannon			Analysis in 2024	1,185	845	29,483	2,469
Twisp River	111,918	82,349	26,000 - 36,500	1,416	1,342	19,439	67
Upper Swauk	39,175	35,450	14,000 - 22,000	1,545	1,179	37	0
Upper Wenatchee	74,777	66,277	15,500 - 27,000	2,795	1,495	1,222	1,496
White Salmon	126,688	104,022	38,000 - 54,000	2,484	1,946	302	20,003

Table 13. Forest health treatment acres by calendar year (January 2017 – May 31, 2022) organized by treatment type.

	EASTERN WASHINGTON TREATMENT ACRES						
	2017	2018	2019	2020	2021	2022	Total
Commercial Vegetation	16,694	14,857	16,124	17,599	13,812	9,526	**88,612**
Non-Commercial Vegetation	38,871	50,879	48,045	63,613	50,650	31,551	**283,609**
Prescribed Fire	21,122	36,635	27,383	12,958	20,927	2,214	**121,239**
Total	**76,687**	**102,371**	**91,552**	**94,170**	**85,389**	**43,291**	**493,460**

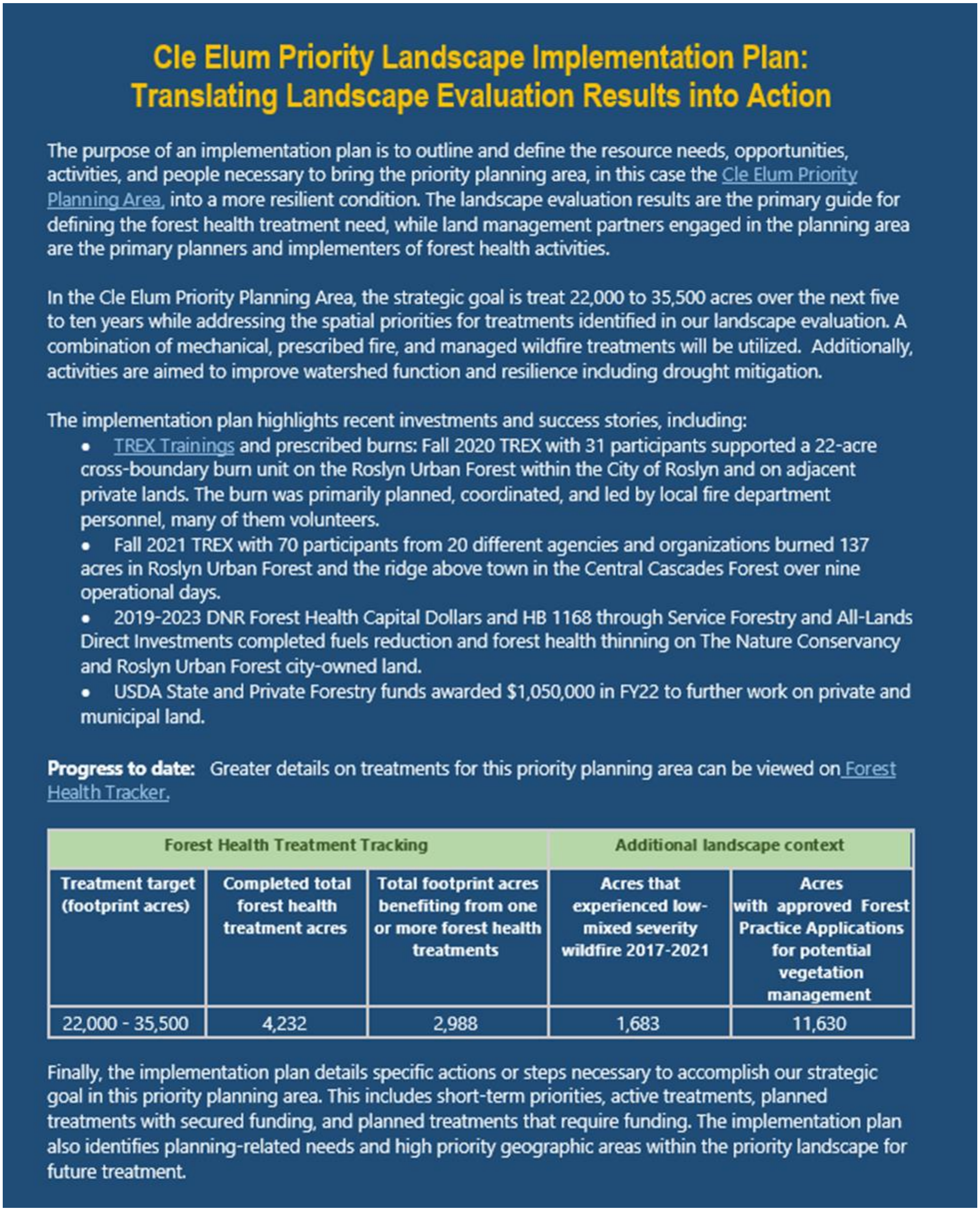
The Forest Health Treatment Tracker includes information about commercial treatments (top left, top right), non-commercial treatments (middle left, bottom left), and prescribed fire (top middle). The Tracker also includes information on low and mixed-severity wildland fire effects. Photo on bottom right shows high severity fire on the left side of the image and low-severity fire on the right side of the image. The photo is from the Schneider Springs Fire. Photos by John Marshall Photography (top left, middle left), Cascadia Conservation District (bottom left), and DNR (top center, top right, bottom right).

Figure 14a. Map of eastern Washington forest health treatments by landowner from 2017-2022.



Equally as important as tracking completed forest health treatments is our understanding of the scale and location of where forest health treatments are planned. DNR defines a "planned" forest health project or treatment as one that has been identified by a landowner or manager and includes a specific prescription or actions that are clearly defined and are anticipated to be implemented within five years. Information about planned projects is critical to understanding where implementation resources may be needed in the future and how to align existing planning efforts with adjacent landowner treatments to achieve cross-boundary outcomes. In eastern Washington:

- On State Lands managed for trust beneficiaries and other resource objectives it is planned to conduct forest health treatments across nearly 58,000 acres in the next biennium. These treatments will include commercial and non-commercial treatments designed to develop a forest system that is sustainable, resilient, and resistant to insects, disease, fires and other disturbances.
- Currently, there are more than 820 Forest Stewardship plans covering more than 126,066 acres active in Washington State.
- Since 2017, US Forest Service has finalized NEPA decisions for planned forest health treatments to implement 305,194 footprint acres of national forest in priority landscapes. This builds upon previous decisions that have treatments still to be implemented.



Cle Elum Priority Landscape Implementation Plan: Translating Landscape Evaluation Results into Action

The purpose of an implementation plan is to outline and define the resource needs, opportunities, activities, and people necessary to bring the priority planning area, in this case the Cle Elum Priority Planning Area, into a more resilient condition. The landscape evaluation results are the primary guide for defining the forest health treatment need, while land management partners engaged in the planning area are the primary planners and implementers of forest health activities.

In the Cle Elum Priority Planning Area, the strategic goal is treat 22,000 to 35,500 acres over the next five to ten years while addressing the spatial priorities for treatments identified in our landscape evaluation. A combination of mechanical, prescribed fire, and managed wildfire treatments will be utilized. Additionally, activities are aimed to improve watershed function and resilience including drought mitigation.

The implementation plan highlights recent investments and success stories, including:

- TREX Trainings and prescribed burns: Fall 2020 TREX with 31 participants supported a 22-acre cross-boundary burn unit on the Roslyn Urban Forest within the City of Roslyn and on adjacent private lands. The burn was primarily planned, coordinated, and led by local fire department personnel, many of them volunteers.
- Fall 2021 TREX with 70 participants from 20 different agencies and organizations burned 137 acres in Roslyn Urban Forest and the ridge above town in the Central Cascades Forest over nine operational days.
- 2019-2023 DNR Forest Health Capital Dollars and HB 1168 through Service Forestry and All-Lands Direct Investments completed fuels reduction and forest health thinning on The Nature Conservancy and Roslyn Urban Forest city-owned land.
- USDA State and Private Forestry funds awarded $1,050,000 in FY22 to further work on private and municipal land.

Progress to date: Greater details on treatments for this priority planning area can be viewed on Forest Health Tracker.

Forest Health Treatment Tracking			Additional landscape context	
Treatment target (footprint acres)	**Completed total forest health treatment acres**	**Total footprint acres benefiting from one or more forest health treatments**	**Acres that experienced low-mixed severity wildfire 2017-2021**	**Acres with approved Forest Practice Applications for potential vegetation management**
22,000 - 35,500	4,232	2,988	1,683	11,630

Finally, the implementation plan details specific actions or steps necessary to accomplish our strategic goal in this priority planning area. This includes short-term priorities, active treatments, planned treatments with secured funding, and planned treatments that require funding. The implementation plan also identifies planning-related needs and high priority geographic areas within the priority landscape for future treatment.

Change Detection Monitoring

Monitoring treatments, disturbances, and resulting changes to forest structure and composition are a key component of the 20-Year Forest Health Strategic Plan Monitoring Framework. This section outlines the change detection products and results, which enable us to locate and attribute changes in forest conditions across eastern Washington, as well as to begin to assess the impact of those changes on forest structure.

This report outlines the change detection products and results, which enable us to (1) map treatments, fires, and insect activity and then (2) quantify the changes in forest structure from these disturbances at regional and planning area levels. These datasets allow DNR to determine changes in treatment needs and report progress towards restoration goals within planning areas. Monitoring changes in other goals related to forest structure, such as habitat, drought vulnerability, carbon, or timber volume, are also possible with these datasets and part of the 20-Year Plan monitoring framework.

To more robustly monitor changes in fire risk and drought vulnerability, as well as other goals, accurate maps of species composition and surface fuels are needed. DNR is currently working with partners at several research institutions to develop improved methods for species composition and surface fuel mapping.

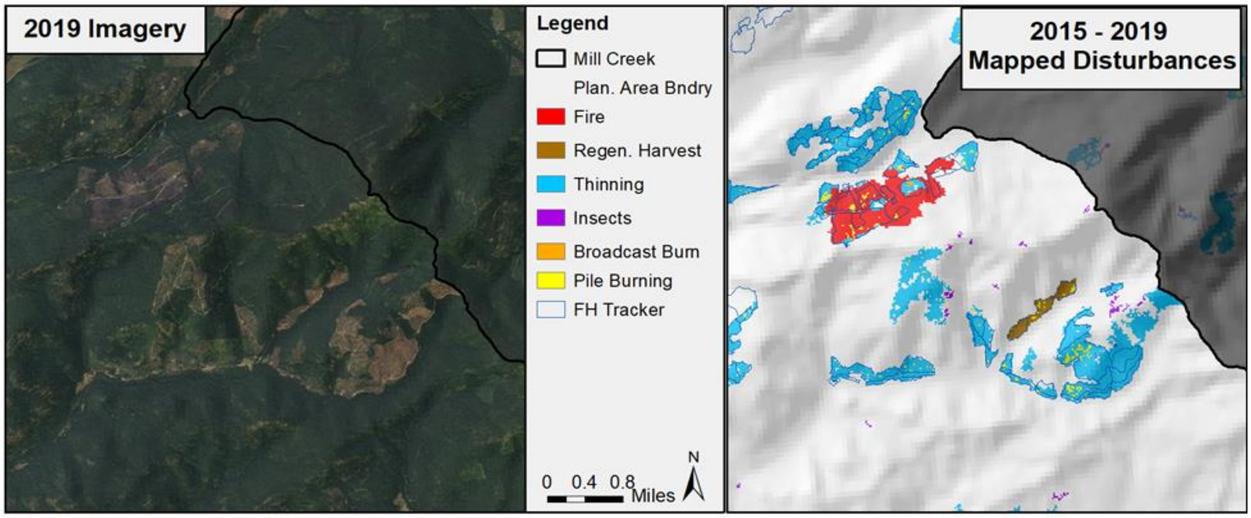
The change detection analysis is a complement to the Forest Health Tracker online platform aimed at gathering and displaying forest health project information. The Forest Health Tracker provides a detailed database of planned and completed treatment locations and timelines, responsible parties, and prescriptions. This change detection report differs in that it includes wildfires and insect activity in addition to treatments, and only covers areas that have already experienced change, not areas where treatments are planned.

Additionally, it is based on remotely sensed rather than reported data, allowing objective analyses of the impacts of forest health treatments at stand and landscape scales. The pairing of the Forest Health Tracker database and change detection products will allow for a more complete view of each treatment and how treatments and other disturbances combine to move landscapes relative to restoration goals.

Methods

The change detection analysis is composed of two components: (1) *disturbance mapping:* satellite-based change detection and attribution, and (2) *forest structure change assessment:* evaluation of forest structure changes using Digital Aerial Photogrammetry (DAP) data. The first component uses the satellite-based USFS Landscape Change Monitoring System (LCMS) product to locate changes, followed by the application of a modeling framework developed by DNR scientists to attribute known change locations to disturbance types (see Methods for details). Annual disturbances, including wildfires, insect activity, regeneration harvest, thinning, broadcast burning, and pile burning, are located and attributed for all years 2015–2021.

Figure 15. Example of disturbance mapping as part of the change detection analysis. The maps show the southeast corner of the Mill Creek planning area, where the Mill Creek A-Z project has resulted in significant thinning. Forest Health Tracker data covers 2017 through 2019.



The first component of change detection – disturbance mapping –correctly attributes most detected disturbances. The rate of accuracy is greater than 80 percent for wildfire, thinning, and insect activity. Regeneration harvest is sometimes confused with thinning, but this is expected, as some regeneration harvest methods, such as shelterwoods, can be similar to a heavy thinning treatment. Similarly, group and single-tree selection harvests can be similar to variable density thinning treatments. Broadcast burning is also sometimes mistaken for thinning. This may be improved in the future with increased training data.

Table 14. Confusion matrix for disturbance mapping results, excluding pile burning. Values are the number of pixels, and the "Class Errors" are the percentage of each class that were incorrectly classified. The row names are the actual class of each pixel, and the column names are the predicted class. Errors were assessed using a sample of known disturbance locations, independent from those used for modeling.

	Fire	Regen. Harvest	Thinning	Insect Activity	Broadcast Burning	Class Errors
Fire	1518	2	10	3	0	1.0%
Regen. Harvest	1	662	643	12	0	49.8%
Thinning	2	85	2657	92	1	6.3%
Insect Activity	6	19	117	690	1	17.2%
Broadcast Burning	115	0	312	16	588	43.0%

Details on disturbance detection accuracy may be found in the LCMS methods documentation (USDA Forest Service, 2022). However, visual inspection of mapping results found that while the majority of disturbances are correctly identified, light thinning treatments that only remove understory trees, such as landowner assistance treatments, are often missed. Disturbances are detected using satellite measures of canopy greenness, so this is to be expected and numerous previous change detection studies have reported similar findings.

The second component of the analysis – forest structure change assessment – is completed within the boundaries of 20-Year Plan priority planning areas. Within these areas, structural changes are evaluated by comparing pre- and post-disturbance structure from DAP data.

Accurate data on forest structure has typically been the most difficult data to obtain, especially given the need for repeated measures that are consistent over all of eastern Washington. The DNR's DAP products are LiDAR-like point clouds from which we can derive fine scale maps of canopy cover and tree height. These derived products enable wall-to-wall forest structure to be analyzed every two years, but the data accuracy and precision are lower than that achieved with LiDAR.

As such, DNR FRD has ongoing work with several internal and external partners to assemble and perform quality control on DAP data. Contracts include ongoing work with the University of Washington to label errors in DAP products and model the relationships among DAP and LiDAR products so that the two can be compared. It is only this year (2022) that the DNR has a sufficient number of data years and a reasonable understanding of data strengths and limitations that large-scale monitoring using the DAP products is feasible.

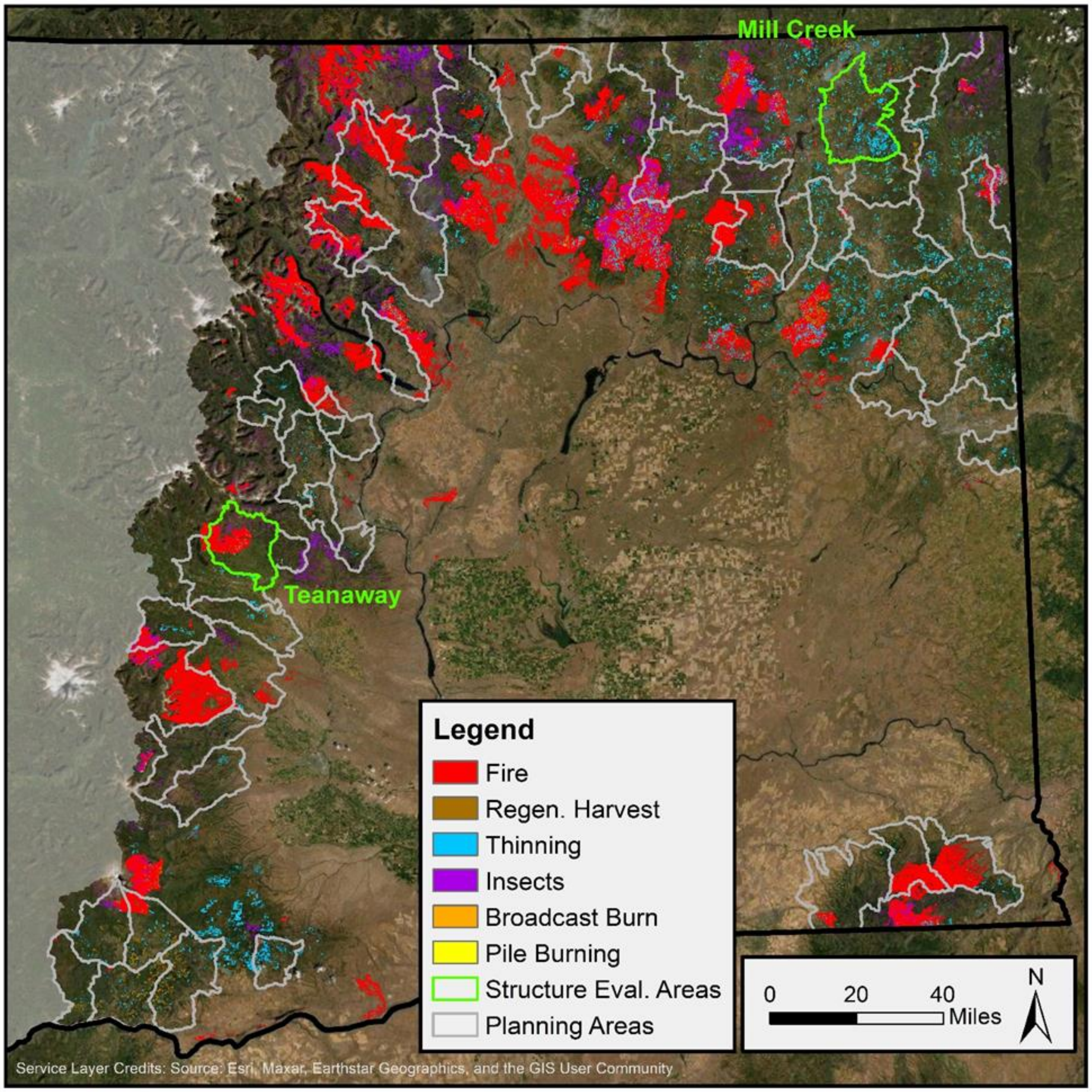
Disturbances Across Eastern Washington

Disturbances were mapped annually across forested areas of eastern Washington from 2015 to 2021 using the satellite based approach discussed above. Disturbances include forest management activities, as well as wildfire and insect activity. Disturbances were mapped and then classified into one of six different categories: wildfire, regeneration harvest, thinning, insect activity, broadcast burning, and pile burning. Areas of wildfire were also labeled with their burn severity class (low, mixed, and high). The amount and drivers of change were evaluated for each planning area to understand patterns of change across eastern Washington. Finally, changes to forest structure were evaluated within a subset of planning areas using DAP structure class data (see Methods).

All six disturbance types were present in the 20-Year Plan priority planning areas. Across all planning areas, wildfire was the primary disturbance agent, affecting 1,433,300 acres from 2015 to 2021, followed by thinning (396,436 acres), insect activity (354,953 acres), regeneration harvest (105,338 acres), and broadcast burning (10,495 acres). Acres attributed to pile burning totaled 22,123, occurring in locations already included in thinning and broadcast burning acreage.

The total footprint affected by all disturbance agents across eastern Washington from 2015 to 2021 was 1,977,327 acres, including 497,488 acres within planning areas. The total acres affected differs from the sum of the total acres affected for each disturbance type, because multiple disturbances can occur in the same area. In particular, insect activity tends to co-occur with other types of disturbance.

Figure 16. Map of change detection locations, attributed to disturbance types, for forested areas of eastern Washington 2015–2021. Wildfire severity is not displayed. Analysis of structure change for the selected planning areas, in green, are presented in the 'Effects of disturbance on forest structure' section.



Service Layer Credits: Source: Esri, Maxar, Earthstar Geographics, and the GIS User Community

Table 14. Forested acres affected by disturbances within planning areas. The top 15 planning areas, according to footprint acres changed, are displayed. Acres in the disturbance-specific columns represent footprint acres for each disturbance. However, multiple disturbances may affect the same area. The "Total Change Footprint" column shows actual footprint acres.

Planning Area	Total Acres	Forest	Total Change Footprint	Wildfire	Insect	Thinning	Regen. Harvest	Broad-cast Burn.	Pile Burn*
Methow Valley	338,246	182,937	59,960	50,332	11,507	4,451	1,478	354	344
Asotin	149,152	93,329	47,716	45,016	1,257	3,678	495	49	173
Republic	180,553	144,350	46,520	34,441	16,667	13,278	1,108	69	775
Twisp River	111,918	82,349	38,047	35,806	8,853	1,816	-	665	503
Teanaway	132,120	111,696	30,816	28,508	5,609	995	16	580	231
Mill Creek	186,306	162,060	26,151	410	1,001	20,553	5,144	24	735
Glenwood	104,501	83,758	18,777	11,306	269	2,582	4,453	67	137
Little Naches	95,433	92,914	16,777	14,312	3,984	1,900	221	27	112
Trail	105,242	94,948	16,552	11,856	2,184	4,861	1,541	80	326
Chewelah	195,408	158,352	14,839	1,160	821	12,238	1,474	6	371
Stranger	89,904	72,061	10,209	952	46	7,898	1,645	7	163
Trout Lake	117,153	105,015	9,614	5,057	1,933	2,210	1,149		81
White Salmon	126,688	104,022	9,506	335	1	2,193	7,313	5	56
Klickitat	149,649	103,274	9,308	87	11	3,000	6,479	-	50
Mt. Spokane	121,767	95,814	9,092	-	178	6,422	2,829	-	189

*** Pile burning acreage is in addition to locations within regeneration harvest or thinning projects, as pile burns were limited to patches that had already experienced those types of disturbances.*

Among individual planning areas, the total acreage affected by disturbances varied substantially, as did the primary modes of disturbance. The top five planning areas in terms of footprint acres affected were Methow Valley (59,960 acres), Asotin (47,716 acres), Republic (46,520 acres), Twisp River (38,047 acres), and Teanaway (30,816). Eight of the top 10 planning areas in terms of acreage had wildfire as their primary change agent; two had thinning. The high acreage affected by wildfire tended to be due to a few large fires, rather than a series of smaller burns.

For instance, in Methow Valley and Twisp River, the wildfire change detected (>85,000 acres) was almost entirely due to the Cedar Creek (2021), Cub Creek 2 (2021), Crescent Mountain (2018), and Twisp River (2015) fires. Mill Creek had the most acres thinned of all planning areas, thanks to the implementation of the Mill Creek A-Z project. While planned and begun prior to the 20-Year Plan, this is an important project to monitor as an excellent case study of the effect of forest health treatments over time.

The results across all of eastern Washington mirror those from the planning areas, where the primary change agent in terms of footprint acres was wildfire, followed by thinning and insect activity. On an annual basis (Figure 3b), insect activity has a very high average affected area, due to the nature of the disturbance. Insect outbreaks tend to be long-duration but less intense than other disturbances. While wildfire typically receives the most attention as a disturbance agent, the acreage is much more episodic due to annual variability in weather and fuel conditions.

While not presented here, WA DNR also maps the severity of fires, and has compiled an atlas of fire perimeters and severity from 1984-2021. The amount and patch sizes of different levels of fire severity determine the extent to which wildfires move landscapes towards or away from restoration goals. 2021 wildfires, for example, likely had beneficial effects on at least 230,000 acres and negative effects on 85,000-125,000 acres (see DNR 2021 Work of Wildfire report). We also evaluate the 2017 Jolly Mountain fire at the end of this section.

The spatial variation of disturbance and change patterns among planning areas was also present across eastern Washington. Most of the wildfire change detected was in the northern Cascades and north-central region, while insect activity tended to be concentrated in central, northeastern, and northwestern regions. Thinning and regeneration harvest were most common in the northeastern and southwestern regions of eastern Washington. The Blue Mountains in the southeast had a number of large fires in both 2015 and 2021. The 2021 fires in the northern Cascades and Blue Mountains are discussed in more detail in the Work of Wildfire report.

Figure 17a. Total acres affected by fires, regeneration harvest, thinning, insect activity, broadcast burning, and pile burning* 2015–2021 across forested areas of eastern Washington. (a) shows the percentage and total footprint acreage for areas of change. *Pile burning is not included in (a) because it affects areas that have changed due to other disturbances such as regeneration harvest or thinning.

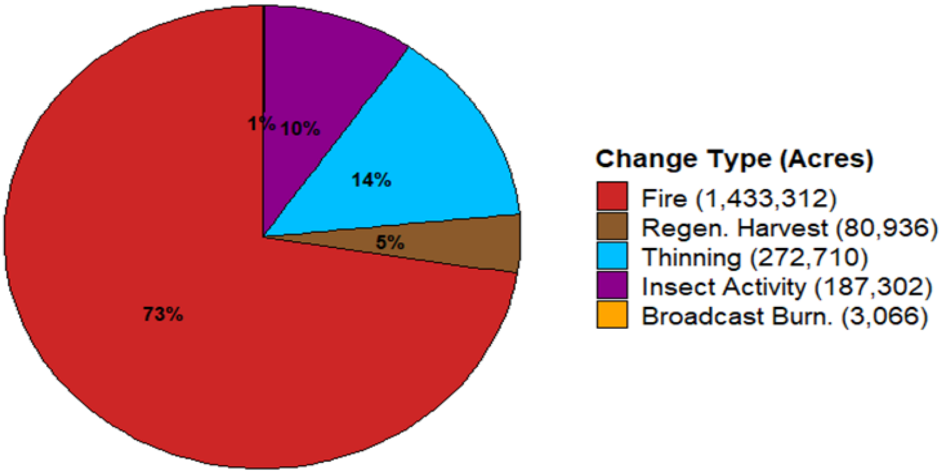
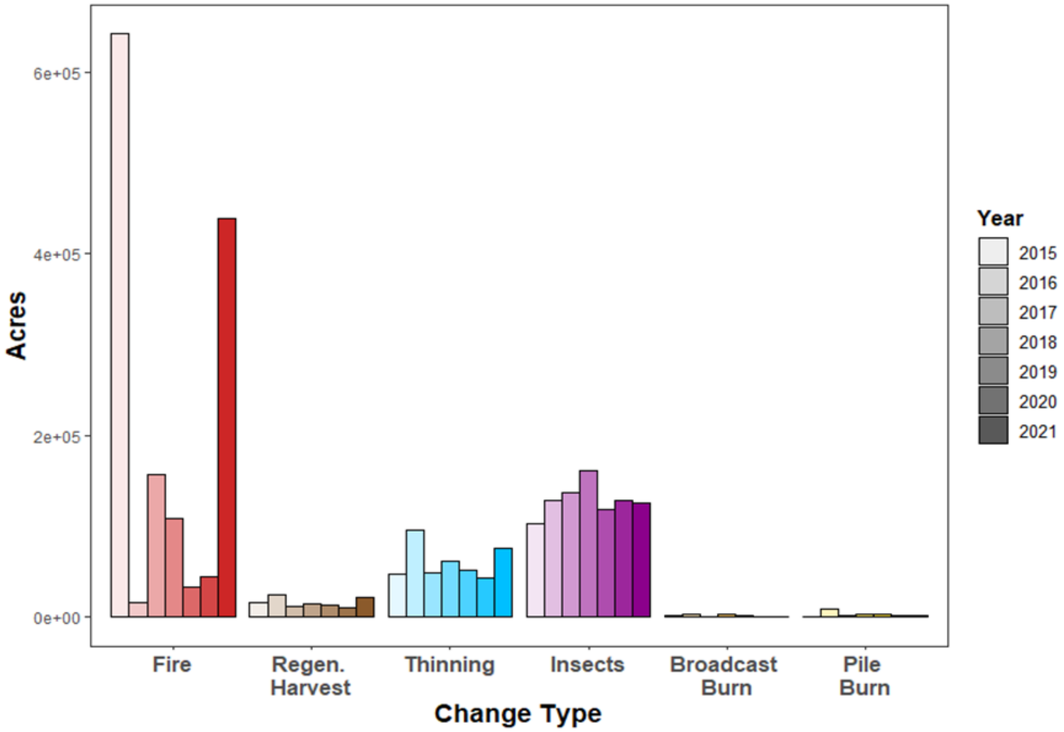


Figure 17b. Annual acreage affected for each disturbance type. This figure shows all acres affected per year, including those that may have previously experienced change. Insect activity in particular affects the same area over the course of an outbreak and will have acres counted multiple times across years.



Effects of disturbance on forest structure

The second component of the change detection process is forest structural change assessment. This component builds off of the first part of change detection – disturbance mapping – by determining how the forest changed in areas where disturbances were mapped and attributing changes to disturbance types. Tools developed for structural change assessment may also be applied across all of eastern Washington, including areas where change was not mapped, to pick up lower intensity changes or growth and regeneration.

To determine the typical changes seen as a result of specific disturbance types, we analyzed seven planning areas with high levels of disturbance that are spread across eastern Washington. In this section, we highlight two of these planning areas to demonstrate the utility of these tools for determining shifts in restoration needs due to disturbances. These types of analyses are an example of those that will be done on individual planning areas that experience significant disturbances over time.

Structure transitions resulting from disturbance

Disturbances have varying impacts on forest structure, depending on disturbance agent, severity, extent, timing, and initial conditions. To better understand the general trends of disturbance impacts on structure across eastern Washington, we evaluated how DAP-based structure changed due to each type of disturbance (low- to very high severity wildfire, insect activity, thinning, regeneration harvest, and broadcast burning). Seven planning areas – Mill Creek, Republic, White Salmon, Twisp River, Methow Valley, Teanaway, and Upper Swauk – were included to evaluate how different disturbances shift forest structure. These planning areas had high levels of disturbance between 2015 and 2021 and a wide geographic coverage.

For all disturbances except for thinning, pre-disturbance structure from 2015 was compared to post-disturbance structure from merged 2019–2021 DAP data. Data from multiple post-disturbance DAP years were merged because annual data from 2019, 2020, and 2021 were not complete. Combining the years resulted in a more complete post-change dataset, with each pixel representing the most recent DAP data available. Transitions for thinning were assessed using the nearest pre-disturbance DAP data year compared to the nearest post-disturbance DAP data year. This was done to minimize the impacts of regrowth or secondary disturbances on results, whereas the other disturbances were evaluated over the entire time period to account for delayed mortality.

Additionally, many of the thinning treatments occurred in 2019 or later, so using the nearest post-disturbance DAP year ensured that post-disturbance structure was evaluated, rather than pre-disturbance structure.

Table 15. Structure classes used in the DAP structure change analysis.

Structure Classes	Definition
Small Open	canopy cover[1] < 10% OR dbh[2] < 10”, canopy cover ≥ 10% dbh and < 40%
Small Closed	dbh < 10", canopy cover ≥ 40%
Medium Open	dbh ≥ 10” and < 20”, canopy cover ≥ 10% and < 40%
Medium Moderate	dbh ≥ 10” and < 20”, canopy cover ≥ 40% and < 60%
Medium Closed	dbh ≥ 10" and < 20", canopy cover ≥ 60%
Large Open	dbh ≥ 20", canopy cover ≥ 10% and < 40%
Large Moderate	dbh ≥ 20", canopy cover ≥ 40% and < 60%
Large Closed	dbh ≥ 20", canopy cover ≥ 60%

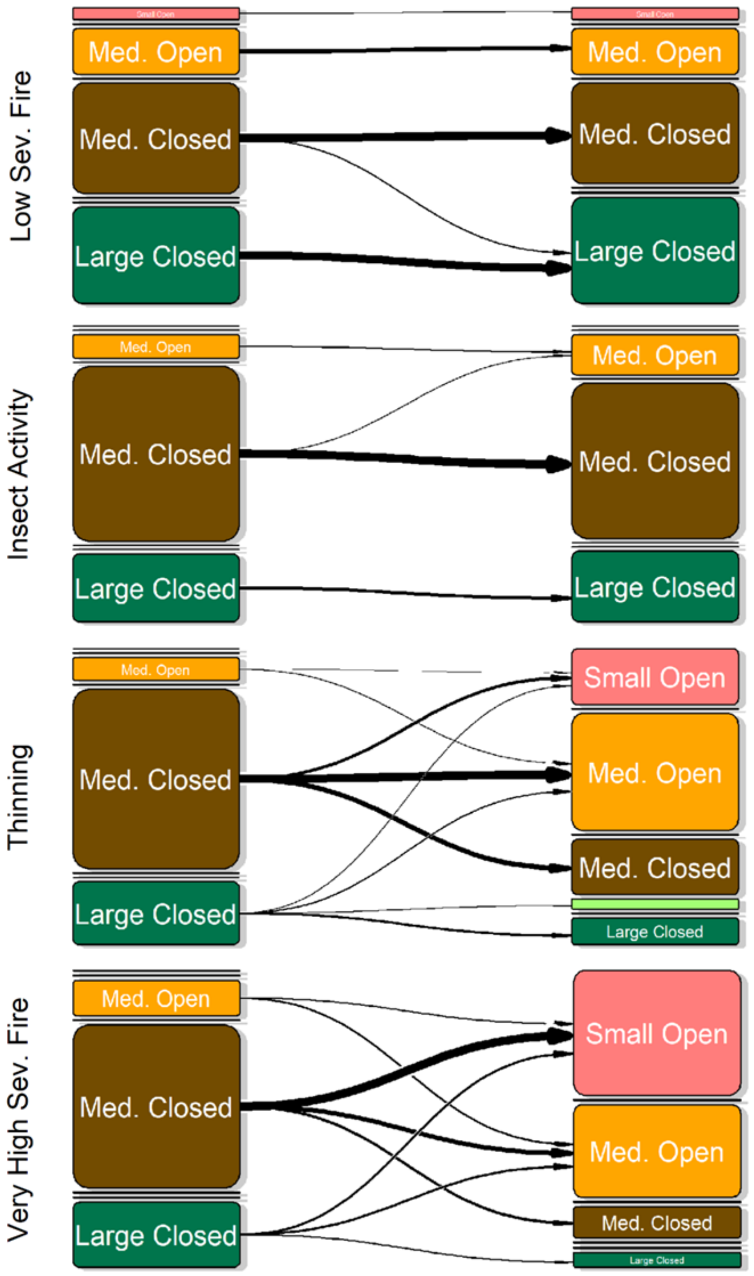
[1] Canopy cover is derived from DAP using the percent of returns above 6.6 feet.

[2] Tree diameter at breast height (DBH) was derived from modeling relationships between DAP tree height layers and tree diameter from field plots. Tree diameter used to define structure class is based on the mean diameter of the dominant and co-dominant trees in a field plot. It is calculated by deriving the quadratic mean diameter of trees whose diameters are in the top 25% of trees that are greater than 5" in diameter.

To quantify changes in forest structure, eight structural classes were used. These classes are based on canopy cover and overstory tree size. They are the same classes used for Landscape Evaluations in most of eastern Washington. They are compatible with the landscape scale reference information that WA DNR (see Landscape Evaluation Methods), the Colville National Forest (USFS, 2019), and USFS Region 6 (Hemstrom et al., 2014 use for departure assessments and estimating treatment needs.

Results from the transition analysis show that lower-severity disturbances including low-severity fire, insect activity, and broadcast burning resulted in more subtle changes to forest structure, while higher-severity disturbances including very high-severity fire and regeneration harvest caused most areas to convert to the small open structure class. Moderate severity disturbances including thinning resulted in a wider array of transition types. In the future, these transitions can be improved with more data and used to predict the impact of various disturbances on treatment goals.

Figure 18. Forest structure transitions for four types of disturbance: low severity fire (<25% BA loss), thinning, insect activity, and very high severity fire (>95% BA loss). Transitions for fire and insects were assessed using 2015 DAP data compared with merged 2019 – 2021 DAP data, and the thinning transitions were assessed using the closest pre-change DAP year compared with the closest post-change DAP year. Transitions represent change across seven planning areas: Republic, Mill Creek, White Salmon, Twisp River, Teanaway, Methow Valley, and Upper Swauk. Arrow thickness indicates the relative acreage for each transition type, with pre-disturbance conditions on the left and post-disturbance conditions on the right. Transitions with less than 2.5 percent of the total acreage are not shown. Note that our methods under-represent the amount of the large-open structure class, as well as the large closed in some areas.



Impact of forest structural changes on restoration needs

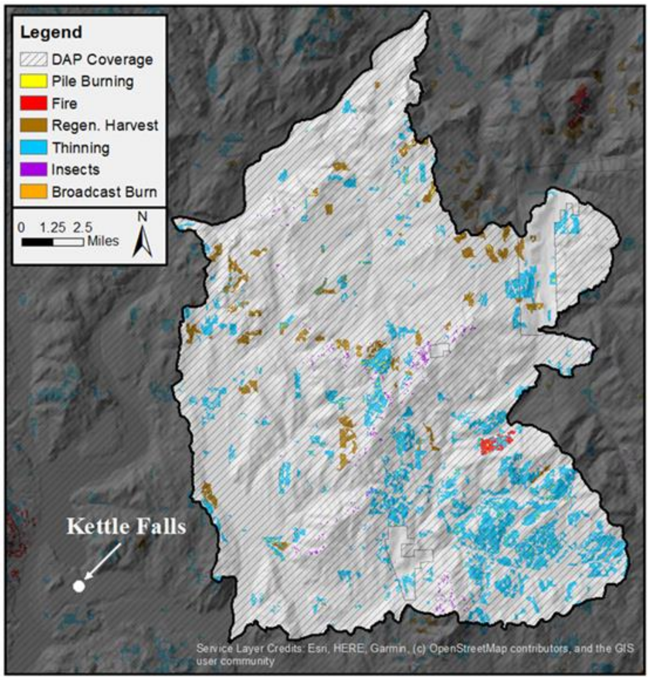
The effects of disturbances on forest structure and restoration needs were evaluated between 2016 and 2021 for the Mill Creek planning area and the area burned during the 2017 Jolly Mountain fire. The years for the structure assessment were limited relative to the disturbance mapping component (above), because pre- and post-change structure data were required for the assessment, and DAP data was only available from 2015 to 2021.

The Mill Creek planning area was picked for this analysis based on total acreage affected, as well as the high proportion of that acreage attributable to forest health treatments. The Mill Creek assessment serves to provide a more detailed view of how treatments and other disturbances result in movement towards or away from restoration goals within priority landscapes. We also report on forest structural changes following the Jolly Mountain Fire to demonstrate how wildfires move landscapes towards and away from restoration goals. In the future, analysis of forest structural changes will be completed over all planning areas across eastern Washington that experience significant change.

Case Study: Mill Creek

The Mill Creek planning area is located in northeastern Washington, just northwest of the town of Colville. The area is about 87 percent forested, with a little over half categorized as being moist or cold forest. About 42 percent of the forested area (57,000–80,000 acres) is in need of treatment. Land ownership is split between the Colville National Forest, private parties, industry, and DNR state lands.

Figure 19. Forest disturbances from 2016 to 2021 in the Mill Creek planning area.



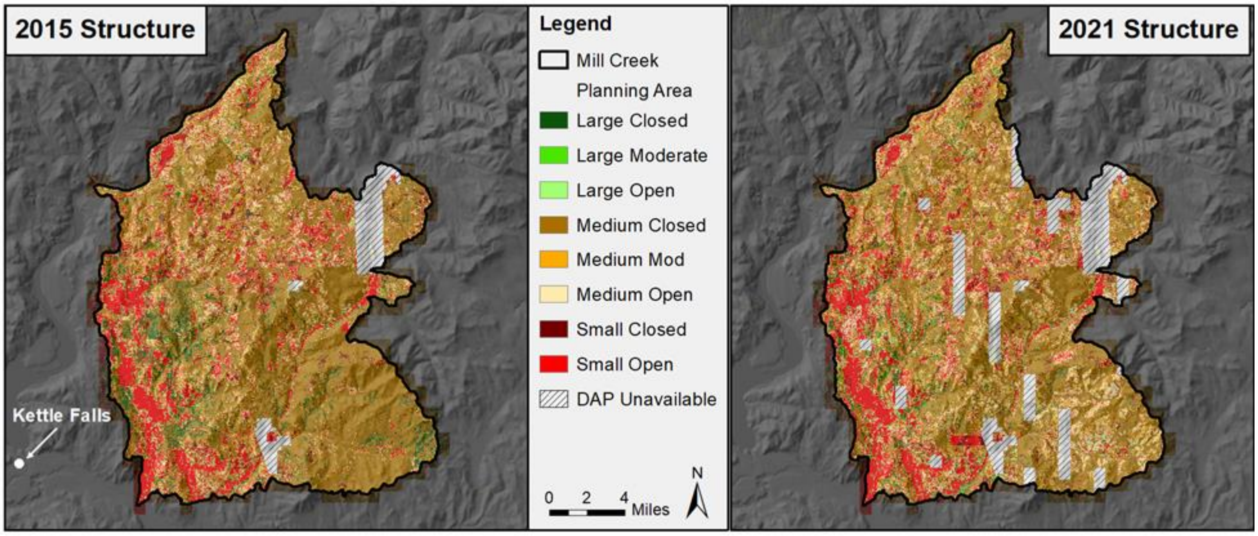
The Mill Creek A-Z project was underway in the southeastern portion (USFS land) when the landscape evaluation was completed in 2018, with plans to treat roughly 14,000 acres by 2023. Satellite-based change detection and attribution (see Methods) found 24,592 acres of change between 2016 and 2021, with most of that attributed to thinning. Thinning was focused in the Colville National Forest, where most patches are part of the A-Z project. There was also regeneration harvest on industrial and DNR lands, as well as a small fire in 2019 within the National Forest (North Mill Creek Fire, ~400 acres).

Nearly all of the landscape had DAP data available for structure change assessments, with only some small strips in the south and northeast not covered due to incomplete DAP data processing. These missing areas will be added once the DAP data have been fully processed.

Table 16. Treatment targets for Mill Creek and acres affected by disturbances between 2016 and 2021 in forest types and structure classes needing treatment.

Forest Conditions to Treat			**Acres of change by disturbance***					**Total Acres by Forest Type and Size Class**
Type	**Size Class**	**Treatment Need (Acres)**	Wildfire	Regen. Harvest	Thinning	Insect Activity	Broadcast Burn	
Dry Dense	Small	1,000-2,000	-	17	108	2	-	**127**
Dry Dense	Medium-Large	46,000-58,000	-	2,982	11,220	279	-	**14,481**
Moist + Cold Dense	Small	-	16	9	74	35	-	**134**
Moist + Cold Dense	Medium-Large	8,000-14,000	394	1,059	6,358	543	23	**8,377**
Dry + Moist Open	Small	-	-	116	246	9	-	**371**
Dry + Moist Open	Medium-Large	2,000-6,000	-	196	848	58	-	**1,102**
Total Acres by Disturbance			**410**	**4,379**	**18,854**	**926**	**23**	**24,592**
Total	**57,000-80,000**		*Change can move the area towards or away from target structure classes.					
Anticipated Treatment Type	⬜	Non-commercial thin + fuels treatment, may be fire only.						
	🟦	Commercial thin + fuels treatment if access exists. May be non-commercial, fire only, or regeneration harvest.						
	🟩	Maintenance: prescribed fire or mechanical fuels treatment.						

Figure 20. DAP forest structure in the Mill Creek planning area for 2015 and 2021. Structure was evaluated in areas where both years were available. 2021 data have more missing areas because the DAP data had not been completely processed by the time of this analysis.

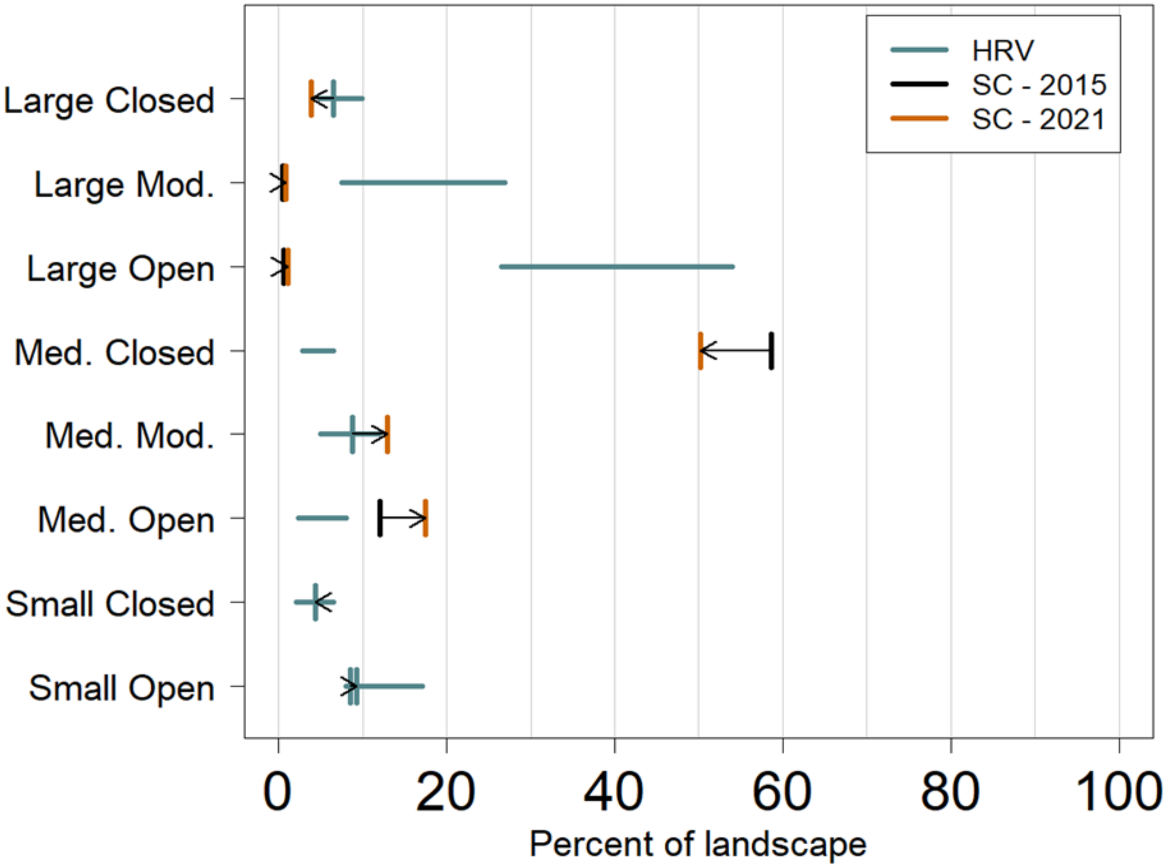


DNR’s landscape evaluation for Mill Creek identified the need for treatment across much of this planning area, within dry, moist, and cold forest types, and within small and medium-large size classes (Table 16). All types of disturbances that occurred 2016–2021 had an impact on structure types recommended for treatment. The total affected acres were lower than recommended treatment acres for most forest types and structure classes, with the exception of the moist and cold, medium-large dense class (8,377 acres affected out of 8,000–14,000 recommended for treatment).

Table 16 shows the treatment types detected across Mill Creek are similar to those recommended as part of the 2018 landscape evaluation; namely, thinning as the main treatment type, followed by regeneration harvest. Across all forest types, the primary changes to forest structure were a reduction in medium closed forest, and a subsequent increase in the medium moderate and medium open classes.

While these two classes are now higher than the landscape target, these classes will grow into the large moderate and large open classes that are very low relative to targets. In addition to the total amount of change, patch sizes of the medium-open and medium-moderate appear to be large enough in the SE portion of the planning area to flip this watershed from being dominated by a single, contiguous patch of closed forest to a patch mosaic that will be less likely to experience large, high severity disturbances (Churchill et al., 2022).

Figure 21. Forest structural departure from landscape target ranges for areas with DAP coverage within the Mill Creek planning area 2016–2021. See Landscape Evaluation methods for a description of how these ranges are derived. Initial structure classes are derived from 2015 DAP, while post-change structures are from 2021 DAP. Note that current structure class maps underrepresent the amount of the large-open structure class and large-closed classes. Methods to derive structure class maps from DAP data are being fine-tuned to address this.



Much of the Mill Creek planning area is designated as having moderate treatment priority, with a region of higher priority in the southwest. Many of the thinning treatments detected occurred in regions of moderate priority, with very little change seen in the high priority areas, which occur primarily on private land at lower and drier elevations near the town of Colville. While much progress towards meeting treatment targets and landscape restoration goals has been accomplished, there is still significant need to work with private landowners in these high priority areas that have high vulnerability to drought and significant wildfire risk.

In addition, our methods only quantify changes to forest structure from disturbances. The extent to which surface fuels have been treated through prescribed fire or mechanical methods also needs to be assessed to determine changes to fire risk. A wide range of studies and examples from recent fires (e.g. Cansler et al., 2022, Prichard et al., 2020) show that mechanical density reduction is not sufficient to reduce fire intensity.

Case Study: Jolly Mountain Fire

Photo of mortality and regrowth following the 2017 Jolly Mountain fire. Photo by Stan Sovern, 2019.

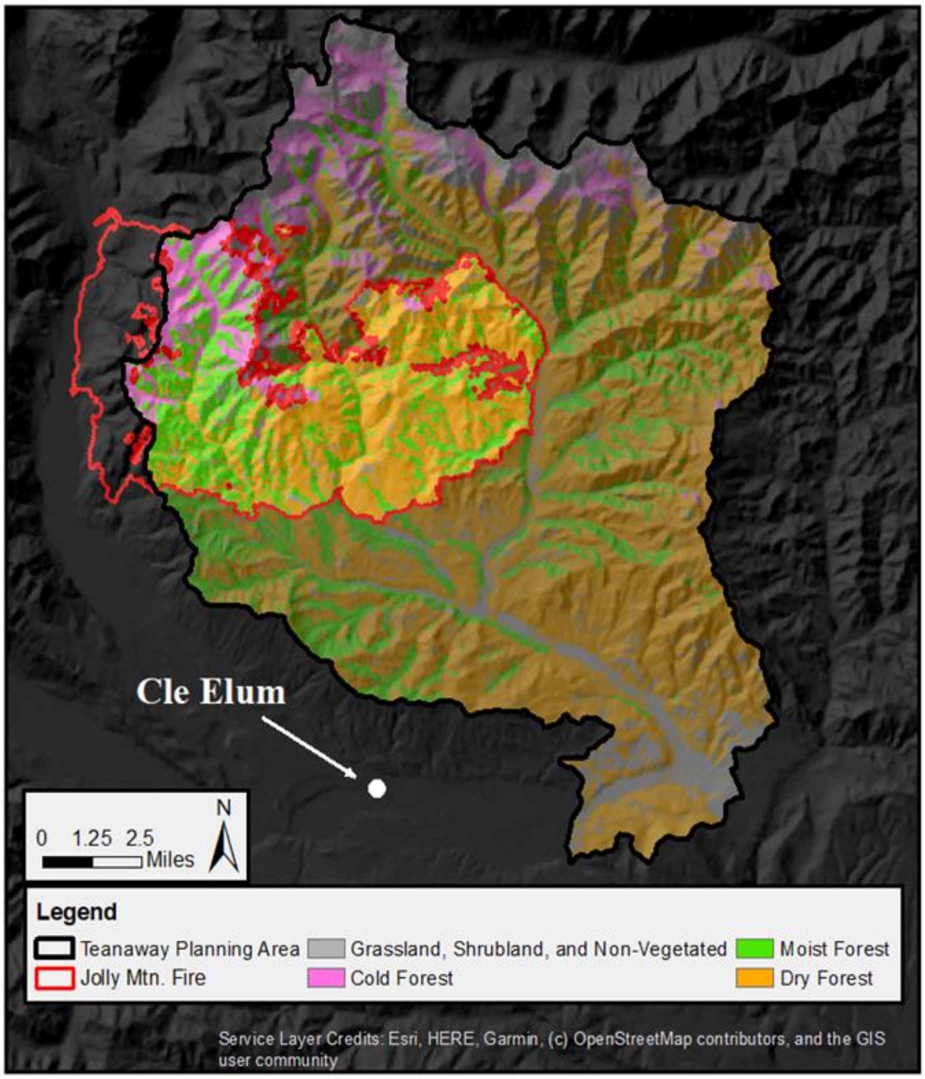
Across eastern Washington and the western United States, wildfires have the largest impact on forest structure. Large wildfires are increasingly occurring in planning areas before treatments can be completed. Given the projected climatic warming and related increase in wildfire, landscape change will likely be driven by a mix of treatments and fire in most places. Understanding how specific fires impact the overall movement of a landscape towards or away from restoration goals is thus essential.

In partnerships with researchers and land managers, DNR piloted a rapid methodology for post-fire landscape evaluations to meet this need and inform immediate post-fire management actions (see the full DNR 2021 Work of Wildfire report). However, actual maps of post-fire forest structure are not available until 1 to 4 years after the fire. Thus, the Work of Wildfire approach uses pre-fire structure, fire severity maps, and assumptions on how different fire severities drive structural changes to model post-fire structure and thus assess landscape change. This rapid approach is designed to meet short-term needs.

Complementing the Work of Wildfire approach, the structural change assessment portion of change detection, presented here, allows for a longer term evaluation of the changes caused by wildfires based on actual post-fire structure data. Delayed mortality that occurs 1-2 years after the fire can be detected. This information can be used to update treatment targets and landscape evaluations 2-4 years post-fire.

Here, we present a post-fire evaluation of the Jolly Mountain Fire, which burned in the northwest corner of the Teanaway planning area in 2017. The landscape evaluation for Teanaway was completed post-fire; this analysis is not meant to update that evaluation, but rather to demonstrate how change detection can be used to understand the impact of individual disturbance events on forest structure.

Figure 22. The 2017 Jolly Mountain fire burned in the northwestern region of the Teanaway planning area, and covered dry, moist, and cold forests.



The Jolly Mountain fire burned on DNR and USFS land within four subwatersheds in the Teanaway planning area – the West Fork Teanaway, Middle Fork Teanaway, Lower North Fork Teanaway, and a small portion of the Upper North Fork Teanaway. Much of the fire is within inventoried, roadless areas, and wilderness and thus is inaccessible. The fire burned at a range of severity levels and covered a variety of forest types. Only areas where the fire fell within the planning area boundary were considered for this analysis. We only focused on the burned area within the planning area, rather than conducting an analysis by watershed, in order to understand the impacts of wildfire alone on forest structure, excluding any other changes that may have occurred during the time period.

Figure 23. Fire severity for the Jolly Mountain fire within the Teanaway priority planning area.

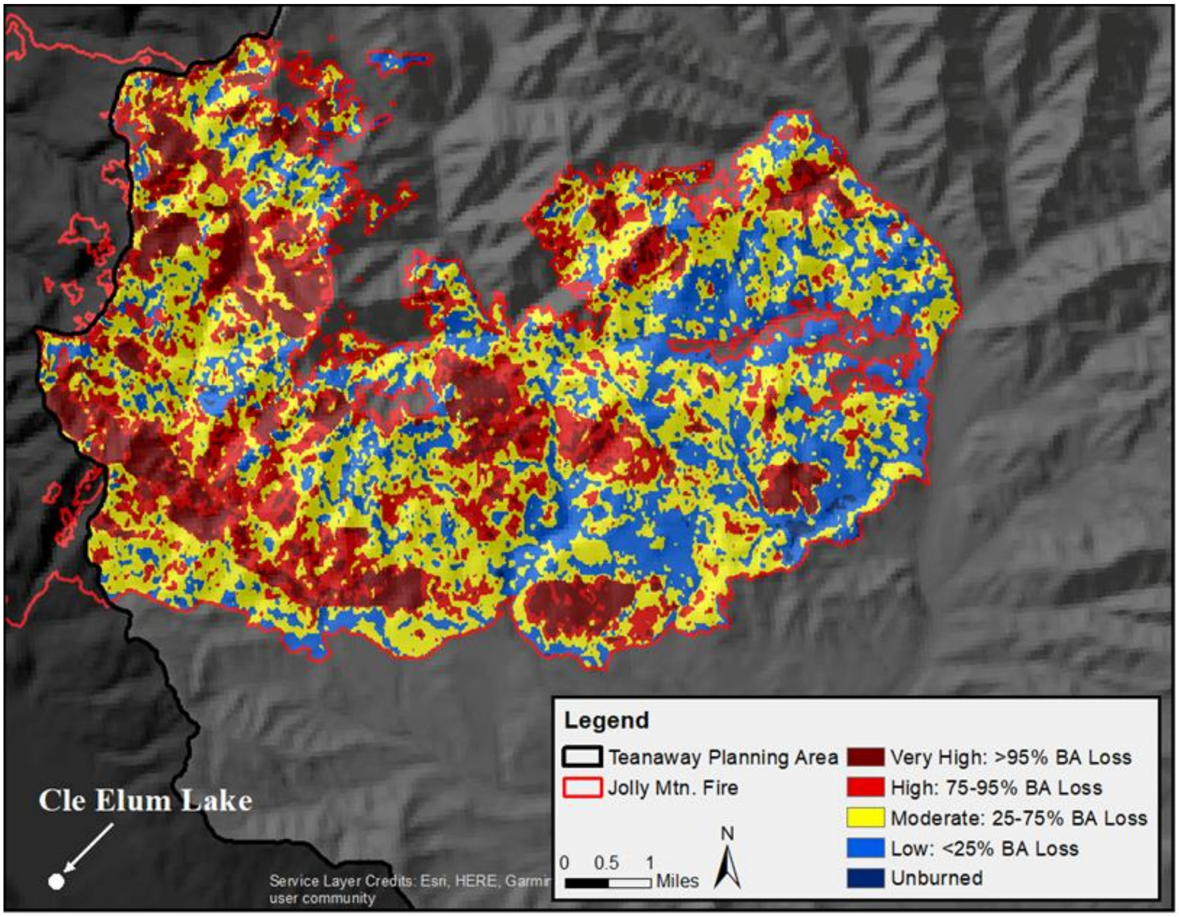
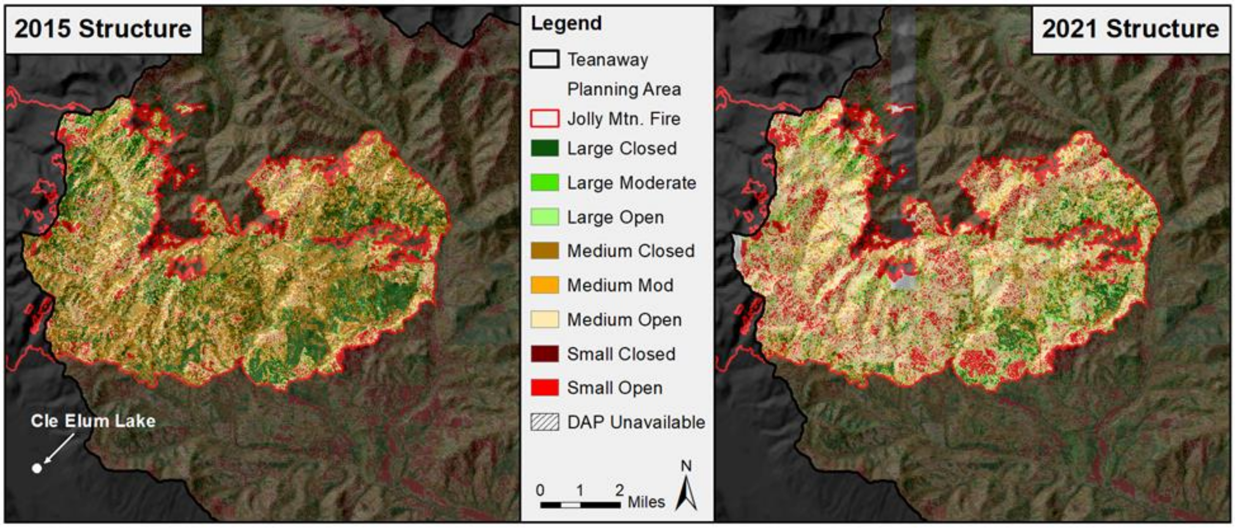


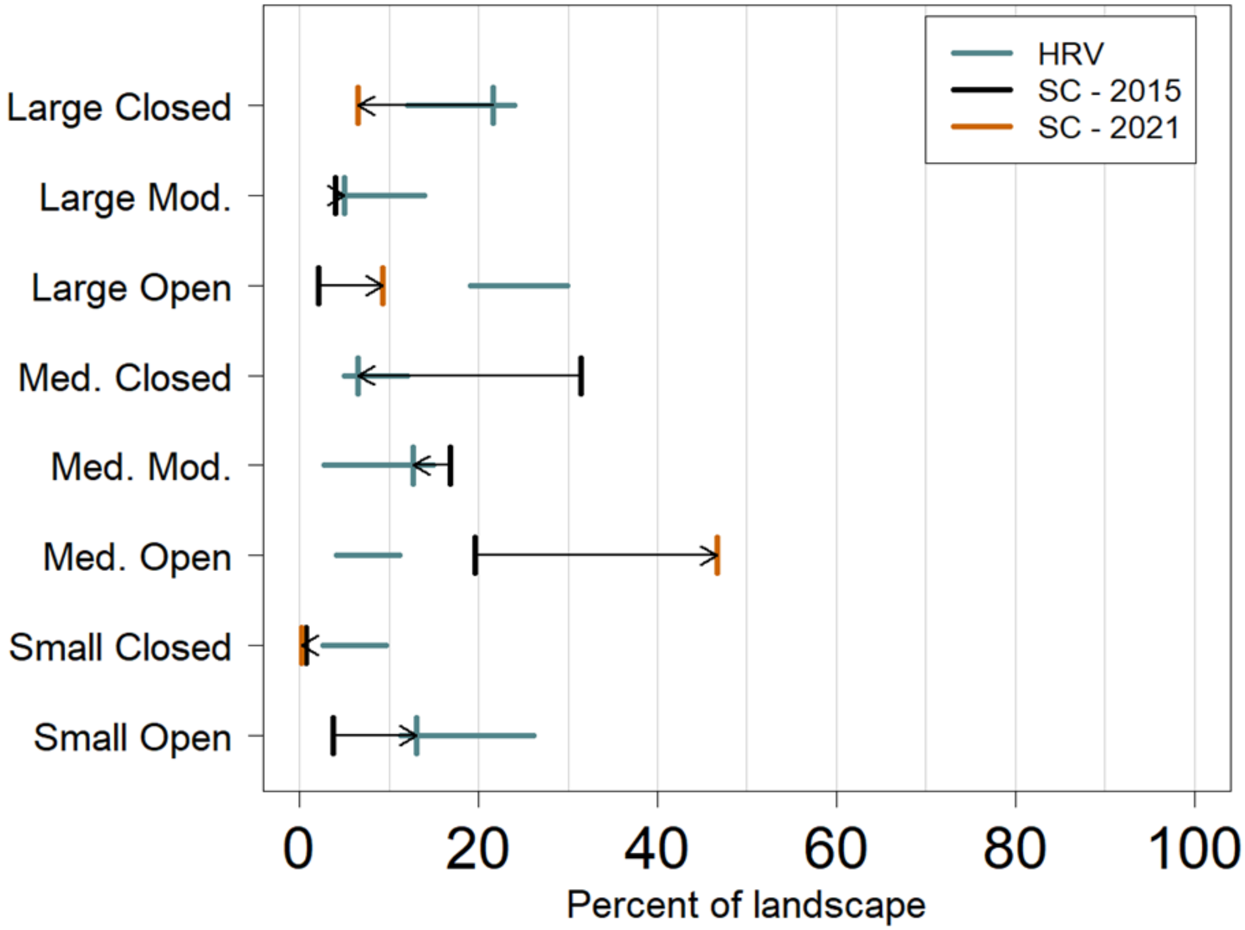
Figure 24. Pre- and post-fire DAP structure within the Jolly Mountain burned area in the Teanaway priority planning area.



Overall, the fire resulted in much of the burned area shifting from a closed to a more open forest structure. Very high-severity fire resulted in patches of small open forest, while moderate and high-severity fire tended to shift the forest to a medium-open condition. It can be difficult to differentiate between live trees and snags with DAP alone, meaning that some medium open forest where fire severity was high may include a number of standing dead trees. Data from future DAP or LiDAR structure class maps will provide more accurate information.

Across all vegetation types, forest structure moved towards target conditions within the wildfire perimeter. Five out of the eight possible structure classes are now within the desired range, most notably medium-closed, which is highly departed in most landscapes. The medium-open class moved further away from its target, but will grow into the large-open and large-moderate classes that are low. Some areas that burned at high severity that are small open will grow into small-closed as trees regenerate.

Figure 25. Movement towards or away from landscape targets for each structure class for all potential vegetation types present in the Teanaway planning area following the 2017 Jolly Mountain fire.



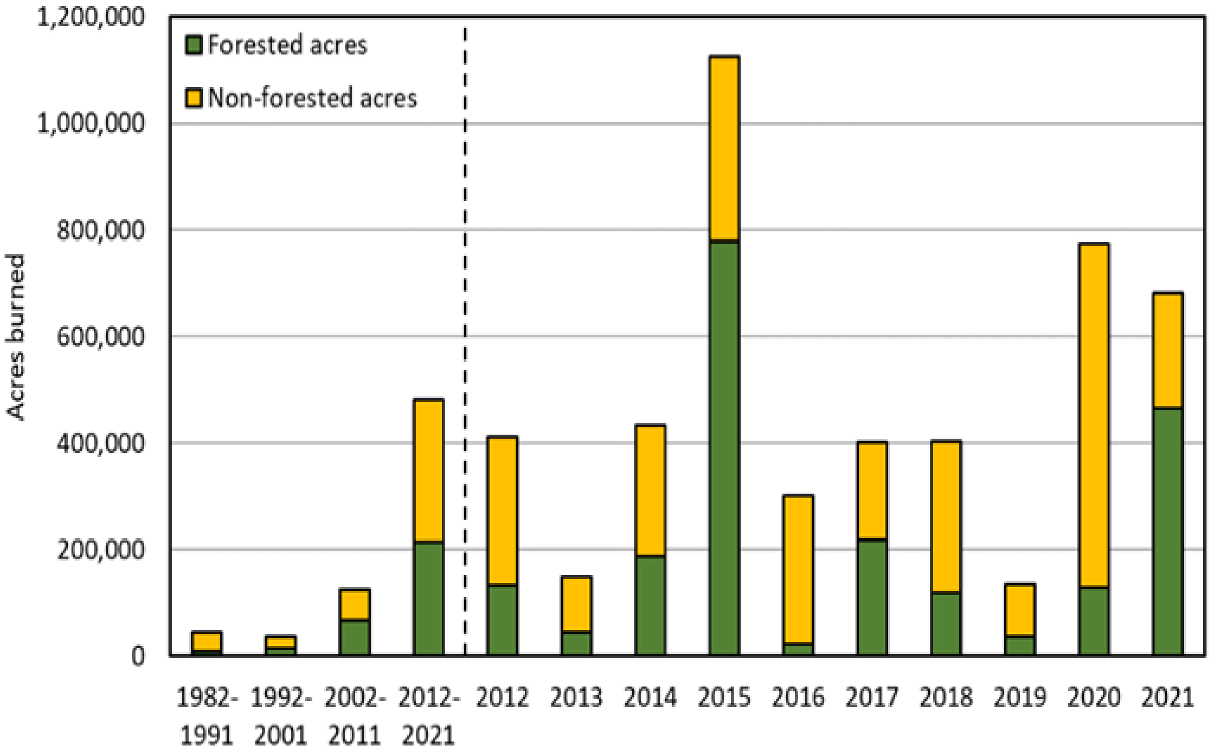
In general, these results matched those from Churchill et al. (2022) for the West Fork Teanaway subwatershed. That study used photo-interpreted data rather than DAP, and six structure classes rather than eight. However, the results were similar, with increases in small, medium, and large open classes and a decreased percentage of the landscape falling into the medium and large closed classes.

While this analysis shows that the wildfire moved the landscape towards target structural conditions, it does not account for post-fire fuels that will accumulate as the dead trees fall in moderate and high-severity areas (Larson et al., 2022). Thus, additional fire under moderate conditions, or other treatment types, will be needed to treat these fuels over time in order to keep flame lengths low in future wildfires. Also, this analysis did not incorporate the unburned portions of the Teanaway Planning Area, which still has significant treatment needs (see 2020 landscape evaluation).

Work of Wildfire Rapid Assessment Protocol

Throughout the western United States, 2021 was a very challenging fire season that impacted communities and strained wildland fire management resources. In eastern Washington, wildfires affected 679,761 total acres, including 463,345 acres of forest that burned with a wide range of effects across different forest types. In terms of acres burned, 2021 was the third-largest overall in recent Washington history, and the second largest in terms of forested acres burned (Figure 1). Many communities experienced heavy smoke impacts, evacuations, and damage to property and other resources. These fires also had substantial effects on forested landscapes and the many benefits they provided to people.

Figure 26. Average annual acres burned in eastern Washington State from 1984 to 2021 by decade and individual year (2012-2021; bars to the right of the dashed line). Large fire perimeters include all events over 100 acres and are compiled by the WA DNR Wildland Fire Management Division. 2015, 2020, and 2021 have been the largest fire years to date.



To better understand the impacts of the 2021 fire season, DNR scientists developed a rapid assessment to evaluate the work of wildfire. The work of wildfire was defined as the degree to which fire effects are consistent with the landscape resilience and wildfire risk reduction objectives of the 20-Year Forest Health Strategic Plan. The highlights of this pilot project fall into four related themes: (1) summary of 2021 fires; (2) effects of individual fires; (3) forest health treatments; (4) wildland fire operations. All 2021 wildfires in this report were managed for suppression objectives and report results are based on preliminary burn severity maps that may change due to delayed tree mortality and other factors. A detailed example of individual fire effects on landscape departure and treatment needs is included in the full Work of Wildfire Report. Key findings from the 2021 Work of Wildfire pilot assessment include:

1. *The 2021 wildfires had both positive and negative effects on resilience and wildfire risk reduction objectives.*

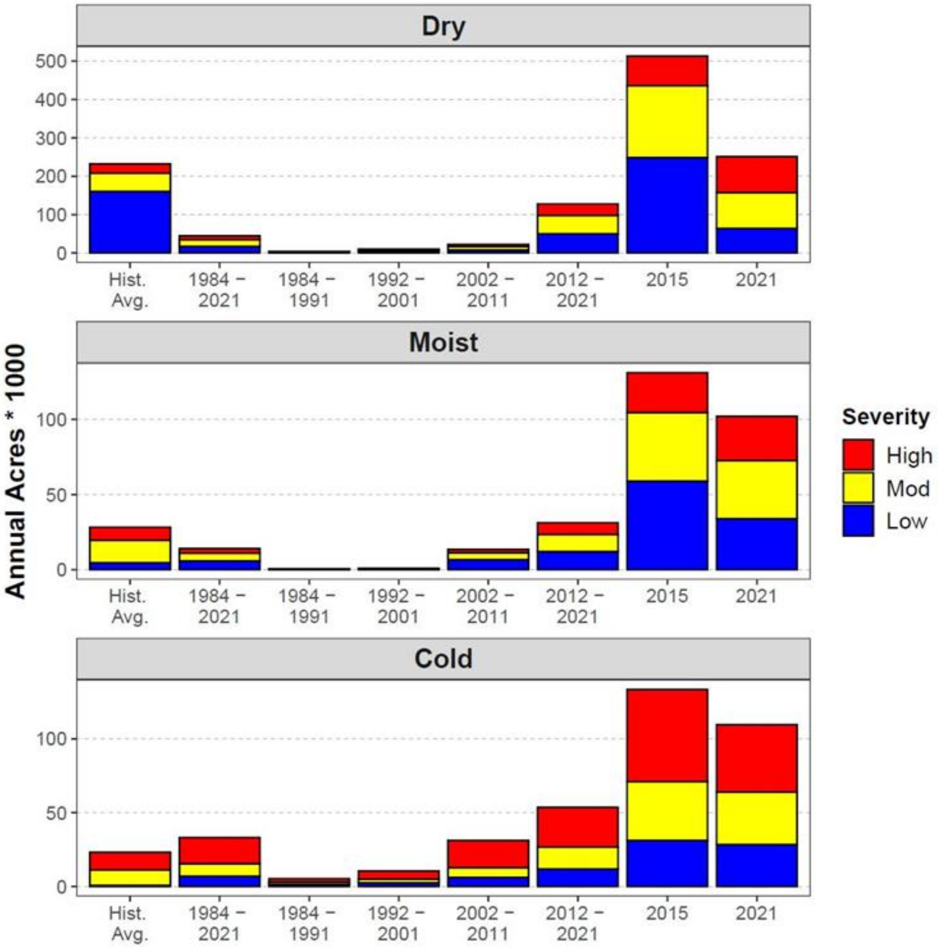
Uncharacteristically severe impacts occurred in dry forests and portions of moist forests. High-severity fire (>75% tree mortality) occurred across an estimated 125,000 acres of dry and moist forests (Figure 2), including 85,000 acres within medium and large patches (>100 acres). High-severity fire reduced large tree habitats, seed sources for natural regeneration, and soil stability, all of which compounded the impacts of previous large fires and will limit options to restore more resilient landscapes and lower wildfire risks.

Conversely, fires likely had beneficial effects on landscape resilience and wildfire risk in many locations. Low- and moderate-severity fire (<75% tree mortality) occurred across an estimated 230,000 acres of dry and moist forests. Fires reduced fuels and tree densities in these areas, mitigating fire risk and facilitating management of future fires – particularly if resilient conditions are maintained by future treatments or low-severity fire. This total compares to 210,000 footprint acres of mechanical and prescribed fire treatments done the prior four years across eastern Washington (2017-2020).

2. *Individual wildfire events spanned a wide range of forest conditions across eastern Washington.*

Each large fire exhibited distinct spatial patterns of burn severity (i.e., tree mortality), with corresponding implications for landscape resilience goals. The Schneider Springs Fire was the largest fire event (97,320 forested acres), while the Cub Creek 2 Fire included the most high-severity fire in dry forests (21,646 acres). The Cedar Creek Fire produced a variety of outcomes, illustrating many of the overall patterns of the 2021 fires. For example, the Cedar Creek Fire included uncharacteristically large patches (>1,000 acres) of high-severity fire in dry forests as well as low- and moderate-severity fire that partially addressed treatment needs in the Methow and Twisp River priority landscapes (see below).

Figure 27. Preliminary burn severity across forested areas of Washington State from 1984 to 2021 and historically by potential vegetation type (Haugo et al. 2019). Low, moderate, and high-severity classes correspond to 0-25%, 25-75%, and 75-100%, respectively. Note the larger Y-axis range for dry forests.



3. *Forest health treatments burned at low, moderate, and high severity.*

The 2021 wildfires included many examples where prior treatments burned at low severity (<25% tree mortality) and gave fire managers more options to directly engage and safely manage fires. However, exceptionally hot and dry weather, high winds, fuel conditions, and other factors led to moderate and high severity in other treatments. Based on limited field observations, treatments that included prescribed fire, or piling and burning to reduce surface fuels, were more likely to be effective; mechanical-only treatments often experienced comparatively higher tree mortality.

4. *Wildfire managers utilized some forest health treatments to manage wildfires more effectively and safely.*

Wildfire incidents are dynamic, and the utility of prior treatments for wildland firefighting operations depends on fire weather, resource availability, and strategic considerations specific to each fire. As such, not all treatment units are directly used in fire operations. During the Cedar Creek Fire, fire managers utilized some treatment units to reduce fire spread and severity, accomplishing work faster and with fewer resources. Where treatments were used operationally, fire managers were able to protect communities, infrastructure, forest resources, and other high-value resources.

In addition to these key findings, the 2021 wildfire season demonstrated numerous lessons for future assessments. Given recent trends and climate projections, wildfires are likely to continue to be a major disturbance agent shaping forest health and landscape resilience. Despite the sharp increase in total acres burned since 2014, the 10-year average is below estimated historical levels that maintained resilient landscapes. Evaluating the positive and negative effects of wildfires, forest health treatments, and wildfire operations will become increasingly important for climate adaptation strategies.

Individual Fire Effects

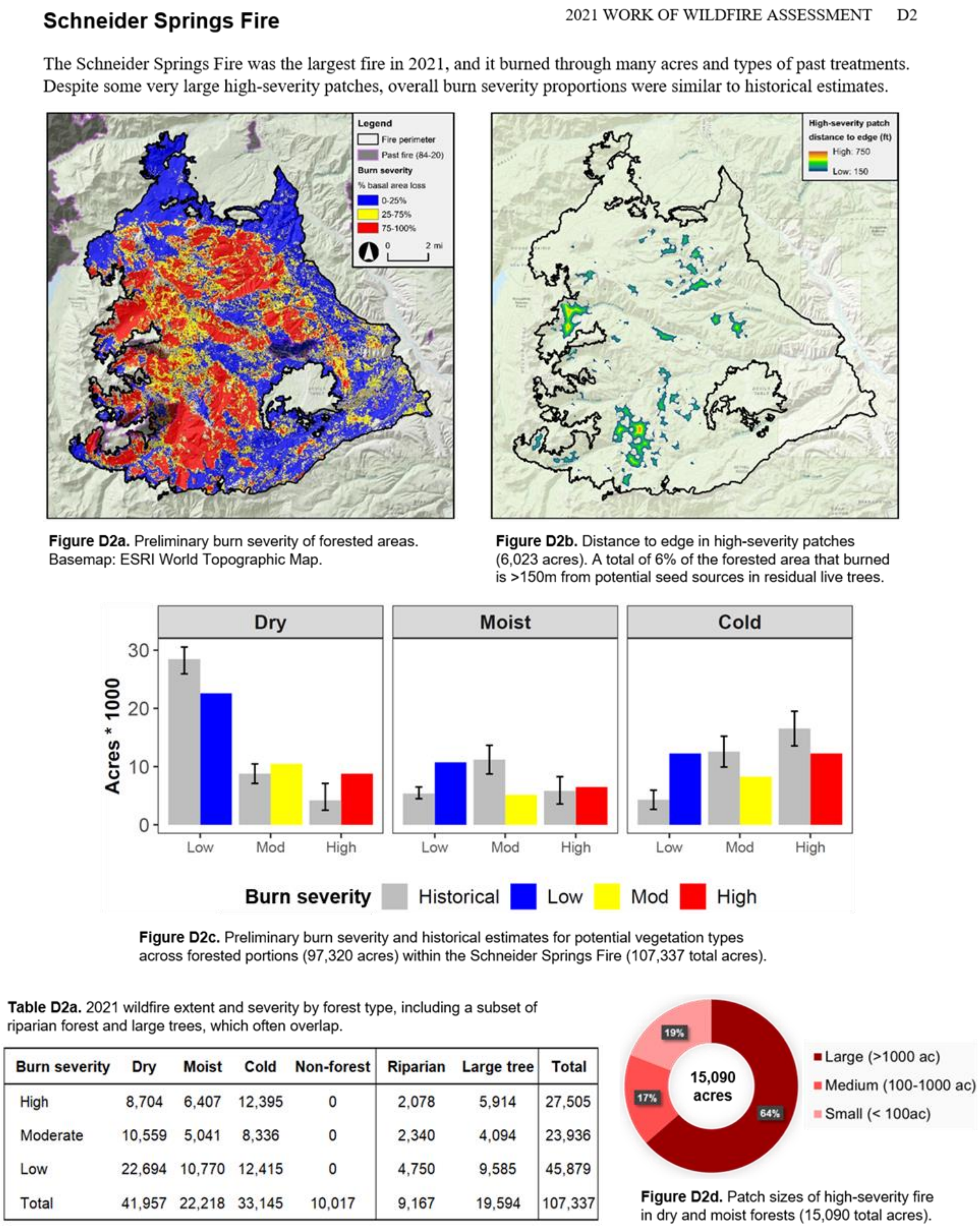
To more fully evaluate the work of the 2021 wildfires, we analyzed the largest 14 of the 73 fires that occurred in eastern Washington. These 14 fires each burned more than 5,000 acres of forest, collectively accounting for 96% of the 463,345 acres of forest that burned in 2021. The outcomes of each wildfire varied widely and depended on multiple factors, including fire weather, fuel conditions, fire management operations, past treatments, and terrain. Fire effects occurred under suppression objectives for all fires. With the exception of the Bulldog Mountain Fire, the amount of high-severity fire in dry forests exceeded the desired ranges from historical reference conditions. Many fires greatly exceeded the desired ranges for high severity (e.g., 35-55% of dry forests burned at high severity vs. the historical range of 5-18%).

Each large fire exhibited distinct spatial patterns of burn severity, with variable implications for landscape resilience goals. For each fire, we assessed the following key indicators of positive vs. negative forest health outcomes: (1) burn severity in dry and moist forests; (2) high-severity fire patch sizes in dry and moist forests; (3) potential seed source limitation for tree regeneration; (4) mortality of large trees; (5) amount of low-, moderate-, and high-severity fire in stream-adjacent forests. We demonstrate a one-page summary for all of these metrics for the Schneider Springs Fire (Figure 28).

Table 17. Total acres, forested acres, and acres burned by forest type and burn severity for the 14 large fires that burned over 5,000 acres of forest in 2020. Bold italic numbers indicate that the amount of high-severity fire was higher than would be expected under historical/characteristic conditions. Historical severity proportions are from Landfire as applied by Haugo et al (2019). Historical comparisons are not shown for low- and moderate-severity fire in all forest types nor for high-severity fire in cold forests.

Fire Name	Total Acres	Forested Acres	Dry Forest		Moist Forest		Cold Forest	
			High	Low-Mod	High	Low-Mod	High	Low-Mod
Schneider Springs	107,337	97,320	***8,704***	33,254	6,407	15,811	12,395	20,750
Cub Creek 2	70,248	62,214	***21,646***	23,479	***1,266***	884	7,517	7,421
Cedar Creek	55,235	47,576	***7,695***	16,490	***1,064***	896	10,702	10,729
Summit Trail	49,595	47,568	***9,652***	16,226	1,515	2,896	6,449	10,830
Lick Creek	80,426	46,340	***7,920***	8,217	7,315	22,146	74	668
Green Ridge	43,719	41,659	***1,750***	4,749	9,479	24,849	77	757
Walker Creek	23,765	20,595	***4,068***	8,360	457	737	3,570	3,402
Twentyfive Mile	22,118	17,907	***4,028***	8,931	209	650	869	3,221
Whitmore	58,279	16,758	***6,821***	9,742	51	115	4	25
Chuweah Creek	36,753	13,383	***6,568***	5,512	0	0	333	970
Ford Corkscrew	15,718	12,639	***6,642***	5,490	***254***	246	5	3
Muckamuck	13,312	8,680	***3,015***	3,804	***431***	512	289	629
Bulldog Mountain	6,214	5,652	419	2,149	584	1,777	119	604
Chickadee Creek	5,859	5,455	***1,294***	2,368	148	246	315	1,084

Figure 28. Example of one-page summary for the Schneider Springs fire, one of the 14 large fires that burned over 5,000 acres of forest in 2020.



Schneider Springs Fire

2021 WORK OF WILDFIRE ASSESSMENT D2

The Schneider Springs Fire was the largest fire in 2021, and it burned through many acres and types of past treatments. Despite some very large high-severity patches, overall burn severity proportions were similar to historical estimates.

Figure D2a. Preliminary burn severity of forested areas. Basemap: ESRI World Topographic Map.

Figure D2b. Distance to edge in high-severity patches (6,023 acres). A total of 6% of the forested area that burned is >150m from potential seed sources in residual live trees.

Figure D2c. Preliminary burn severity and historical estimates for potential vegetation types across forested portions (97,320 acres) within the Schneider Springs Fire (107,337 total acres).

Table D2a. 2021 wildfire extent and severity by forest type, including a subset of riparian forest and large trees, which often overlap.

Burn severity	Dry	Moist	Cold	Non-forest	Riparian	Large tree	Total
High	8,704	6,407	12,395	0	2,078	5,914	27,505
Moderate	10,559	5,041	8,336	0	2,340	4,094	23,936
Low	22,694	10,770	12,415	0	4,750	9,585	45,879
Total	41,957	22,218	33,145	10,017	9,167	19,594	107,337

Figure D2d. Patch sizes of high-severity fire in dry and moist forests (15,090 total acres).

Changes to Landscape Departure and Treatment Need

As detailed in the full report, the Cedar Creek Fire burned through a portion of the Twisp River priority landscape, thus changing the underlying vegetation structure and composition – a departure from target reference conditions and treatment needs quantified in the 2020 landscape evaluation. The Okanogan-Wenatchee National Forest was in the process of planning a large restoration project in the area and had prepared a draft environmental assessment. The area burned before the project could be implemented, which is an increasingly common trend in eastern Washington.

During the fall of 2021, DNR scientists worked with USFS managers and the North Central Washington Forest Health Collaborative to assess how the fire changed restoration treatment needs and to prioritize locations for post-fire treatments. This in-depth evaluation applied and refined the conceptual framework and toolset for post-fire management developed for a Joint Fire Science Program research project called NEWFIRE (Larson et al. 2022, Churchill et al. 2022). We conducted this post-fire landscape evaluation for the entirety of the Little Bridge Creek sub-watershed, including both burned and unburned portions. We also included small parts of the Thompson Creek and Wolf Creek sub-watersheds. This area is the only part of the Twisp River priority landscape that was affected by the Cedar Creek Fire.

The post-fire landscape evaluation and prioritization show that the Cedar Creek Fire accomplished some landscape treatment needs, but also created new ones. High-severity fire converted approximately 6,000 acres of dense forest into early-seral conditions. Prior to the fire, closed-canopy, medium- to large-size forest structure was over-represented relative to target reference. The fire shifted the amount of this forest type into the target ranges, although it is still on the high end, especially on dry sites.

The amount of open canopy, large tree forest is also below target ranges. While the fire reduced the need for density and fuel reduction treatments by 2,000-2,500 acres, treatments are still needed in the unburned portions of this landscape. Treatments are also needed in low-severity areas to reduce tree density, although fire probability in these areas will remain lower for 10-20 years. To guide location of these treatments, we re-ran the landscape treatment prioritization from the 2020 Landscape Evaluation while incorporating the effects of the fire.

In contrast, the amount of early-seral vegetation is now over-represented, consistent with the conclusions drawn from other large, high-severity fires in the Methow Basin. Natural regeneration is likely to be abundant in moist and cold forests (Povak et al. 2020), and thus a significant amount of this early-seral type may transition to young forest within several decades. However, seed source limitations in large patches, ongoing climate warming, and reburns are likely to limit establishment of new forests, especially on drier sites. Post-fire tree planting is thus warranted to improve chances of re-establishing forest in key locations and with climate-adapted tree species and planting stock (Larson et al. 2022). We conducted a prioritization analysis to guide reforestation efforts. In addition, prescribed fire and explicit management of wildfires to protect planted areas will likely be necessary to give seedlings and saplings enough time to reach more fire-resistant size classes (Stevens et al. 2021).

Figure 29. Top left: Section of the WA DNR Twisp River priority landscape that burned in the Cedar Creek Fire. Burn severity and units proposed for treatment prior to the fire are shown. Top right: Prioritization for tree planting based on severity, distance to surviving trees, and higher moisture deficits (Larson et al. 2022). Bottom: Post-fire landscape treatment prioritization for density and fuel reduction treatments (see WA DNR 2020 for methods).

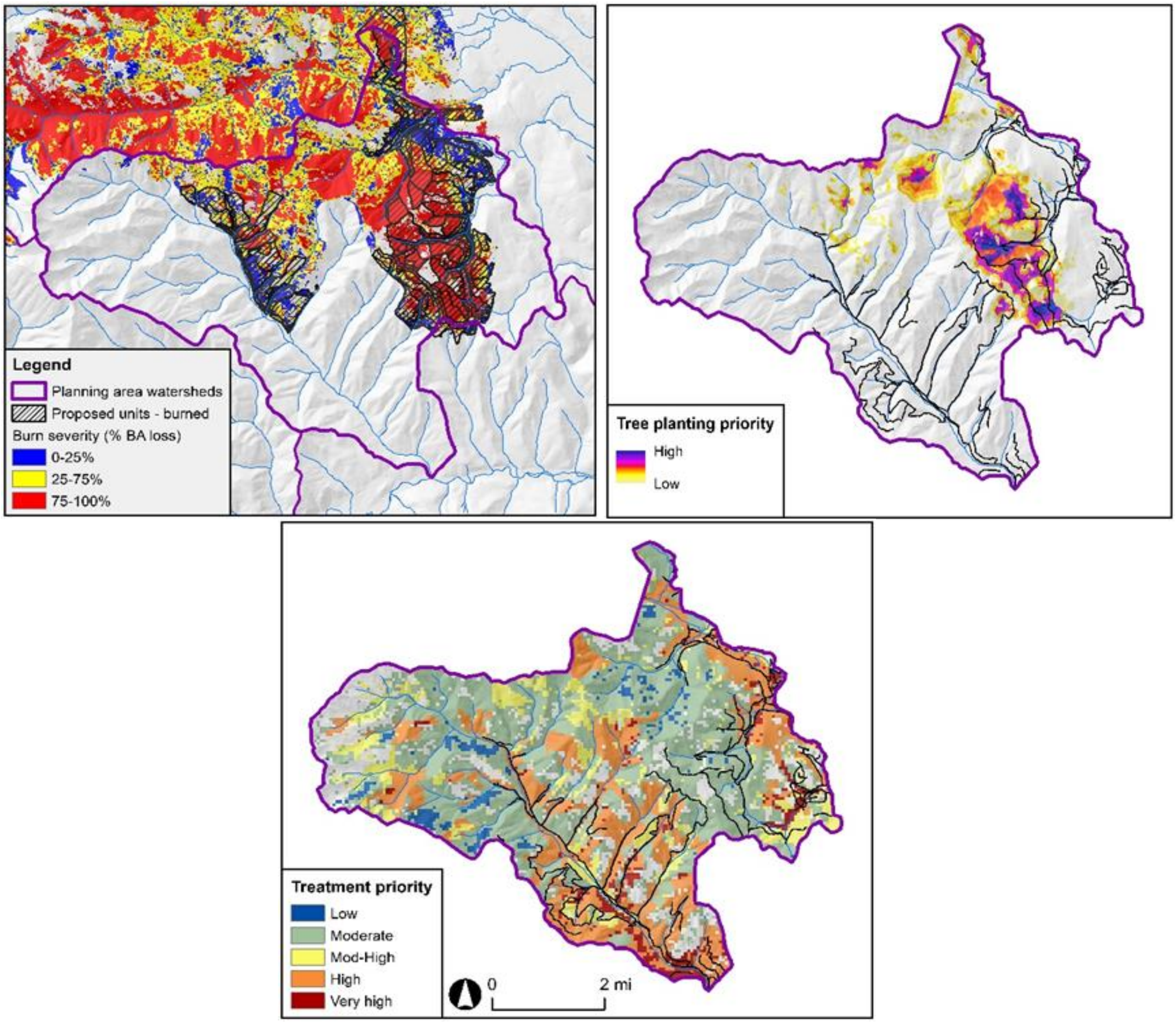
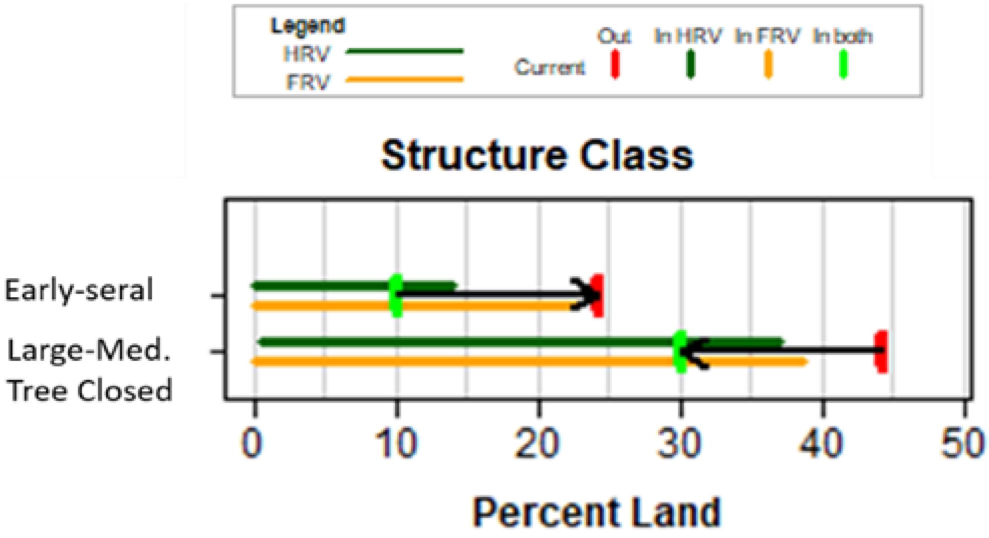


Figure 30. Effects of the Cedar Creek Fire on landscape departure from historical and future ranges of variation (HRV and FRV) for the Little Bridge Creek Sub-watershed in the Twisp River priority landscape. The black arrow indicates the change from pre- to post-fire conditions. Red and bright green indicate conditions outside and inside the HRV and FRV range, respectively. HRV and FRV ranges for landscape-level vegetation conditions were derived from early to mid-century aerial photographs. See Hessburg et al. 2013 for details (Larson et al. 2022).



Moving forward, DNR's Work of Wildfires assessment will include:

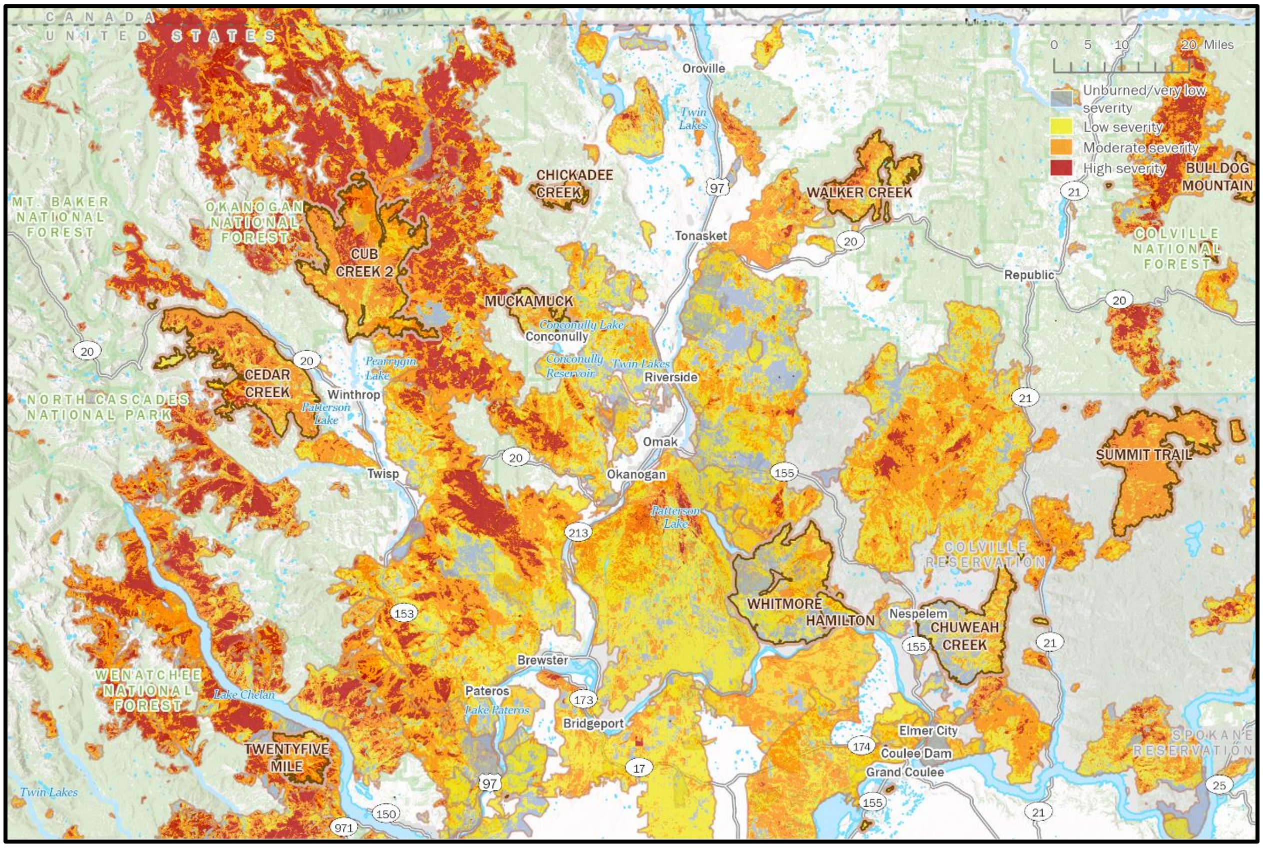
- Annual rapid assessments, including updates of prior year's assessments with more comprehensive mapping of burn severity that includes delayed mortality. Field data and observations from managers related to the work of specific fires will also be included where possible.
- More detailed evaluation of treatment effectiveness under different weather conditions. This will require collaboration with USFS personnel and other partners in the region to standardize fire-treatment monitoring and improve maps of past treatments.
- More detailed analyses of specific fires that are of high interest. We are currently working with researchers at the University of Washington to quantify the outcomes and effectiveness of treatments on the Schneider Springs Fire.
- More information gathering and analysis related to how fire managers utilized treatments during fires and integrated the framework of PODs (e.g., strategic thinning along POD boundaries connected to landscape treatments).

North Central Washington Wildfire StoryMap

Contributing Authors: **Gina Cova, Susan Prichard, Saba Saberi** (University of Washington)

Over the past decades, large wildfires have become increasingly frequent in North Central Washington, with major impacts to communities, forests, rangelands, and air quality. The Wildfires in North Central Washington StoryMap documents the past 35+ years of wildfires in the region, including recent record-breaking large fires such as the 2020 Cold Springs and Pearl Hill Fires, the 2015 North Star Fire, and the 2014 Carlton Complex Fire.

Figure 31. History of burn severity across the region since 1985. Fires that burned in 2021 are noted with darker perimeters and labels.

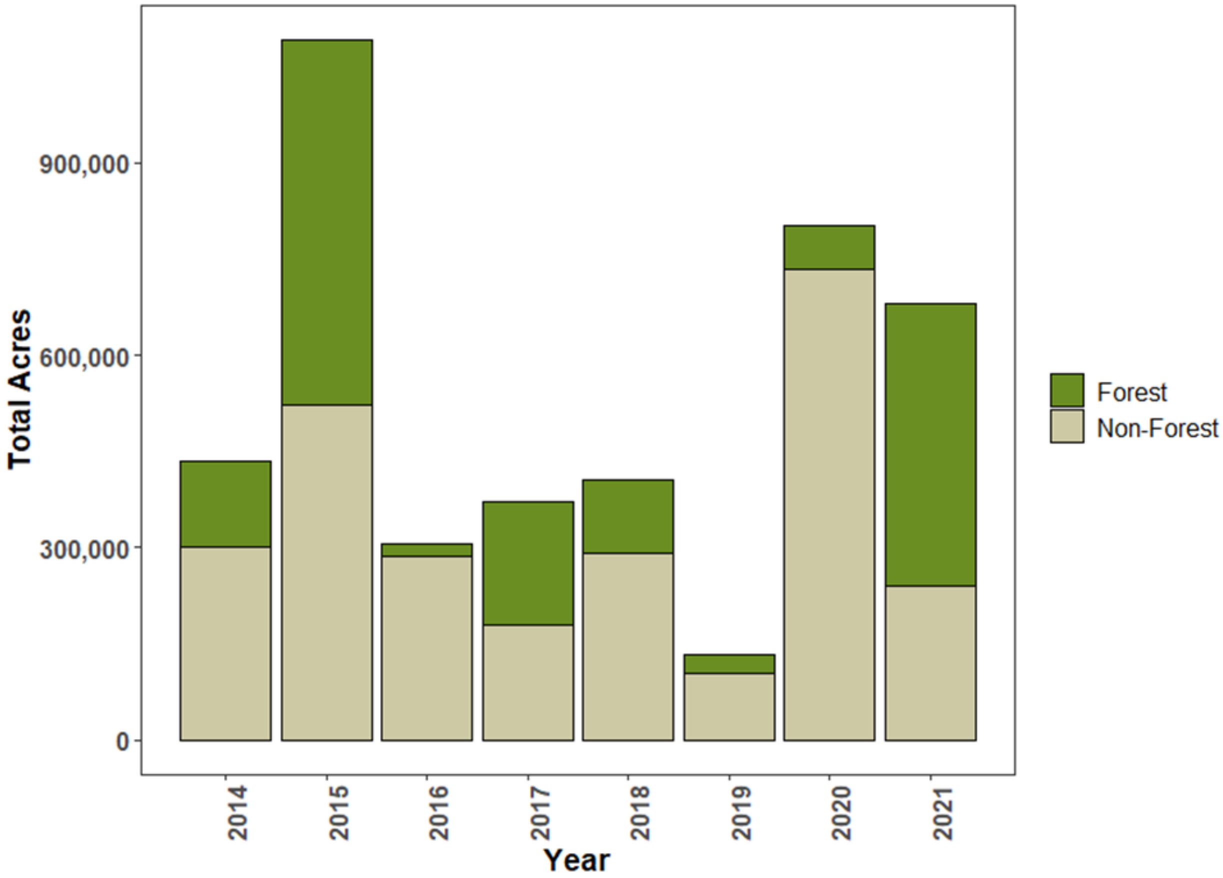


The StoryMap, produced in partnership with University of Washington and DNR, explores trends in annual area burned and fire severity, threats to forest regeneration, and patterns in high severity and unburned patches over time. The visuals illustrate these trends through maps and figures and include photos from recent high-profile fire events. The goal of our project is to provide a lens into the role of wildfire and a better understanding of fire impacts across the region. This mapping approach could be readily expanded to the greater Pacific Northwest to communicate the impacts of wildfire across broader areas.

Wildfire Emissions 2014-2021

Wildfires are a major source of carbon emissions in the western United States. To better understand how these emissions fit with the overall carbon budget for the state of Washington, DNR scientists analyzed wildfire emissions between 2014 and 2021 using the best available methods. This analysis assesses how emissions change over time, for both forested and non-forested lands. Overall, wildfires burned more than 4.2 million acres across Washington State, resulting in emissions of approximately 60.2 million metric tons CO2e. Annually, emissions were equivalent to between <1 – 18% of the total non-wildfire emissions for Washington.

Figure 32. Wildfire acres burned from 2014 to 2021, divided into forested and non-forested areas.



Emissions 2014-2021

Between 2014 and 2021, wildfires burned more than 4.2 million acres across Washington State, resulting in emissions of approximately 60.2 million metric tons CO2 equivalents (Table 18). The acres burned per year varied considerably over the time period, from fewer than 150,000 acres in 2019 to more than 1 million acres in 2015. The highest emissions resulted from the 2015 and 2021 fire seasons. Although the 2021 fires burned 400,000 acres fewer than the 2015 fires, emissions from the two years were very similar due to the higher percentage of burns occurring on forested lands in 2021 (Figure 1). Similarly, while over 800,000 acres burned in 2020, most of the fires burned in shrublands and grasslands, resulting in the third lowest emissions over the analysis period.

Table 18. Wildfire emissions from 2014 to 2021.

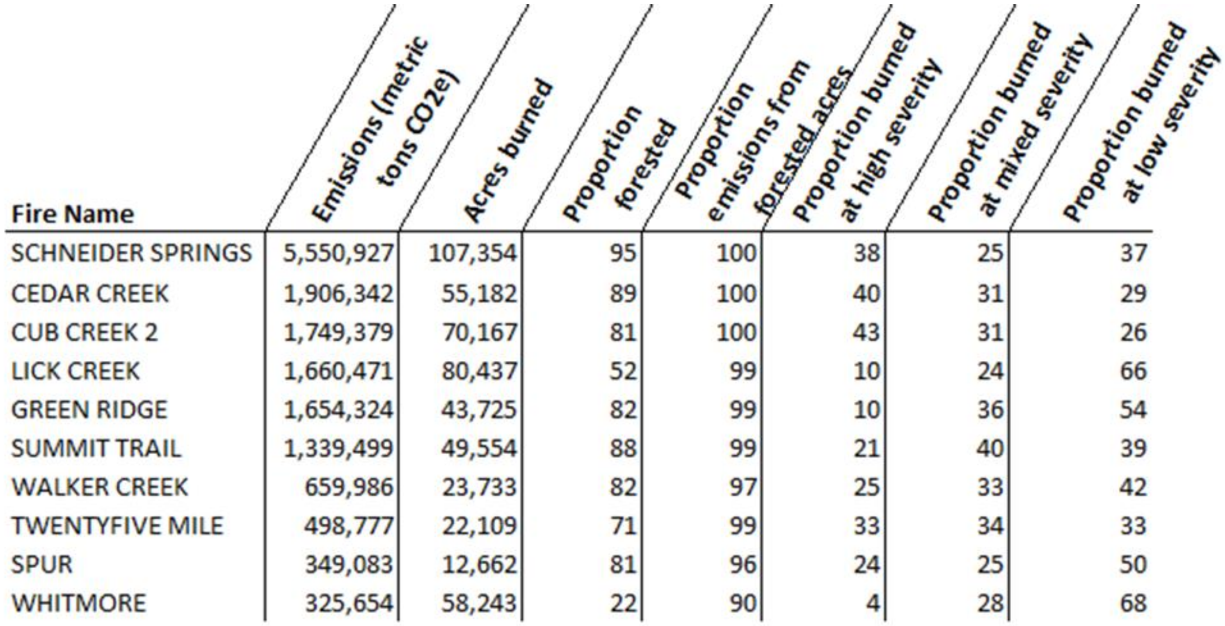
Year	Total wildfire emissions (metric tons CO2e)	Total acres burned in Washington State
2014	4,190,336	434,586
2015	16,915,986	1,091,277
2016	930,947	305,153
2017	10,902,073	372,004
2018	5,273,569	406,468
2019	938,121	133,162
2020	3,757,628	802,630
2021	17,364,131	679,414

Wildfire emissions were equal to between <1% and ~18% of other emissions across the state. Annual emissions from 2014 through 2018 for Washington, excluding wildfire emissions, ranged from 92.97 to 99.57 million metric tons CO2e (Department of Ecology, 2018). Wildfire emissions over the same time period ranged from 0.9 to 16.9 million metric tons CO2e.

Emissions from the 2021 fire season

The 2021 fire season resulted in over 17 million metric tons of CO2e released into the atmosphere. The vast majority of emissions were due to a small number of very large fires in the Cascades and Blue Mountains (Table 19). The fires responsible for most of the emissions tended to be large, occur in mostly forested areas, and burn at higher severity. The Schneider Springs Fire in the central Cascades was by far both the largest fire and responsible for the highest emissions, combining all three of these characteristics.

Table 19. Emissions, acres burned, proportions of forested acres and acres burned at high, moderate, and low severities for 2021 wildfires. The top 10 wildfires in terms of carbon emissions are shown.



Fire Name	Emissions (metric tons CO2e)	Acres burned	Proportion forested	Proportion emissions from forested acres	Proportion burned at high severity	Proportion burned at mixed severity	Proportion burned at low severity
SCHNEIDER SPRINGS	5,550,927	107,354	95	100	38	25	37
CEDAR CREEK	1,906,342	55,182	89	100	40	31	29
CUB CREEK 2	1,749,379	70,167	81	100	43	31	26
LICK CREEK	1,660,471	80,437	52	99	10	24	66
GREEN RIDGE	1,654,324	43,725	82	99	10	36	54
SUMMIT TRAIL	1,339,499	49,554	88	99	21	40	39
WALKER CREEK	659,986	23,733	82	97	25	33	42
TWENTYFIVE MILE	498,777	22,109	71	99	33	34	33
SPUR	349,083	12,662	81	96	24	25	50
WHITMORE	325,654	58,243	22	90	4	28	68

Social Science Monitoring Assessment of the 20-Year Forest Health Strategic Plan

Contributing Author: Joshua Petit, Socio-Eco Research Consultants

Five years following the release of the 20-Year Forest Health Strategic Plan, DNR hired a third-party social science consulting firm to assess plan implementation from the perspective of engaged stakeholders and partners. The project was designed and executed by Socio-Eco Research Consultants in conjunction with DNR.

Utilizing a mixed-mode design of surveys and semi-structured interviews the project aimed to answer the following questions:

1. How effectively is DNR implementing the plan from the perspective of key stakeholders and partners?
2. Where is the DNR excelling in these efforts?
3. What are areas of focus where DNR might invest additional resources to enhance capacity and strengthen existing partnerships?
4. How can the agency maintain and build broader social support as these efforts are scaled-up?
5. How much social support exists for potentially increasing science-based, landscape-scale treatments?
6. How can DNR better incorporate stakeholder feedback in planning and implementing projects/practices related to scaling-up science-based restoration?

More than 100 unique individuals responded to the survey or were interviewed by Socio-Eco Research Consultants for this project. The largest proportions of survey respondents focused their work in North Central (28%) and Northeast (26%) Washington and a quarter (25%) of respondents reported working statewide. Respondents identified DNR as the primary agency responsible for shepherding the 20-Year Forest Health Strategic Plan. Partners indicated in the survey and interviews that they view DNR as dynamic leaders that must wear many hats such as connecting and coordinating partnerships, conducting background scientific analyses, and providing technical support and tools to partners and stakeholders.

Self-Assessed Knowledge, Preferences, and Concerns

- Almost all survey respondents (90%) reported themselves as either moderately or very knowledgeable on the topic of wildland fire.
- Three-quarters (74%) of respondents were 'very concerned' about fire, more than half (56%) were most concerned about drought, and almost half (48%) reported being very concerned about a lack of active management.
- Most respondents (83%) were fully supportive of noncommercial thinning and prescribed

fire followed by commercial thinning (79% supportive).

- Almost all (97%) respondents were either somewhat or fully supportive of treating 30-50% of forested priority landscapes.
- Respondents collectively felt that forest resilience and community wildfire protection were the resource values most positively impacted by the plan.

20-Year Forest Health Strategic Plan: Eastern Washington Steering Committee. Photo by DNR.

Key Findings: Plan Implementation

- Partners felt that collective progress is being made on the five goals of the plan, but that substantial work remains to be done on all fronts.
- Partners felt that identifying priority planning areas, conducting landscape evaluations, and scientific analyses have been very effectively implemented by DNR, while the implementation of cross-boundary and all-lands treatments has been somewhat less effectively implemented to date.
- Partners expressed appreciation in the survey and interviews for DNR's science-based approach and associated tools, analyses, and support.
- Survey respondents identified the economic viability of forest health treatments, political issues, agency personnel turnover, current land use and forest management policies, limited cross-agency collaboration, limited public funding, and a lack of public acceptance as significant barriers and challenges to implementing the plan.
- Participants reported a lack of awareness related to current and future DNR monitoring efforts.

Management Implications

Socio-Eco Research Consultants identified a number of actions and next steps that DNR and partners could take to respond to study findings. These include potentially: educating partners and the public on what a managed landscape looks like to mitigate concerns over aesthetics and better articulate how healthy forest landscapes relate to recreation and other human uses of the forest; educating partners and the public about other forest health threats in addition to fire, given climatic projections and potential implications associated with drought, insects, and pathogens; communicating with partners about current and future cross-boundary and all-lands activities, including both successes and challenges to implementing forest health projects across multiple landowners and agencies.

Where possible, respondents suggested exploring options to streamline agreement execution to increase the pace and scale of partner implementation, and investing additional resources in partnership coordination to enhance cross-boundary work and support where capacity is lacking.

Successful plan implementation will require collective action among a diverse range of landowners and partner organizations. Communicating the important role of partners and enabling action across all-lands will further encourage buy-in and engagement, especially given findings that many partners see DNR as the critical stakeholder to the plan's success.

Economic Impacts of Investing in the 20-Year Forest Health Strategic Plan

DNR, in partnership with RTI International, U.S. Climate Alliance, and the Doris Duke Charitable Foundation, evaluated economic opportunities associated with the implementation of the 20-Year Forest Health Strategic Plan: Eastern Washington. The partnership culminated in the release of a report in 2022, detailing the methodology, assumptions, and key findings (see Woollacott et al. 2022).

Restoring forest health will require a mix of commercial harvesting, noncommercial thinning, site preparation, and controlled burning with many acres needing multiple treatments. Healthy forests contribute a range of benefits from wildfire resilience to improved air, water, and soil quality, biodiversity, and cultural value. Implementing forest health treatments also offers Washington economic opportunity.

The study modeled the low and high treatment targets across all-lands in priority planning areas and analyzed the economic impacts based on the results of the landscape evaluations. This study also analyzed low- and high-level implementations of a separate "State Lands" scenario, specifically only considering state trust lands throughout eastern Washington and identifying 336,000 to 432,000 acres that could receive forest health treatments.

The report found that DNR's forest health strategies, if fully implemented, can provide significant economic contribution to eastern Washington's local communities, including the logging and forestry services sectors and their suppliers. The all-lands scenario would support an annual average of 1,518 (low scenario) to 2,572 (high scenario) total jobs (direct, indirect, and induced) and the State Lands scenario 199 (low scenario) to 272 (high scenario) total jobs if implemented over the next 20 years.

For every dollar spent on forest health in eastern Washington, 78 cents become income for a Washington resident. Addressing forest health needs in eastern Washington will deliver significant direct and indirect economic benefits to rural eastern Washington communities while at the same time achieving meaningful ecological and social outcomes.

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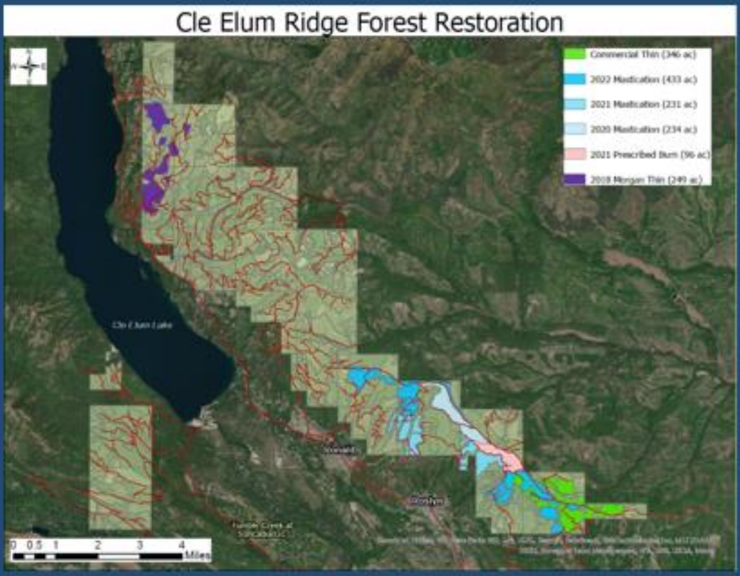
Rural Economic Development and Forest Health: Cle Elum Ridge Fuels Contractor

As financial resources to implement fire and community resiliency increase, the need for contractors to do the work also increases. Connor Craig, a local entrepreneur and owner of Wildfire Home Protection, sees value in forest restoration and community protection and has taken business risks to implement more of this work in the high wildfire prone areas of the eastern Cascades. Connor started his comprehensive forestry services business focusing on fuels treatment and forest restoration activities seven years ago. His background is in wildland and structure firefighting, which is where he began to think about proactive forest management activities that could help protect communities, increase forest health, and improve firefighter safety. His business started out small, with a used Vermeer wood chipper and a focus on fire-wising around homes and small residential properties, but through intentional relationship building with other contractors and land managers he's been able to expand to larger projects and make an impact on a larger portion of the landscape.



One key relationship Wildfire Home Protection has is with The Nature Conservancy (TNC), the manager of thousands of acres of forestland around the high fire risk communities of Roslyn, Ronald, and Cle Elum. TNC has been working in partnership with DNR, the City of Roslyn and Wildfire Home Protection to complete fuels treatments and forest restoration activities on the lands they manage adjacent to communities. This, in addition to other forest restoration demands in the area, has facilitated Connor and his team to specialize in large scale thinning projects ranging from 50 to 1500 acres. Wildfire Home Protection currently maintains a staff of four employees, and a cadre of tools, trucks, trailers, three tracked skid mulchers, and a feller buncher with a mulching head. Connor noted, *"We would not be where we are now without the work the The Nature Conservancy and Washington DNR have laid out and committed to doing."*

As Wildfire Home Protection has scaled up, they have faced challenges ranging from equipment breakdowns to fickle weather conditions. *"Just because the business is small doesn't mean we haven't taken some big risks and invested a lot of money to get this work done," said Connor Craig.* Contractors and small businesses rely on consistent work in order to increase capacity, invest in equipment and personnel, and take on larger and more complex projects.

Modeling Landscape Scale Treatment Effects on Snowpack and Streamflow

Project lead: **Tucker J. Furniss** (Pacific Northwest Research Station)

Contributors: **Paul Hessburg**, **Nicholas Povak**, **R. Brion Salter** (Pacific Northwest Research Station), **Mark Wigmosta**, **Zhuoran Duan** (Pacific Northwest National Laboratory)

Background

This project evaluated the potential effects on snowpack retention and streamflow of the landscape-scale restoration strategies of the 20-Year Forest Health Strategic Plan for the Nason Creek Priority Planning area in western Chelan County. Climate changes are projected to reduce snowpack and late-season streamflows, with detrimental impacts on anadromous fish. Drier summers also increase wildfire risk, increasing the vulnerability of human communities within the wildland urban interface. Forest restoration in these fire-prone, dry forest landscapes is necessary to reduce tree density, which in turn increases water availability to the remaining trees, increases snowpack retention, and lowers wildfire risk.

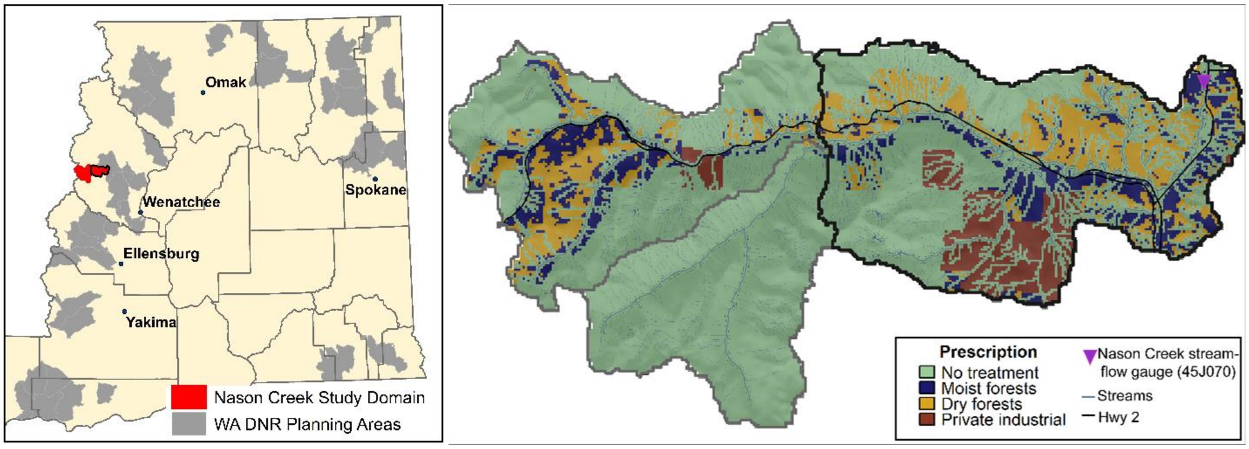
To assess the potential efficacy of forest restoration treatments, and the beneficial work that wildfire alone may do, DNR partnered with the USDA-FS Pacific Northwest Research Station (PNWRS) and Pacific Northwest National Laboratory (PNNL) to develop a forest landscape model (LANDIS-II) that can simulate treatments, forest growth, and wildfire over time. Future simulations from this model can be evaluated in terms of forest health, wildfire risk, snowpack retention, total annual streamflow, and late-season flow volume.

Project summary

The project was focused on the Nason Creek Priority Planning Area, where DNR completed a Landscape Evaluation in 2020 that specified treatment targets and prioritized locations for treatments. In order to effectively model snowpack and streamflows, we also included two higher elevation, tributary watersheds (Upper Nason Creek and Whitepine Creek) to the west of the Lower Nason Creek priority planning area. Treatable area, including private industrial forests and actively managed public lands, comprised 29 percent of the total area in the three watersheds. The remaining 71 percent was considered "not treatable", comprising primarily federal lands managed as wilderness or roadless areas. The Nason Creek study domain serves as a pilot study from which future work may expand in scope to explore additional priority planning areas.

We used LANDIS-II (www.landis-ii.org) to simulate forest growth, wildfire, and treatments over a 20-year simulation period. We used outputs from LANDIS-II to generate vegetation layers representing the study area at year 2020, 2030, and 2040, which were then fed into the Distributed Hydrology Soil Vegetation Model (DHSVM) to model treatment effects on snow interception, snowpack melting, evapotranspiration, and runoff. To assess results under various future climates, we ran DHSVM using three different water years representing wet (1999), dry (2001), and average (2006) water years. These representative water years were based on climate averages from the late-20th century, so the "dry year" simulation will likely be most representative of a future climate change scenario.

Figure 33. Nason Creek Study Domain (left; planning area denoted by thick black line in both panels) where DNR completed a Landscape Evaluation in 2020 that specified treatment targets and prioritized locations for treatments. In order to effectively model snowpack and streamflows, two higher elevation watersheds were added (right; gray lines). The landscape was partitioned into three management zones and a "no treatment" zone in wilderness and roadless areas on National Forest lands. In the right panel, the thin blue lines show rivers, the thin black line shows US Hwy 2, and the pink triangle shows the location of 45J070 Nason Cr. streamflow gauge in Nason Creek that was used to calibrate modeled streamflows.



Methods

Scenario development

We developed and ran three treatment scenarios based on objectives outlined in the DNR Nason Creek Landscape Evaluation Summary. The primary difference between treatment scenarios was the rate at which treatments were applied (2-3% versus 8-10% area per year, out of total area considered "treatable"), and the method of fuel reduction (mechanical thinning versus prescribed fire). We also ran one scenario without wildfire to simulate forest regrowth in the absence of disturbance, and another wildfire-only scenario to isolate the impacts of natural wildfires.

Table 20. Treatment scenarios, target implementation rate (percentage of area treated per year), and total area treated. Note that total area treated is cumulative, and includes some repeat treatments. Total treatable acres among the mechanical treatment scenarios were 20,000 acres.

Scenario name	Fire	Treatment rate	Acres treated per year	Total acres treated
No disturbance	-	-	-	-
Current Wildfire Mgmt	Yes	Fire frequency based on 1984-2019 fires (suppression strategy + climate during that period)	-	-
GradualTreat+Wildfire	Yes	*More gradual treatment*: Mesic forests: 2% $year^{-1}$, Dry forests: 3% $year^{-1}$, Industrial forests: 3% $year^{-1}$	700	14,000
RapidTreat+Wildfire	Yes	*Accelerated treatment* Mesic forests: 8% $year^{-1}$, Dry forests: 10% $year^{-1}$, Industrial forests: 10% $year^{-1}$	1,100	22,000
Prescribed+Wildfire	Yes	*Rx fire only* across ownerships at a rate of 10% area treated $year^{-1}$	1,500	30,000

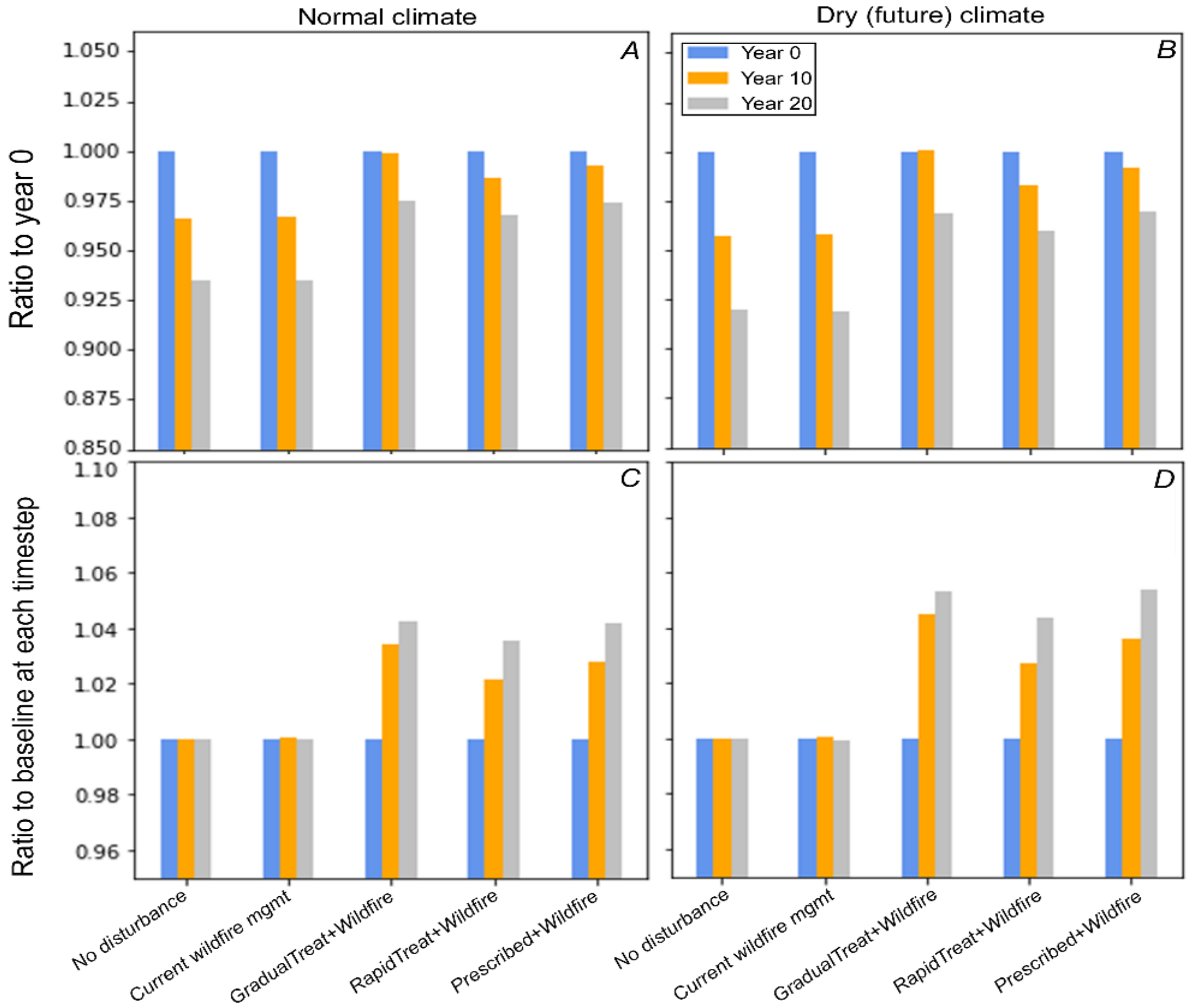
Treatment types

Treatable areas were defined as actively managed public lands (16,400 ac) and privately owned forest lands (3,600 ac), and wilderness and roadless areas in National Forest lands were classified as not treatable (50,000 ac). Treatment type that was applied to a selected stand was determined based on the dominant forest type in that stand, and consisted of three general strategies: restoration and fuel reduction in dry forests (thinning from below, leaving mature ponderosa and larch), climate adaptation and wildfire risk reduction in mesic forest (small patch cuts to increase heterogeneity and understory thinning to reduce fuels), and timber production on private timber lands (regeneration harvests). Treatable areas were buffered using a DNR stream type layer to account for riparian management regulations and guidelines.

Results

Overall streamflow was projected to decrease over the 20-year simulation period, especially in areas where forest cover increases in the absence of active management or wildfire. But despite this decrease in overall flows, active management increased flows relative to the *No Disturbance* baseline. By year 2030 (simulation year 10), restorative treatment increased flows by 2-3 percent in a normal water year, and by 2040, flows reached a maximum potential increase of about 4 percent. This effect was amplified in dry years, with the treatment effect increasing flows by just over 5 percent.

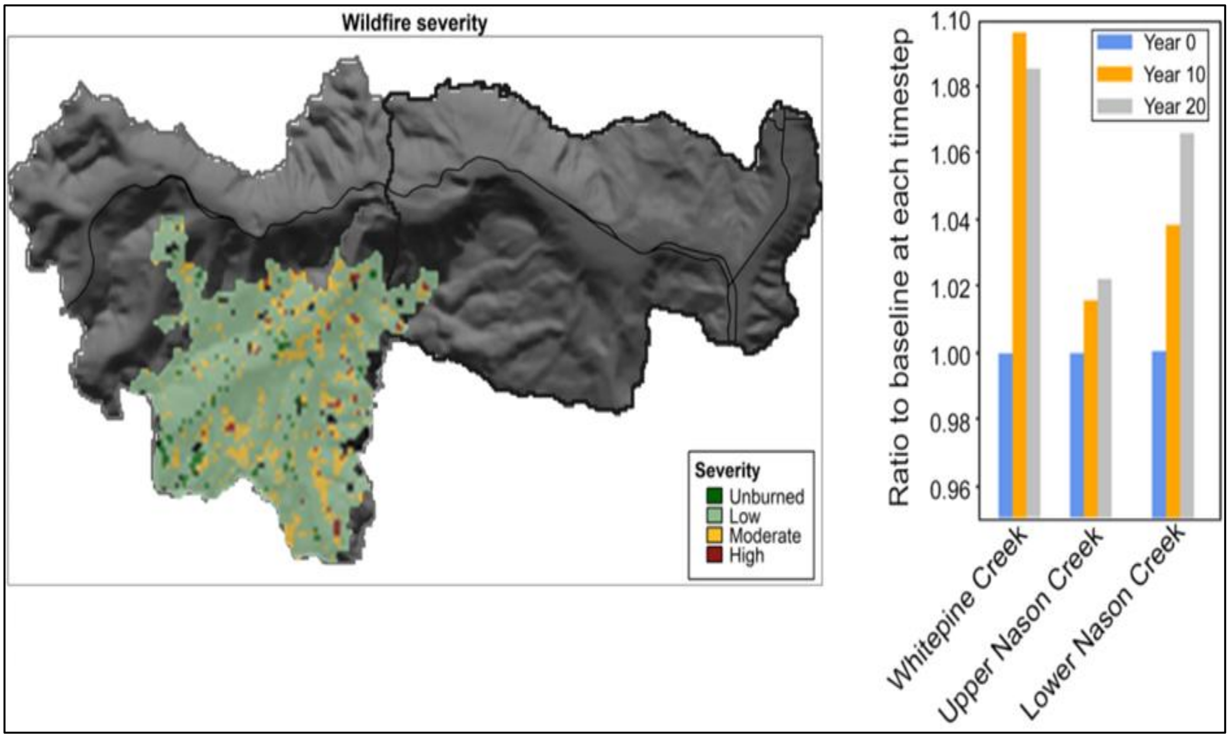
Figure 34. Annual Flow at the outlet of Lower Nason Creek in simulation year 0 (2020), 10 (2030), and 20 (2040). The left column (A & C) represents flows under current climate, while the right column (B & D) represents flows under drier future climates. Bar height in the top row (A & B) represents the ratio of flow relative to the baseline *No disturbance* scenario at the start of the simulation, while bar heights in the bottom row (C & D) are relative to baseline *No disturbance* scenario at each time step.



Large fires were rare in all scenarios, but when wildfires did occur, they had a significant impact on flows. The figure below depicts a moderate-sized wildfire simulated in year nine for the *GradualTreat+Wildfire* scenario. The effects of this fire are evident when flows are broken down into flows at the output of each of the three HUCs. For Whitepine Creek watershed (HUC 202, middle row), we see that by year 10, flows had increased relative to the baseline scenario, despite this HUC being primarily a non-treatable area where mechanical thinning was not applied.

Thus, although the two other HUC12s received more mechanical treatment, the greatest increase in flow among any HUC12 was caused by the wildfire in Whitepine Creek. The *current wildfire management* scenario did not produce a significant increase in stream flows, because there was very little fire activity due to the model calibration (based on the 1984–2019 fire record for Nason Creek, which included very few fires) and the stochastic nature of ignitions in the model.

Figure 35. *Left:* Simulated fire severity in *simulation year 9 in the GradualTreat+Wildfire* scenario. *Right:* Annual Flow at the outlet of each HUC12 in years 0 (2020), 10 (2030), and 20 (2040). Values represent the ratio of flow relative to the baseline *No Treatment* scenario *at each timestep*. The HUCs are ordered, from left to right, corresponding with increasing area treated and decreasing area burned by wildfire. The fire in Whitepine Creek (left) produced a greater increase in flows, despite very little area in that HUC being treatable, compared to the mechanical treatments done in Upper and Lower Nason Creek.



Key Findings

- Streamflows are projected to decrease over the coming two decades, due to forest regrowth in areas such as Nason Creek that are recovering from decades of heavy harvest and past disturbances.
- Active management can offset these decreases in streamflow by lowering stand density which increases snowpack retention and duration.
- Mechanical thinning, Rx fire, and wildfires were all found to increase streamflows by as much as 5 percent
- Late-season flows are linked to snowpack in the upper elevations of this landscape where mechanical treatments are not feasible, making wildland fire use a key management strategy to amplify streamflow potential by increasing snow retention in upper elevation forests.

The next steps for this research include extending the simulation model to a larger domain to capture more wildfire activity, running more iterations of each scenario to assess run-to-run variability in the model, and to simulate climate change scenarios to explicitly model the effects of future climates on forest growth, wildfire, and streamflows.

Cle Elum Snowpack Study

Contributing Authors: **Emily Howe** (The Nature Conservancy) and **Susan Dickerson-Lange** (Natural Systems Design)

Extensive forest thinning across the western United States is being planned, funded, and implemented in order to reduce wildfire risk from legacy fires suppression practices and warming climate conditions. Forest thinning affects the storage of water across the landscape and influences instream water availability and timing. In mountainous watersheds the presence and characteristics of forests influence the amount and duration of snow storage, which is also projected to decline under a warming climate.

Photo by Emily Howe

The net effect of forest management actions on extending or curtailing snow storage varies with climate, topography, and forest characteristics, and considerable uncertainty exists in some climate zones where forest management is most active. The eastern Cascades is one such zone that is particularly vulnerable to wildfire risk and water scarcity, yet there is no empirical data observing the relationship between forest canopy, snowpack, and topographic position. In order to fill this data gap, we collected three years of field observations of snow depth and duration across a range of forest and climate conditions, and across topographic positions. These observations indicate that snow storage duration is similar across forest canopy densities, including continuous and thinned forests as well as forest gaps, but that snow storage magnitude is greater where canopy cover is lower.

Additionally, field observations and lidar-acquired snow depth data across a north-facing and south-facing topographic position at two sites indicate that the forest effect on snow storage magnitude and duration shifts substantially with topographic position in this transitional climate – in particular, snow storage was almost two times higher and snow duration was longer in north-facing gaps as compared to continuous forest, whereas on the south side at the same elevation, snow depth and disappearance timing were almost the same. This data suggests that in our climate zone in north central Washington, forest thinning prescriptions intended to broadly promote fire resiliency and forest health are unlikely to amplify climate impacts on snow storage, and that forest thinning can potentially increase snow storage on north-facing slope aspects.

Upper Wenatchee Pilot Project Collaborative Monitoring Strategy

Contributing Author: **Patrick Haggerty,** Cascadia Conservation District

In 2017 the Okanogan-Wenatchee National Forest initiated planning on approximately 60,000 acres in close coordination with the North Central Washington Forest Health Collaborative (NCWFHC). The project area, known as the Upper Wenatchee Pilot Project (UWPP), completed the initial phase of environmental review in 2020. Collaborative partners recognized the importance of monitoring and initiated a taskforce to develop a monitoring strategy in 2021.

The UWPP was developed with a conditions-based NEPA approach, meaning that while the range of treatments or activities authorized will be described and analyzed in the environmental assessment (EA), the specific locations and methods will be determined during implementation based on defined conditions in the alternative selected in the Decision Notice. During the development of UWPP, the importance of adaptive management and the desire for a monitoring strategy were often noted. These two things are interrelated with meaningful, quantifiable measures of relevant indicators necessary for guiding subsequent management.

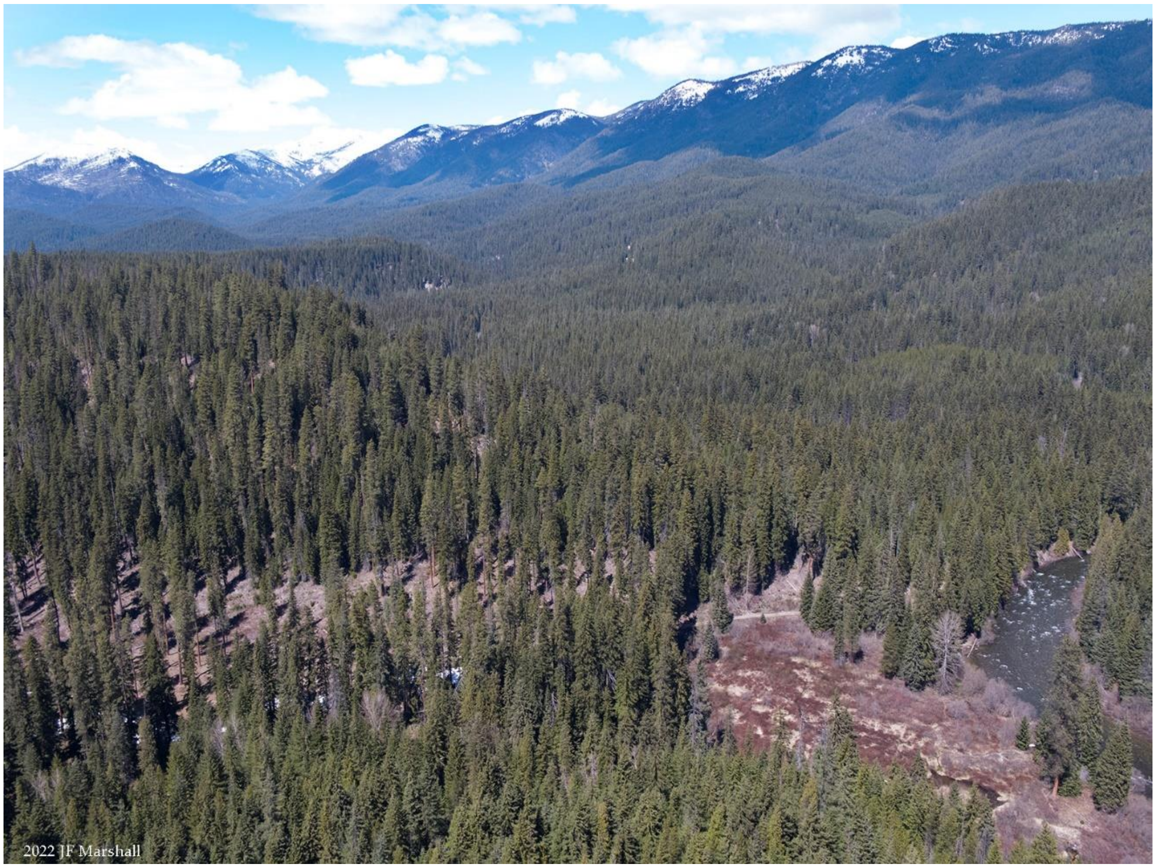
In spring 2021 over 50 stakeholders and agency personnel came together for a monitoring workshop focused on the UWPP landscape. Stakeholders identified key issues and monitoring questions to be answered through data collection in the project area. These issues were reviewed by national forest staff to form the foundation of the Collaborative Monitoring Strategy. The UWPP Collaborative Monitoring Team was formed to support outreach and train stakeholders that would be involved in data collection and on-the-ground monitoring. Initial training included field trials of the DNR Forest Treatment Effectiveness Monitoring Protocol and data collection application.

Overarching questions that guided the monitoring strategy include:

- What is the status of project implementation: what has been accomplished, what is planned next, and what remains to be completed?
- Is implementation consistent with Decision Notice including, are the specific locations and methods determined for treatments during implementation consistent with moving towards the defined conditions in the final proposed action and the Decision Notice?
- Are the project goals and the project's purpose and need on track to be met?
- Are we having the effect that we intended with our treatments and non-treatment areas?
- What lessons are we learning that apply to the next phase of implementation and other project planning in north central Washington and the Okanogan-Wenatchee National Forest?

Key components of the monitoring strategy include;

- Evaluate project implementation relative to overarching questions, stakeholder interests, and project design including potential/recommended adaptive management actions.
- Evaluate short- and long-term treatment impacts on stakeholder identified ecological indicators.
- Engage local residents, stakeholders, and partner agencies in monitoring on public lands.
- Assist the WRRD with regular project updates to the public.
- Coordinate with existing and emerging monitoring efforts on Okanogan-Wenatchee National Forest.



Upper Wenatchee Priority Planning Area in the Chiwawa River Watershed. Photo by John Marshall Photography.

The project's implementation has received funding through the Collaborative Forest Landscape Restoration Program and Central Washington Initiative. Both efforts require significant monitoring as a condition of funding. The UWPP Monitoring Collaborative Strategy was developed with a goal of being relevant to all landscape scale restoration projects through North Central Washington, the strategy is now being closely coordinated with other monitoring efforts.

Treatment Unit and Stand-Level Monitoring

There is a strong level of understanding and support among landowners, agencies and partners about the importance of monitoring forest health treatment implementation, effectiveness, and outcomes. Are treatments meeting our prescriptions and desired future conditions? Are treatments having the effects we assumed when planning them? These are important questions and require coordinated and sustained effort to answer.

Currently, landowners, agencies and research institutions conduct a variety of forest health monitoring and research activities. However, there is a clear need for more coordination and investment in monitoring efforts to robustly answer the short and long-term questions we have about forest health treatment effectiveness and outcomes. Partners need to work together to prioritize monitoring questions and efforts, so that the full monitoring cycle is completed: develop monitoring questions and methods, collect data, analyze data and share results.

Before (left) and after (right) a dry-mixed conifer commercial thinning in the Trout Lake project area on the Colville National Forest. Thinning was administered by the DNR Federal Lands Program and photos were taken by DNR staff at a photo monitoring point.

We should only be collecting data that answers a relevant question and we should be analyzing the data and sharing results. Collecting data that only sits in a spreadsheet does not help us answer the many questions we have. DNR is in the early stages of investing in monitoring coordination; it will take several years working with partners to build the capacity to more robustly complete the monitoring cycle.

During the 2018-2020 biennium, DNR worked with partners to begin addressing some of the barriers to monitoring forest health treatments. DNR contracted with Mount Adams Resource Stewards to develop a field forest health treatment monitoring protocol. DNR staff developed a Survey 1,2,3 field data entry system and an ArcGIS online storage platform for the forest health treatment protocol that partners can access. Over the last two years, we refined and utilized the protocol, and developed a common format to analyze and report treatment results. We helped partners use the protocol and field data collection system on numerous treatment units across the region.

In this section, we provide an example of this treatment unit monitoring system for a recent forest health treatment completed by Washington State Parks on the Bullfrog property within the Palouse to Cascades State Park Trail near Cle Elum, WA. The project is an example of the type of treatment-level monitoring and reporting that we anticipate replicating with more partners in the future. The Bullfrog study combines field plot data with remote data from drone-based imagery and LiDAR. This project was led by DNR and developed in close partnership with State Parks and WDFW. A similar project was conducted in partnership with DNR State Lands for the Virginia Ridge timber sale, which is summarized in Appendix D.

Bullfrog Forest Health Treatment Monitoring Report

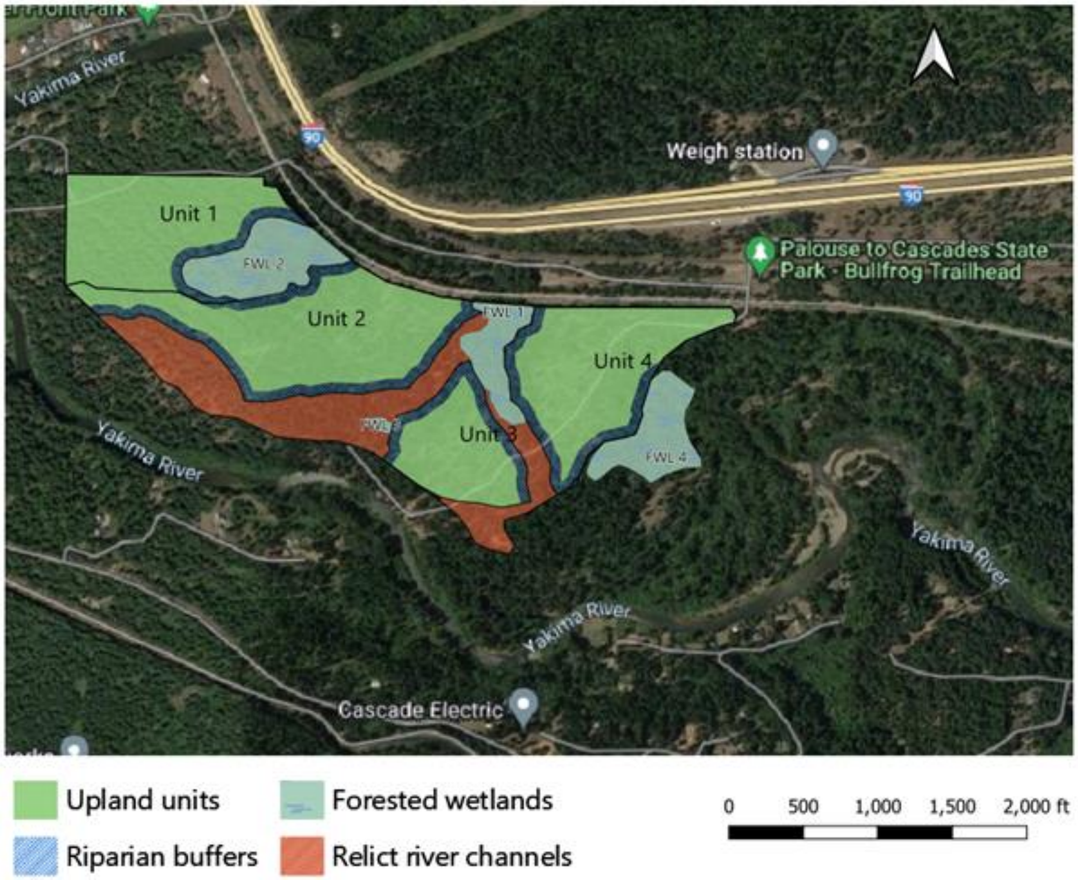
Contributing Authors: Russel Kramer (Resilient Forestry) and Derek Churchill (Washington Department of Natural Resources)

Project Area and Background

The project is located within the Bullfrog Property managed by Washington State Parks five miles west of Cle Elum, WA. The 270-acre property is part of the Palouse to Cascades State Park Trail and sees heavy recreational use. The I-90 freeway runs along the northern edge of the property. It is bordered by private property with homes to the west and south, and thus is a priority for fire risk reduction. Within the 270-acre parcel, 88 acres were treated.

The Yakima River forms the southern edge of the property. The entire site sits on the historic flood plain and channel migration zone of the Yakima River. It is a flat site at 2,000 feet above sea level, and is bisected by abandoned (relict) river channels. These channels are occupied by trees 110 to 130 years old, likely having regrown following clearcut logging and burning.

Figure 36. Local imagery, roads, and subunits in the Bullfrog Project Area.



The forest is dry mixed-conifer with some mesic patches. Productivity varies considerably and is high in the western portion. Species composition consists of ponderosa pine (PP), Douglas-fir (DF), and grand fir (GF). Prior to the treatment, the forest was dense with multiple canopy layers in some places, although some more open patches were present. Four forested wetlands within the unit additionally contained quaking aspen (QA), black cottonwood (BC), willow species (Salix), and western red cedar.

Objectives and Prescription

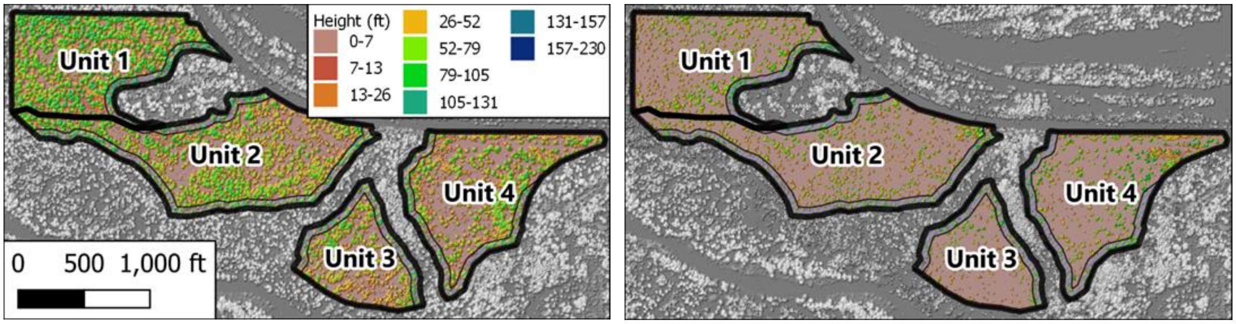
This 88-acre forest restoration project was undertaken during the summer of 2022 by Washington State Parks. The purpose was to reduce fire risk and improve forest health and stand resiliency, while maintaining current and future riparian functions in the channel migration zone of the Yakima River. When these channels flood, forests need to provide large wood inputs, sediment retention, and other riparian forest functions. The project seeks to balance maintenance of riparian function and reduction of wildfire risk.

The prescription for the 88-acre upland thinning area is based on the principles of dry forest restoration (Franklin et al., 2013; Palik et al., 2021). The overall goal is to restore forest conditions characteristic of a frequent, low-severity fire regime. This includes an open canopy forest dominated by large trees, a mosaic spatial pattern of individual trees, clumps, and openings, and species composition dominated by ponderosa pine. More detailed prescription elements are provided in Table 21.

Example of thinning treatment in a forest with dense mid- and under-story trees. Both photos were taken from the same location before (above) and after treatment (below). Photos by Resilient Forestry LLC.

The 88-acre treated area was divided into upland and riparian management zones (RMZ) with different density targets. Buffer widths and density targets for the RMZs were based on Washington's forest practices rules. The treated area was bisected by 33 acres of no-treatment buffers for relict river channels and forested wetlands. The overall polygon for the treatment was thus 121 acres. The project was approved through the Forest Practices Alternate Plan process as the entire project area is within the channel migration zone of the Yakima River.

Figure 37. Canopy surface model showing height above ground as seen by LiDAR pre-treatment (left) and by drone-based imagery post treatment (right). RMZ zones are shaded regions along edges of some units.



Project Objectives

1. Decrease the risk of severe wildfire and increase drought resistance by restoring forest structure, composition, and pattern that is characteristic of frequent fire forests in the East Cascades.
2. Maintain or improve riparian functions in relict river channels and riparian management zones.
3. Enhance habitat value for a broad range of wildlife species by creating a diverse mix of patch types across the treated and untreated portions of the project area.

Table 21: Prescription Elements (GF = grand fir, DF = douglas fir, PP = ponderosa pine)

Prescription
● Reduce density to 25-35 TPA in the main portion of the unit. ● Reduce density to 50 TPA within riparian management zones (RMZs). RMZs are 70 feet from a wetland or relict channel. ● Increase the proportion of fire- and drought-tolerant species: Preferentially remove GF, DF and retain PP and hardwoods. ● Retain larger trees: Leave all trees >24” diameter, and thin from below. ● Increase tree diversity: Leave all hardwoods and uncommon conifers such as western red cedar. ● Maintain key habitat elements: Leave “defect” habitat trees, maintain or create snags, leave mistletoe-infected trees scattered or in clumps, and leave sufficient downed logs. ● Create spatial variability in forest structure: Thin by leaving single trees, clumps, and scattered 0.5-1 acre gaps (avoid gaps in RMZs). Vary density across units. ● Reduce potential negative effects of treatment activity: reduce activity fuels after treatment and follow with noxious weed control. ● No harvest within 30 ft of the relict channel or in forested wetlands.

Monitoring

As part of the 20-Year Forest Health Strategic Plan: Eastern Washington, DNR Forest Resilience Division staff collaborated with Washington State Parks, Washington Department of Fish and Wildlife, and third-party partner Resilient Forestry to monitor this project using new monitoring methods for treatment level monitoring, including drone-based imagery. However, detailed monitoring was not planned when this project was being developed. A range of pre-and post-treatment data collection methods were thus utilized. Lessons learned from this monitoring project will inform future monitoring at this site, as well as others.

The results presented in this report are a single snapshot in time. The data collection for this monitoring report was conducted immediately after the commercial thinning operation, but before mastication of landing piles, potential prescribed fires, or small tree thinning. These follow-up actions will change the results presented here, especially with regards to dead wood and fine fuels. Understory vegetation will also regrow in the next few years, and additional tree regeneration will be established.

Example of savanna type forest before (above) and after (below) treatment. Both photos were taken from the same location. Photos by Resilient Forestry LLC.

Monitoring Highlights

- Density targets were achieved, but at the higher end of retention targets in upland areas.
- Large trees were retained. The abundance of trees >24″ DBH did not change and smaller trees were preferentially removed.
- Species composition was shifted towards ponderosa pine. In upland areas, the proportion of ponderosa pine >10″ DBH increased from 63 to 86% of TPA.
- Downed wood, a key habitat element, was maintained with >3″-diameter wood at 4.1 tons per acre, and >10″-diameter wood at 1.9 tons per acre, roughly equivalent to 6.3 10″-diameter logs per acre.
- Overall regeneration is sufficient, but reducing Douglas-fir in small diameter classes and shifting towards ponderosa pine is needed. This can be achieved with small-tree thinning or prescribed fire.
- Snag levels are low. Tree mortality and top breakage will increase levels, but increasing the number of dead trees with prescribed fire or creating snags may be needed.
- Spatial variability in canopy cover and patch types is high across the treated and untreated areas. However, additional medium and large tree clumps, as well gaps, are recommended for future projects to be consistent with reference conditions and to restore a wider range of ecological functions.

Data Collection Methods

This monitoring report is designed around specific questions that can be answered with pre- and post-treatment ground-based plot data, as well as via LiDAR and drone-based tree mapping. The primary goal of this project is implementation monitoring; to assess whether specific treatment targets were met where targets exist (e.g. density targets); or quantify the amount and direction of change in forest structure variables relative to a prescription objective where targets do not exist (e.g. create spatial variability). Observations related to effectiveness monitoring – whether treatments will achieve management goals over time – are also included where possible.

Specific targets from the treatment prescription were used to assess whether the treatment met various objectives. In cases where there were no targets, the pre- and post-treatment data were compared to assess directional change in metrics. Fuels data were not collected post treatment, so potential fire behavior could not be evaluated at this time. The shift in species and tree size can still provide some evidence for the effect of treatments on fire. A full assessment of how the treatment affected predicted flame lengths, tree mortality, and overall fire risk would require that fuels data be collected and analyzed after mastication and potential prescribed fire.

Two basic types of data sources were used for monitoring. First, plot data were used to derive tree density, species composition, and size class distribution. Second, remote data were used to summarize spatial patterns of trees, gaps, and canopy cover.

The first data source was from inventory plots. Detailed post-treatment monitoring was not anticipated when this project was planned, so plot locations pre- and post-treatment were not in the same locations nor of the same type. Variable radius timber cruise plots (n=33, BAF = 20) were used for pretreatment data. Post treatment, fixed area plots (n=34) were used as they more accurately capture all size classes of trees and are better for long term re-measurement and monitoring. DNR's treatment monitoring protocol and the Survey 123 field data collection system were employed, using 1/10th acre plots for trees >5"-DBH, and smaller plots for saplings (1/50th acre) and seedlings (1/100th acre). Plot locations were monumented and thus plots can be re-measured in the future.

The differences in plot location and measurement type increased sampling error and confidence intervals for results. This additional sampling error will not occur if the same fixed area plot network is re-measured in the future.

The second data source was from maps of individual trees derived from 1 to 3-ft-resolution canopy height models (CHMs). CHMs show the height of vegetation above ground. CHMs came from two sources: 1) LiDAR captured via aircraft in 2014 for pre-treatment conditions, and 2) structure from motion data derived from drone-based imagery acquired post treatment in 2022.

CHMs were segmented into approximations of tree crowns based on their shape—called "tree approximate objects" or TAOs (Jeronimo et. al 2019). Because TAO data represents a complete census in real-Earth coordinates, data from both acquisition vehicles were comparable. A detailed description of these methods is provided in Appendix C.

TAOs from LIDAR and Drone imagery offer an exciting new methodology to monitor changes in forest structure from treatments and compliment plot data. However, the overall utility and accuracy of TAO based monitoring is not fully known. Thus, a secondary goal of this project is to compare results from plot- and TAO-based data for metrics where both types of data can answer the same question.

Monitoring Questions and Results

In this section, we sequentially describe for each question, targets or goals for the treatment, methods specific to the question, results, and a brief discussion of their management implications.

Q1: Were density targets met in upland and RMZ areas?

Targets: The upland TPA target was 25-35 TPA and 50-70 BA, while the riparian target was 50 TPA and 100 BA.

Methods: Pre and post-treatment plot data were used to compare TPA and BA means and frequency distributions. Remotely sensed data were also used to assess this question, but only plot results are shown here. See Appendix C for a comparison of remote and plot methods. Total canopy cover was also derived from pre and post canopy height models.

Results---: The post-treatment mean values, using the 95% confidence interval range, for TPA and BA were within the prescription targets (Table 2). In upland areas, treatments reduced TPA from 70 ±19 to 37±7 (target 25-35). BA was reduced from 109.4±19 to 80.4±17 (target 50-70). In RMZs, TPA declined from 86 to 49 (target 50-70). BA declined from 124 to 106 (target 100). Overall canopy cover of the entire unit, including untreated forested wetlands and relic channels, declined from 69% to 32%. Cover of the treated area only was 22%. The pre and post treatment frequency distributions show that ranges of 0-100 TPA and 0-300 BA were retained across all the plots in the upland areas.

Management implications and recommendations: The treatment successfully achieved the desired targets and ranges. The fact that the mean value for post-treatment BA (80) in the upland was above the target range (50-70) suggests that additional treatments could be needed. The 95% confidence interval (80 ±17) overlaps the target range, however.

The wide range in density across the unit was desired, given the spatial variability goals. From a fire standpoint, gaps and low-density areas will interrupt crown fire spread.

Table 22: Specific targets set in the prescription to evaluate treatment implementation. Pre and post values are mean ±95% confidence interval. DF = Douglas-fir, PP = ponderosa pine, GF = grand fir, BC = black cottonwood, QA = quaking aspen, SALIX = willow species.

Question	Metrics & Targets	Pre	Post	Interpretation
Were density targets met in upland and RMZ areas?	Upland: 25-35 TPA[1]	70±18.9	37±6.9	Post TPA met target, high end
	RMZ: 50 TPA	86±12.5	49±5.6	Post TPA met target
	Upland: 50-70 BA[2]	109.4 ±18.8	80.4 ±17.34	Post BA ± range overlaps target, but at high end.
	RMZ: 100 BA	123.8 ±20.12	105.9 ±18.00	Post BA met target
Was composition shifted towards fire-tolerant species?	Increased proportion TPA of PP and hardwoods vs DF and GF >10" DBH	**Upland** DF: 35% PP: 63% GF: 1.5% QA:<1%	DF: 9% PP: 87% GF: 1% BC: 3% QA: <1%	DF was reduced and PP increased. GF was similarly sparse. Hardwoods remain minor components
		RMZs DF: 40% PP: 55% GF: 2% BC: 2% QA: 1%	DF: 32% PP: 65% GF: 1% BC: 1.5% QA: 0.5%	Same as above
Were larger trees retained?	Stable TPA of ≥24" trees upland* and in RMZs**	6±2.0* 11±3.7**	8±3.2* 11± 3.7**	Number of large trees was stable
Was a mosaic pattern of diverse habitat patch types created?	60% in individual trees, 18% in 2-4-tree clumps, and 22% in 5-9-tree clumps. High variation in canopy cover across the entire unit.	Figures 8 & 9	Table 3. Figures 8 & 9	Treated areas lacked 5-9 tree and 10+ tree clumps. Canopy cover variation & patch diversity is high.
	Greater presence of gaps 0.5 - 1 acres.	Figure 10	Figure 10	Gaps were created, but are low in subunits 3 & 4.
How many small trees (advanced	Describe saplings per acres (**S**),	—	**S**: 79±323* **Plot**: 44% **PP**: 13.4%	Probably sufficient, but extremely variable and Douglas-fir dominated

regeneration) were retained?	proportion of plots with regeneration (**Plot**), and proportion of saplings and seedlings of each species (**PP**, **DF**, **GF**, **SALIX**)		**DF**: 82.1% **GF**: 3.0% **SALIX**: 2%	
How much large dead wood is present?	Snag count	1.3±1.86	0.9±1.04	Need more, but sample size was limited
	Log count* and log tons per acre**	—	6±2.0* 1.9±1.20**	Appears sufficient

[1]TPA = trees per acre >6” DBH
[2]BA = basal area per acre (ft^2 ac^{-1})
[3]QMD = quadratic mean diameter (in)= sqrt(sum(diameters)/number of trees)
[4]Log equivalent based on log mass >10”, see methods

Q2: Was composition shifted towards fire-tolerant species?

Targets: Increase the proportion of ponderosa pine and hardwoods relative to Douglas-fir and grand fir.

Methods: Tree density (TPA) was summarized within plots by species, and the mean and confidence intervals across all plots were compared between datasets.

Results: The treatments increased the proportion of ponderosa pine relative to Douglas-fir for both upland and riparian areas. Ponderosa pine now comprises 86 percent of the density in the upland areas and 69 percent in the RMZs. Trees 5-10″ DBH were greatly reduced in the plot data for all species.

Grand fir and quaking aspen remained minor components after upland treatment and were not abundant enough in the plots to assess stand-level differences. In RMZs, quaking aspen was released from competition with conifers, although it still represents a small portion of trees.

Management implication and recommendations—Retained ponderosa pines have been given a competitive edge from reduction of similarly sized Douglas-fir in small to medium diameter classes. This will allow pine trees to become more vigorous, develop thick fire-resistant bark sooner, become more disease and drought resistant, and increase their regeneration potential.

Ponderosa pine is not dominant in the 5-10″ DBH class. Small-diameter Douglas-fir and grand fir should be reduced during prescribed fire or small tree thinning operations. The release of small quaking aspen is also notable.

Figure 38. Distribution of pre- and post-treatment TPA and BA for upland areas from 33 pre- and post-treatment plots.

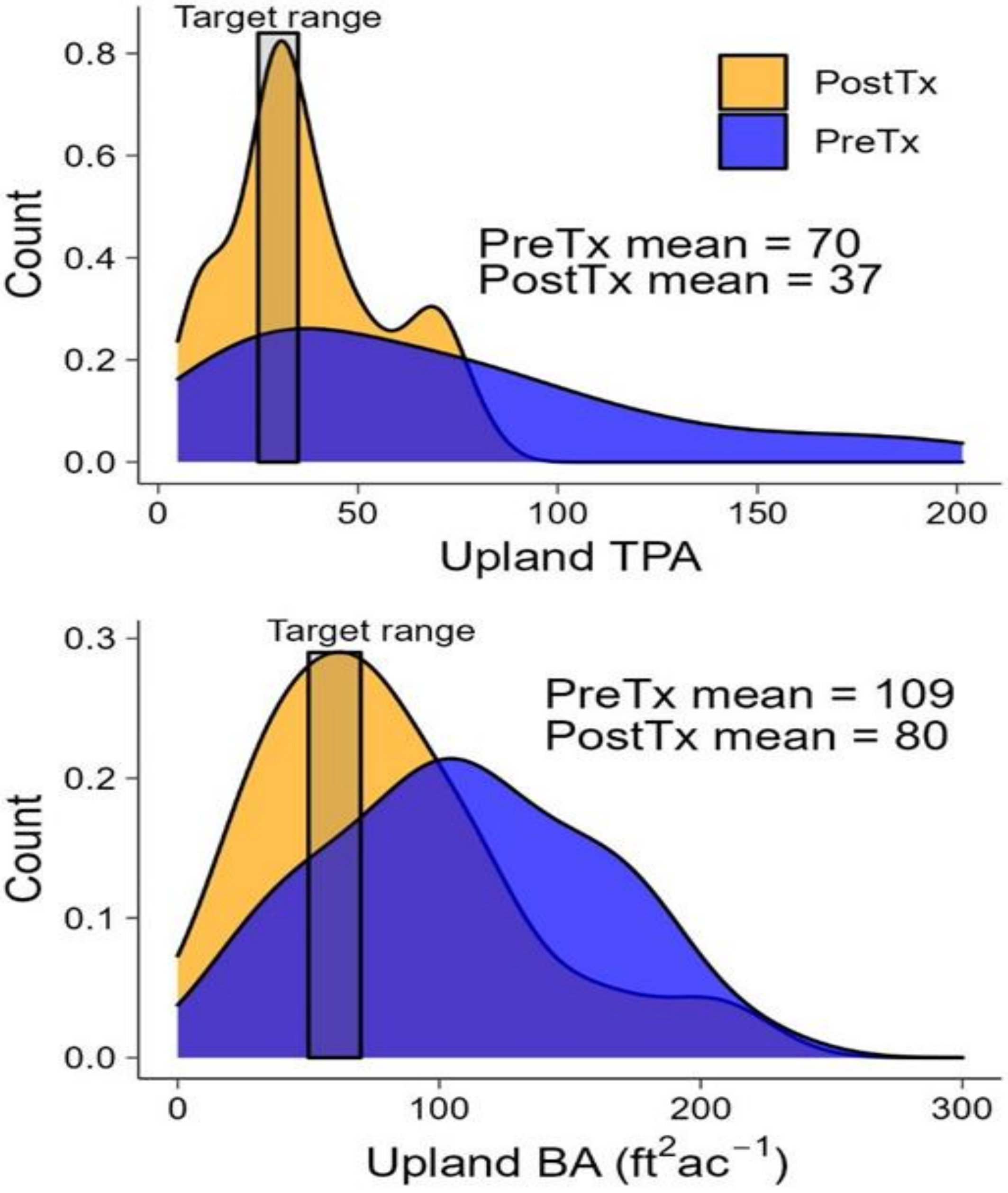


Figure 39. Distribution of pre- and post-treatment TPA and BA for RMZ areas from 45 pre- and 46 post-treatment plots.

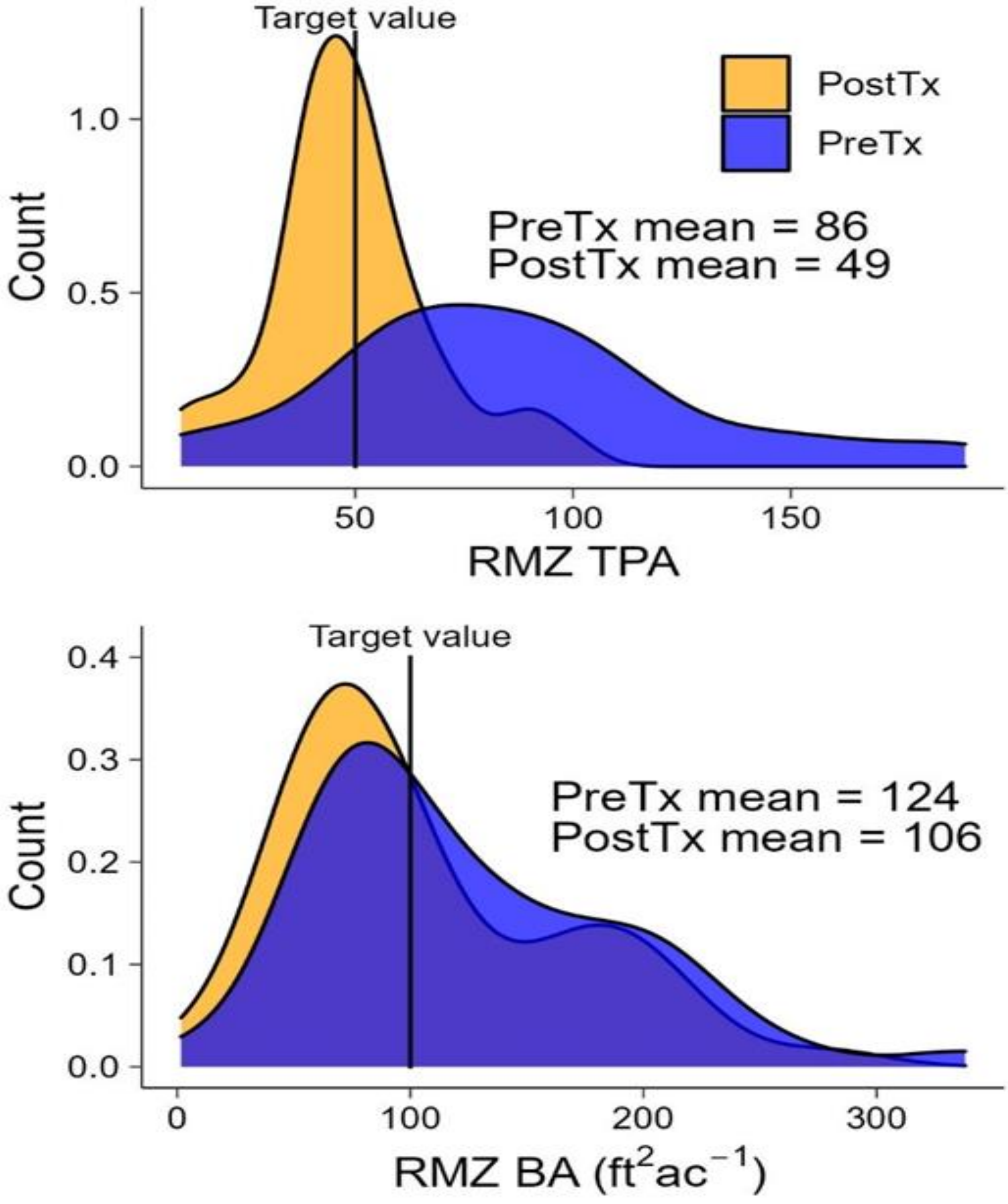


Figure 40: The diameter distribution of mean TPA across plots by species in upland areas. Diameter is aggregated in 5″-DBH bins pre-treatment a) (N = 45) and post-treatment b) (N=46). The proportion TPA of live trees ≥10″ DBH are shown in the inset of b). Error bars are one standard error. Columns without error bars only had one plot in that diameter class of that species. Differences in plot type (variable radius and fixed area) and plot locations between and pre and post treatment measurements account for some of the observed differences.

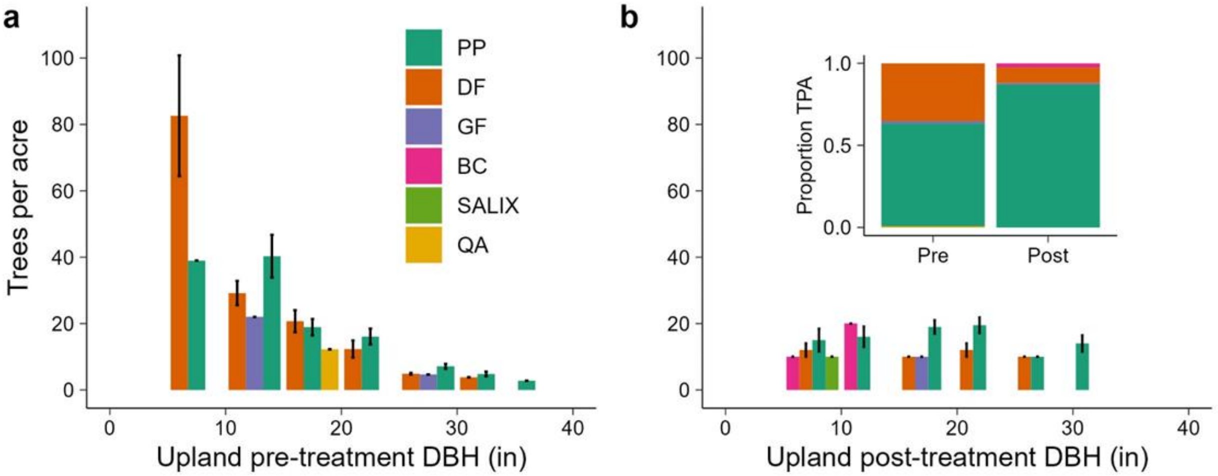
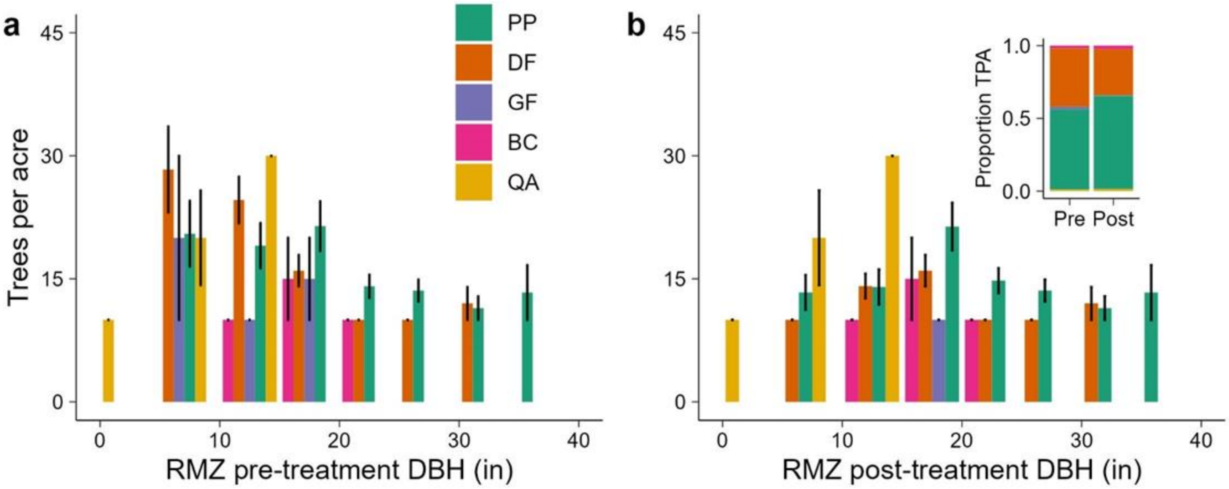


Figure 41. The diameter distribution of mean TPA across plots by species for RMZs. Diameter is aggregated in 5″-DBH bins pre-treatment a) (N = 45) and post-treatment b) (N=46). The proportion TPA of live trees ≥10″ DBH are shown in the inset of b). Error bars are one standard error. Columns without error bars only had one plot in that diameter class of that species. PP = ponderosa pine, DF = Douglas-fir, GF = grand fir, BC = black cottonwood, and QA = quaking aspen.



Q3: Were larger trees retained?

Targets: Stable TPA of trees ≥24”-DBH. Greater density reduction in smaller diameter classes.

Methods: Using plot data, the diameter cutoff for the largest 25% percentile of trees (24”-DBH) was calculated and used as a filter for trees post treatment. TPA of trees ≥ 24” DBH were then compared pre and post treatment. The reduction in TPA by 5” diameter classes was also compared.

Results: There were at least as many ≥24”-DBH trees after the treatment as before. Although the mean TPA of large trees across plots was greater post treatment, the overlap in 95% confidence intervals indicates that they are not statistically different. The large tree counts were exactly the same post treatment in RMZs because these plots were in the same locations and no large trees were removed. Comparison of TPA reduction by diameter class for both upland and RMZ shows that density reduction was most pronounced in the 5-10” DBH class, followed by the 10-15” class, and then the 15-20” class. Trees in the 20-25” class showed relatively little reduction.

Management implications and recommendations: Results indicate that the treatment met the goal of leaving the largest trees and generally removing smaller trees (thinning from below).

Based on field observations, a number of larger Douglas-fir (>20” DBH) were removed, likely in yarding corridors. Large trees are less abundant and commonly under sampled in plot inventories. This is why the estimate of the large tree numbers increased post treatment and why both pre- and post-treatment estimates had wide confidence intervals. Unfortunately, tree heights from the pre-treatment LiDAR in 2014 were not sufficiently comparable with the heights from drone-imagery to assess this question in a more robust manner. For future projects, obtaining comparable drone imagery from right before the treatment and right after is recommended.

Q4: Was a mosaic pattern of diverse habitat patch types created?

Targets: Marking guidelines called for 60 percent of trees to be individuals, 18 percent as small clumps (2-4 trees), and 22 percent in medium clumps (5-9 trees) for the upland areas. Increasing the number of 0.5-1 acre gaps was another objective. Diversity of habitat patch types was quantified by change in canopy cover across the unit, including untreated areas.

Methods: Drone-base tree maps were used to identify individuals and clumps. A 20-foot distance between trees was used to group them into clumps. Gaps were delineated using canopy height models (CHM) from both pre-treatment LiDAR and post-treatment drone imagery Canopy cover for 66′ pixels across the unit was derived from CHMs.

Results: The target proportions for individuals and clumps were generally met, although the treatment created fewer individuals and more small, medium, and large clumps than the targets. The prescription targets, however, are not consistent with reference conditions from the Eastern Cascades for stand-level patterns than were included in the alternate plan application (Churchill et al. 2016). Compared to these reference conditions, the pattern created by the treatment is low on medium and large sized clumps (10+ trees). This was apparent from field observations, especially in subunit 1.

Post-treatment conditions showed an increase in the area occupied by gaps. Gaps, especially large gaps (0.5-2 acre), were concentrated in subunits 3 and 4. Less than 5 percent of the RMZ area was in 0.1-0.5 acre gaps post treatment.

High variability in canopy is present post treatment. The amount of area and patch size of low and moderate cover areas increased, while high cover patches were retained in untreated areas. Small patches of moderate to high cover patches are missing from within the treated areas.

Table 23: Proportions for individual trees and clumps of different sizes for Eastern Cascade reference sites (Churchill et al. 2014), prescription targets, and the treated area of the Bullfrog unit. RMZs and edge trees were excluded from this analysis.

Sites	TPA	Clump Size (# of trees)				
		1	2-4	5-9	10-15	16+
Reference - High	40-60+	0.22	0.38	0.24	0.10	0.06
Reference - Mod	25-40	0.30	0.42	0.11	0.17	
Reference - Low	15-25	0.45	0.433	0.12		
Bullfrog Rx Target for Upland. RMZ not included	30	0.60	0.18	0.22		
Treated Bullfrog Unit Upland Area	37	0.41	0.38	0.13	0.01	0.07

Figure 42. Pre-treatment distribution of canopy cover across the entire 121-acre area. Cover was calculated for 66′ pixels.

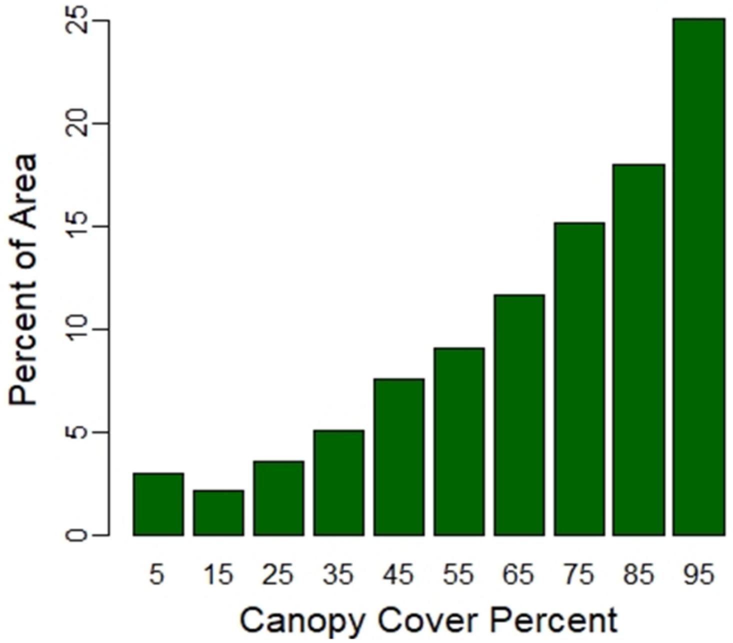


Figure 43. Post-treatment distribution of canopy cover across the entire 121-acre area that includes 88 acres of treatment and 33 acres of untreated forested wetlands and relic channels.

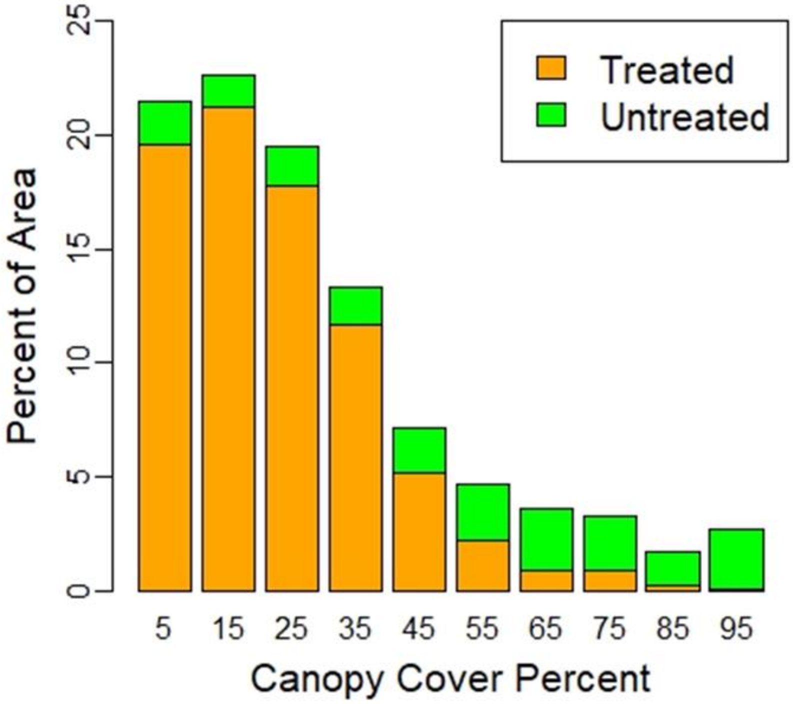
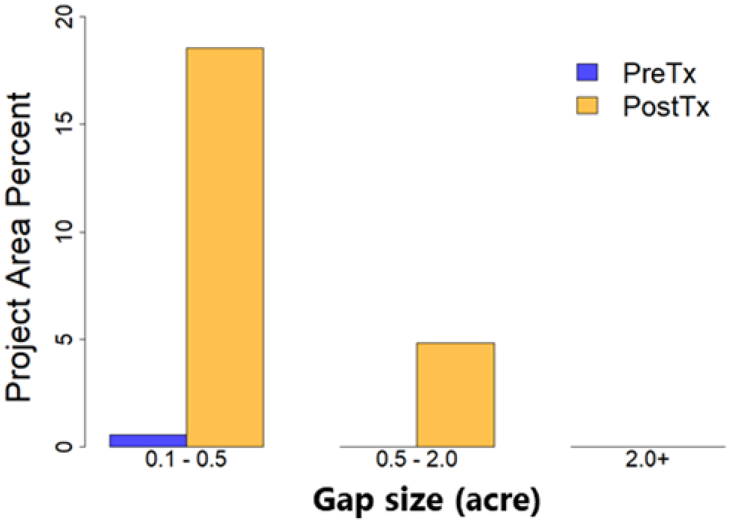


Figure 44. Percent area in classes of mean gap size summarized for each raster pixel in the Upland area for pre and post treatment (Tx) observations. Less than 5% of the RMZ area was 0.1-0.5 acre gaps post treatment.



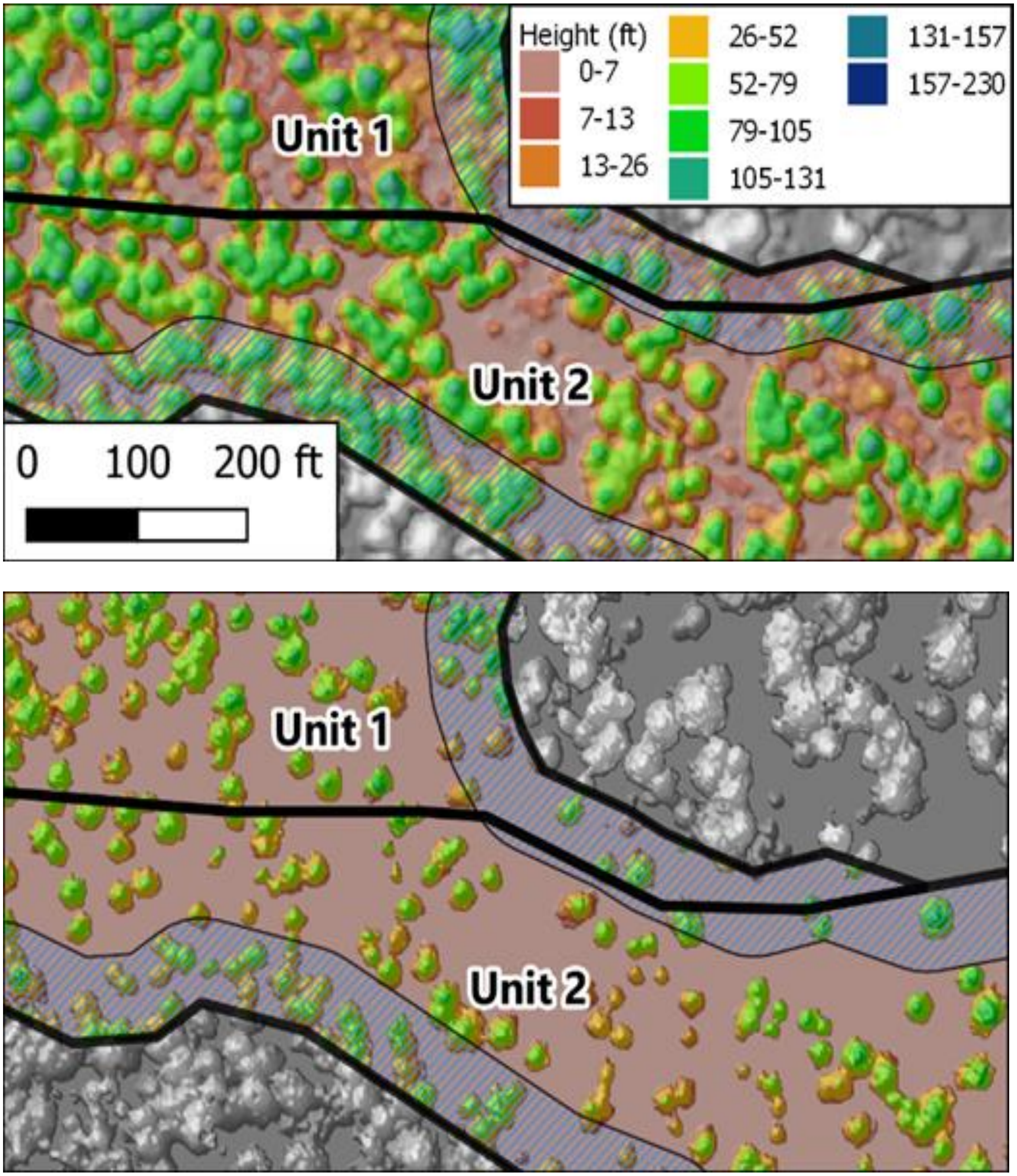
Management implications and recommendations: Restoration treatments dominated by individual trees and small clumps, such as this one, achieve the goals of reducing fire and drought vulnerability while increasing the vigor of remaining trees. However, the relative lack of medium and large-sized clumps, as well as larger gaps (subunits 1-2), reduces the variability in light, temperature, and soil moisture levels, as well as fuel deposition. This translates into lower understory plant diversity, habitat value, snowpack retention, and variable fire behavior, compared with a more complex pattern that is consistent with reference conditions (Churchill et al. 2018). Establishing and growing new cohorts in openings is also much more challenging.

Uniform spatial patterns also affect visual and recreation values for some users as the forest can appear plantation-like and “parked out.” This can reduce social support for restoration work.

At the same time, the untreated forested wetland areas and relic channels that bisect the treated parts of the unit provide some of this habitat diversity. Patches of moderate and high cover are present within the overall treatment unit, as well as on the treatment edges. The patches of aspen, cottonwood, and willow also enhance diversity.

For future treatments, adding in a higher number of medium and large clumps within treated areas is recommended. This will increase the functional outcomes of the treatment and be consistent with ecological forestry principles (Franklin et al. 2013, Palik et al. 2021).

Figure 45. Canopy height model showing tree density as seen by LiDAR pre-treatment (above) and by orthoimagery post treatment (below) of the exact same area. The RMZ is the cross-hatched area spanning the two-unit boundaries.



Q5: How many small trees (advanced regeneration) are present?

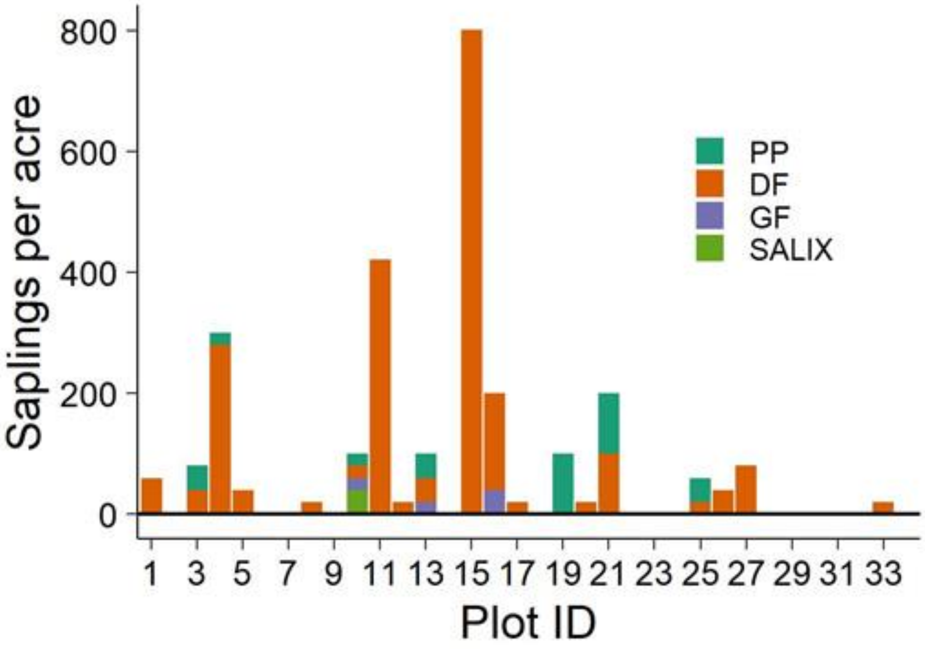
This question was only evaluated in upland areas, where it is more relevant in this less dense and more fire-prone area.

Target: The objective was to ensure sufficient regeneration for the long-term maintenance of the tree population with the desired species composition. Thus, the amount and composition of small trees were quantified.

Methods: Densities of trees <5″ DBH were measured in the field using count plots for two diameter classes (0.1-2.4″ and 2.5-5″). TPA by species was then tallied for each plot. The abundance class (few, moderate, many) for trees between 1-4.5′ in height (DBH=0) was also recorded at each plot.

Results: Small trees (0.1-5″ DBH) occurred on 56 percent of plots (Figure 13). Mean density was 79 ±323 per acre, and ranged from 0 to 802. Douglas-fir was the most dominant species by far (Figure 13). Ponderosa pine is present on one-quarter of the plots, and the absolute TPA ranges from 20-100 TPA. Trees between 1-4.5′ in height were rare.

Figure 46. Saplings per acre summed from both diameter classes (DBH 0-2; 2-5″) of each species shown for each plot. Not all plots are labeled for clarity. PP = ponderosa pine, DF = Douglas-fir, GF = grand fir, SALIX = willow species.



Management implications and recommendations: In frequent-fire forests, regeneration is generally concentrated in thickets within gaps and openings, and is relatively rare in the rest of the area. Widespread regeneration, with many small trees growing underneath large trees, is not desired as it can lead to torching and crown fire initiation.

Given that the overall target density is below 50 TPA, there appears to be adequate regeneration. However, the abundance of Douglas-fir is a concern, and should be reduced during prescribed fire operations or via small-tree thinning, while retaining ponderosa pine as much as possible. Regeneration is often abundant following harvest due to exposed mineral soil.

The high variability of sapling density is in line with the objectives of producing a fire-resistant and ecologically functional forest by providing disrupted fuel beds and a mix of openings and dense regeneration thickets.

Q6: How much large dead wood is present?

Targets: Counts of snags, logs, and tons per acre of ≥3″-diameter wood.

Methods: Snags were counted and scaled to TPA across the pre- and post-treatment plot data. There were no downed dead wood data pre-treatment, so these were only examined post treatment in 33 plots. Logs were accounted for in two 50′ transects per plot by recording the diameter of all wood ≥3″-diameter that crossed the transect using methods from Brown (1974) to calculate wood mass. To convert wood mass to a 10″ log equivalent, we summed the mass of all wood >10″ diameter, then calculated the trunk mass of a 10″-DBH tree (Harrison et al., 2009), and divided it by this scalar.

Results

Snags: The plot data show <1 snag per acre >10″ DBH after treatment (Table 2). Field observations confirmed that snags are rare across the unit. Snags appeared to decrease; however, this could be a result of the large sampling error. There were only two snags in pre-treatment plots and three in post-treatment plots, suggesting that the area sampled was insufficient to accurately characterize the snag population.

Logs and wood: There were 1.9±1.20 tons per acre of logs ≥10″ diameter, which roughly equates to 6±2 logs per acre. The amount of wood ≥3″ is more than double that from logs ≥10″ at 4.1±1.25 tons per acre, so is likely also providing sufficient habitat value.

Management implications and recommendations: There were very few snags encountered post treatment, which was confirmed by field observations. With the large numbers of remaining medium and large-diameter trees, a reliable source for more large snags is present in this area.

Ongoing tree mortality and top breakage from wind and ice will increase snags over time. However, intentionally creating snags during prescribed fire operations or via tree climbing or girdling may be needed to achieve target levels.

Downed wood levels appear sufficient. Many of these logs were created during the harvest operations. However, error estimates for logs are high. Transect data should include log length. Transect length could be longer, as well.

Economic Data

Although not a formal monitoring question, the costs and revenues of the project are presented in table 24:

Table 24. Cost and revenue data for Bullfrog project. Harvest volumes totaled 304 thousand board feet (mbf) and 395 tons of pulp.

Item	Amount
Cultural Resources Survey	-$21,000
Road construction and maintenance costs	-$16,502
Contract harvest services	-$196,830
Slash pile grinding and removal	-$50,000
Log sale revenue	$237,433
Net proceeds	-$46,899

Bullfrog Monitoring Project Conclusion

Key results:

- Density targets were achieved at the higher end of retention targets. RMZ targets were met.
- Species composition of trees >10 DBH was shifted toward ponderosa pine, which is the dominant species.
- Large trees were retained. Smaller trees were preferentially removed.

- Density of regeneration and small trees (<10″ DBH) is sufficient, but is heavily tilted towards Douglas-fir. Small tree thinning and/or prescribed fire will be needed in the future to maintain ponderosa pine as the dominant species.
- Large downed logs are abundant after treatment.
- Snag levels are low. Tree mortality and top breakage will increase levels, but killing trees with prescribed fire or creating snags may be needed.
- A mosaic pattern of diverse canopy cover and habitat patch types is present across the treated and untreated areas.
- Patterns of individual trees, clumps, and gaps met prescription targets. However, treated areas have more individual trees and fewer clumps than reference conditions. Additional medium and large tree clumps are recommended for future projects to restore a wider range of ecological functions and to be consistent with reference conditions. Medium-to-large gaps were also missing in two of the subunits.

The key results presented above from implementation monitoring make clear that this project achieved the prescription targets. While it is not possible to draw definitive conclusions regarding the project's core objectives at this time (effectiveness monitoring), the following observations are possible:

The likelihood of an extensive crown fire has been reduced due to a significant decrease in overstory tree density (crown bulk density) and smaller trees (ladder fuels). The much wider spacing between tree crowns, including gaps, will make it much harder for a fire to carry through the crowns of the trees. Surface fuels data were not collected post treatment, so potential flame lengths could not be evaluated at this time. Without treatment of activity fuels, significant tree mortality could occur in a fire. Follow up data could be collected on fuels after the planned mastication treatment to determine if further surface fuels treatments are needed. Prescribed fire would be the most effective way to ensure that flame lengths in a future wildfire are as low as possible.

Drought resistance has likely been increased, reducing tree density and shifting composition towards more drought resistance species.

The maintenance of high canopy cover in relict river channels, forested wetlands, and riparian management zones should maintain riparian forest functions.

The treatment created a more diverse mix of patch types across the treated and untreated portions of the project area. This should enhance habitat value for wildlife species that use both open and closed canopy habitats. Understory plant abundance and diversity is likely to increase due to the treatment, which will benefit many wildlife species.

The results presented in this report are a single snapshot in time. The data collection for this monitoring report was conducted immediately after the commercial thinning operation, but before mastication of landing piles, and potential prescribed fire or small tree thinning. These follow-up actions will change the results presented here, especially with regards to dead wood and fine fuels.

Lessons learned for future monitoring work

As part of the 20-Year Forest Health Strategic Plan: Eastern Washington, DNR Forest Resilience Division staff partnered with State Parks and WDFWto monitor this project and pilot new methods for treatment-level monitoring, including use of drone-based imagery. However, detailed monitoring was not planned when this project was being developed. A range of pre- and post-treatment data collection methods were thus utilized. A secondary goal of this project was to pilot LiDAR and drone-based monitoring methods to compare them with plot data. Drone and LiDARtree maps were successfully used to monitor changes in several attributes.

A number of key lessons were learned during the project that will inform future monitoring efforts.

- Collecting variable radius plot data pre-treatment and fixed radius plot data post treatment in different locations introduced additional sampling error that made evaluating the effects of the treatment more difficult. Ideally, the same plot type and plot locations should be used pre and post treatment.
- To improve downed wood measurements, transect data should include log lengths and total area sampled to calculate probability of intersecting a log of a particular diameter. This will allow for a direct calculation of the number and length of logs.
- The number of snags tallied on the plots was insufficient, especially given their importance for wildlife. Plot size used for snags should be set based on the density of snags, and will often be larger than the plot size for live trees. In units such as this one with few snags, a 0.25-0.5 acre fixed-area plot should be used, or a basal factor of 10 for variable radius plots.

- Tree damage data were recorded for this project but not used to quantify the number of green wildlife trees. This could be added in the future.

- Plot data and remote data (tree maps from LiDAR and drones) have strengths and weaknesses. Depending on the monitoring goals and resources available, both data types can be collected. Below are some key conclusions for both kinds of data.

    - Plots are necessary for accurate measures of density (TPA, BA) that have known errors. Plot data is needed to measure shifts in species composition and any other questions that require an accurate tree list. Plots are time consuming to install at the density required for reasonable sampling errors, and only a portion of an area is sampled.

    - Remote data has the advantage of complete coverage of the treated area. Remote data are thus especially useful to quantify changes in spatial pattern of trees and canopy cover and to accurately measure changes in height and thus tree size and vertical distribution of the canopy. Remote data can provide reasonably accurate measures of density (TPA, BA), but the amount of error is unknown and can vary depending on the density and height of the forest. Drone-based height maps can be prone to height-flattening issues and other inconsistencies.

    - Drone-based data requires less time than collecting plots, but some plot data should always be collected to calibrate remote data. For this 120-acre project, flying the drone and processing the data took approximately 4 person hours, not including transportation to and from the site. Installing 33 field plots and cleaning the field data took approximately 65 person hours, not including transportation. This could be reduced to ~40-45 hours as crews gain more experience with the protocol.

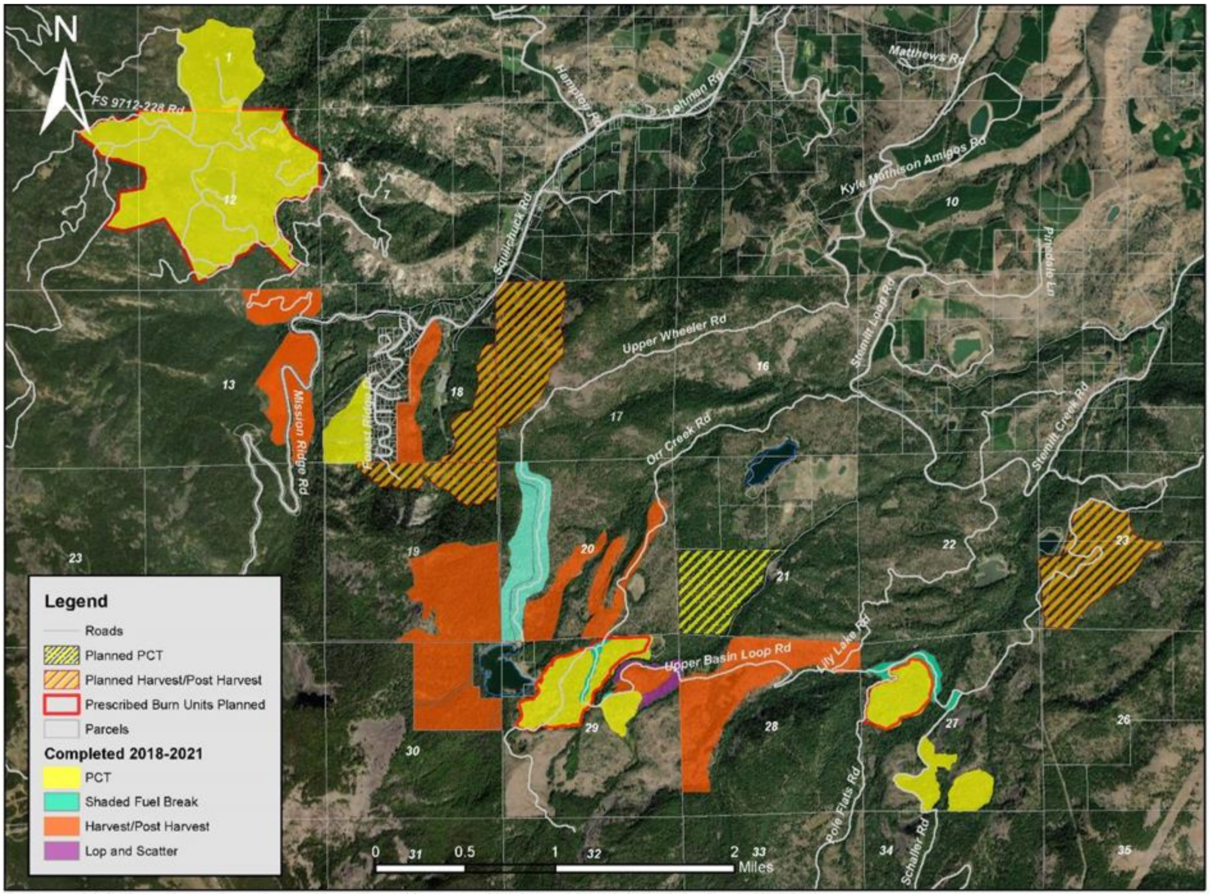
- Collecting pre- and post-treatment remote data with the same LiDAR or drone imaging technology is recommended. Comparing airborne LiDAR data collected 8 years ago with drone-based structure from motion data post treatment proved to be problematic as canopy height models and tree heights were not directly comparable.

Utilizing DNR Forest Health Monitoring Protocols to Monitor a Prescribed Burn in Chelan County

Contributing Author: **Erin McKay** (Chelan County Natural Resource Department)

Chelan County Natural Resource Department is working to restore forest health and resiliency in 20-Year Forest Health Strategic Plan priority planning areas, including the Stemilt Basin. Through implementation of commercial and non-commercial mechanical thinning and prescribed fire, a significant portion of the Stemilt planning area has been restored to a more resilient condition. From 2018-2022, more than 1,300 acres have been treated through overstory thinning, pre-commercial thinning, lop and scatter, hand piling, machine mastication, pile burning, and prescribed burning.

Figure 47. Stemilt Landscape Scale Restoration Area, Completed and Planned Units (January 2022)



Sections are labeled by section number and ownership; sections without ownership labels are privately held. Chelan County GIS 2021.

This summary report describes the use of the DNR Forest Health Treatment Effectiveness Survey (Survey 1, 2, 3) to evaluate a prescribed burn on county land near Upper Wheeler Reservoir in the Stemilt Basin.

Plots were installed in the unit prior to burn implementation and were monitored one month after the burn and again one-year post-burn. Unit elevation is approximately 4000′ and the site has a dominant N/NE aspect. On May 5, 2021 a prescribed burn was implemented across approximately 45 acres. By comparing the treatment objectives outlined in the burn plan with pre- and post-burn plot data and photos, we can identify some key characteristics of treatment outcomes to help evaluate treatment success.

<u>Resource objectives identified in burn plan:</u>

1. Reduce 70% of fine dead woody surface fuels over 70% of the unit.
2. Limit overstory mortality of mature ponderosa pine, western larch, and Douglas-fir (less than 15% mortality of these species).
3. Broadcast burn >60% of unit area.
4. Restore uneven-aged stand structure for resilience to future disturbances.
5. Leave scattered areas of large downed woody material (over 3″ plus) to maintain habitat.

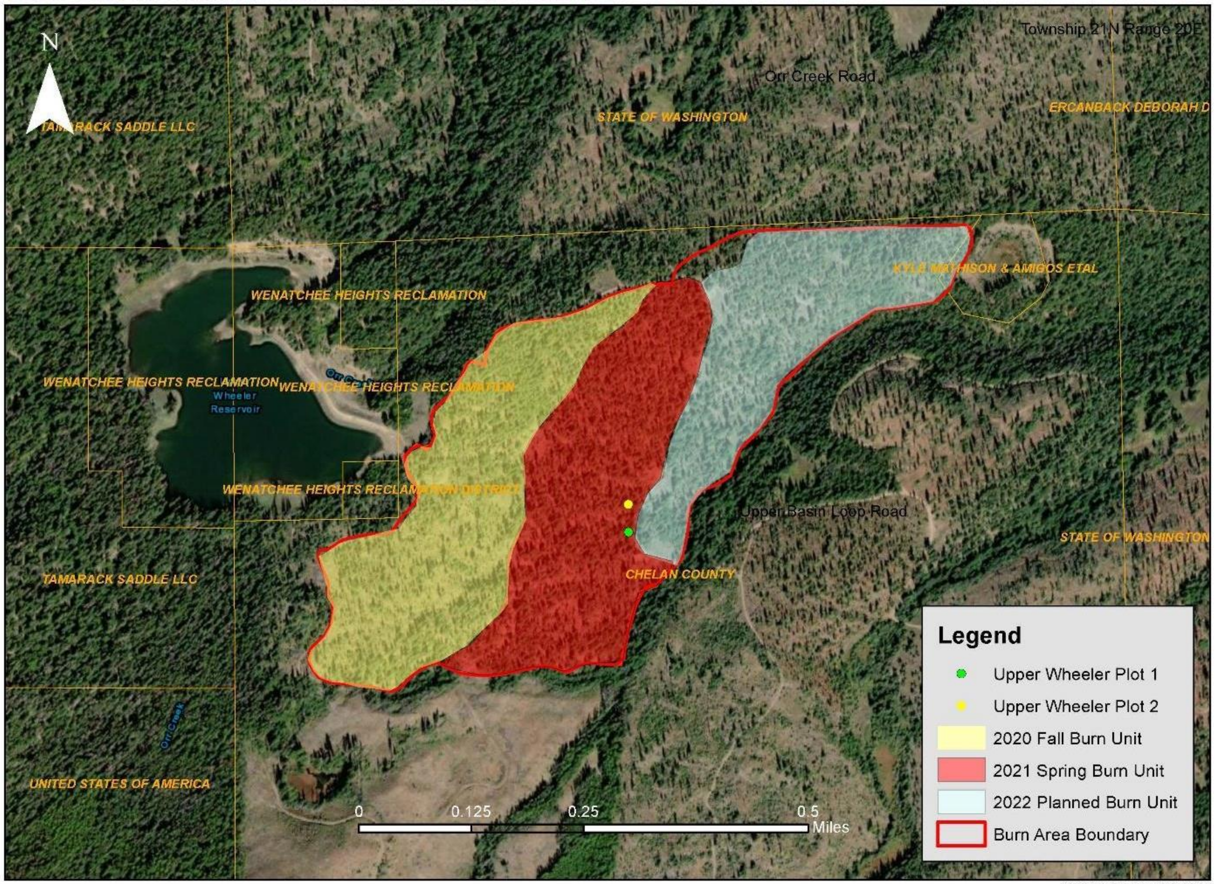
The map below shows the burn unit and the location of the plots within the unit. The yellow highlight shows the boundary of the burn unit. The unit was broken into two separate burn blocks; the plots are located in the red highlighted area that was burned in spring of 2021.

Monitoring Results

Utilizing the Survey 123 tool, pre- and post-prescribed burn treatment plot data in two plots was collected in the Upper Wheeler Burn Unit in Section 29 on county land. In this case, the forest structure did not undergo significant changes within the plots, with the exception of a shift from understory dominant of Douglas-fir to ponderosa pine in one plot and an overall increase in average tree diameter due to mortality of small understory trees.

Plot data collection also includes photos that help determine the amount and pattern of fuel consumption in the plots. This is an important component of evaluating effectiveness of prescribed burning. The figure below shows before and after photos of the Upper Wheeler 2 plot. Different fuel types are visible on the surface in the first photo, ranging from fine fuels to +3″ woody material. The second photo shows a significant reduction of surface fuels, approximately meeting the target of 70 percent fine fuel reduction. Some slash remains in the foreground, but most of the fuel in the middle of the frame has been consumed as a result of the patchy mosaic burn pattern.

Figure 48. Upper Wheeler Section 29 Prescribed Burn Area Map



Chelan County GIS 2022

Evaluating Treatment Effectiveness

The monitoring plots helped determine that treatment objectives were met within the treatment plots. We can see from the data and photos that surface fuels were reduced by 60-70% and within preferred range, overstory mortality of preferred species was minimal (no mortality of the overstory noted within monitoring plots), and uneven aged stand structure was maintained with some mortality of understory fir species. However, other metrics of treatment effectiveness could not be determined through plot data alone.

For example, one target of the prescribed burn was to broadcast burn 60 percent of the treatment unit. Larger-scale unit photos of before and after treatment were very helpful in assessing these treatment effectiveness metrics. Figure 4 illustrates the larger-scale effects of the prescribed burn on the landscape, helping us determine that the goal of burning 60 percent of the unit area was met. Drone footage can also be an effective tool to evaluate unit-scale metrics, and should be used as part of a treatment unit monitoring plan.

Figure 49. Before and after photos of Upper Wheeler plots 1 and 2 (plot 1 azimuth 270; plot 2 azimuth 300). Pre- and post-burn photos were taken on May 4, 2021 and June 9, 2022, respectively.

Photos by Chelan County Natural Resources Department

Fuel Treatment Effectiveness Monitoring

Contributing Authors: **Brenda Hallmark**, **Tracy Martindale**, **Jason McGovern** (USDA Forest Service), and **Garrett Meigs** (Washington Department of Natural Resources)

A tool to assess how treatments have supported fire management is necessary in order to better prepare for, control, and manage wildfires long-term. Starting with the 2017 fire season, USDA Forest Service (USFS) Region 6 staff brought together a team that conducted post-fire data collection throughout the region on many of the major wildfires of that year by recording fire outcomes in the field, and then coordinating and cross referencing these results with past fuel treatment projects. The goal of the project is to evaluate which treatment types and return treatment intervals are most successful in slowing, managing, or stopping the spread of wildfires.

Images from the Cub Creek Fire in 2021, Okanogan-Wenatchee National Forest. Image on the left shows an example of a thinned and underburned stand that burned at low-severity. The image on the right shows a stand that burned at high severity.

This effort of comparing wildfire interactions with fuel reduction treatments is called Fuel Treatment Effectiveness Monitoring (FTEM). The USFS produces fuel treatment effectiveness reports for major fires when data is available, as well as online dashboards that summarize monitoring results. The 2018 and 2021 dashboards are the first iterations where this treatment effectiveness dataset is publicly available, released by the region as the R6 Fuels Treatment Effectiveness Monitoring (FTEM) Dashboard.

Following the initial development of this effort in 2017, Region 6 did not collect FTEM data in 2019 – it happened to be a low fire year, and 2020's data collection did not result in a report due to COVID and other unforeseen complications.

Through the portals, users can click on major wildfires throughout Region 6, outlined and labeled in red. Users can zoom in and out, with the upper right-hand sidebar, visualizing fire outcomes in terms of three primary questions:

1. Did fire behavior change as a result of the treatment?
2. Did the treatment contribute to control or management of the fire?
3. Was the treatment strategically located to facilitate fire control?

Users can also examine data at a treatment unit level, including information on the size of the treatment area and how the treatment intersected with the wildfire both from a management standpoint and also in geographic space. Many data entries also include photos of treatment areas post-fire, as well as additional data collection comments.

The Forest Service made the data public to help demonstrate the need for various treatment types and repeat treatments. Brenda Hallmark, Region 6 Regional Fuels Coordinator with the Forest Service, explained that the dashboard will help to "show why one piece of land may have so many steps to treatment… [that] we can show differences between just thinning and its effectiveness versus an area that has a follow-up treatment of slash removal."

The tool is meant to offer a broad, regional look at how different treatments are distributed across the landscape and how they interact with large wildfires. USFS hopes to use this tool (and associated data) to more strategically locate treatments and treatment types, ultimately answering the question, "are we implementing treatments to reduce wildfire risk in the right places?" The tool has also been increasingly used to help incident management teams utilize fuels treatments as part of their management strategies.

Fuel Treatment Longevity Study

Contributing Authors: **Don C. Radcliffe**, **Brian J. Harvey**, **Jon D. Bakker** (University of Washington), **Derek J. Churchill** (Washington Department of Natural Resources)

A key component of the 20-Year Forest Health Strategic Plan is to estimate the amount of treatment needed to reduce wildfire risk and restore ecosystem functions in landscapes across eastern Washington. The longevity of treatments and resulting timeframe in which areas need retreatment is a major driver of long-term treatment need. However, scientific information on treatment longevity is sparse. During the 2019-2021 biennium, DNR funded a team at the University of Washington (UW) to investigate treatment longevity and future treatment needs using literature review, dataset compilation, and field data collection.

Project Objectives:

1) Estimate treatment longevity for common fuel treatment methods (e.g., thin, burn, thin-plus-burn) applied in eastern Washington forests.
2) Quantify fuel profiles in areas 10-20 years after application of common fuel treatment.
3) Assess how treatment effectiveness relates to pre-treatment stand conditions, forest type, site productivity, and treatment intensity.
4) Identify knowledge gaps in fuel treatment longevity.

The UW research team conducted a comprehensive search for long-term fuel treatment studies and monitoring projects in eastern Washington to identify and leverage existing datasets. More than 50 managers and scientists responded, and relevant project information and data were compiled into a database. The team re-measured sites from two projects: the long-term Mission Creek Fire and Fire Surrogates (FFS) study near Cashmere, and the Colville National Forest Collaborative Forest Landscape Restoration Project near Republic and Kettle Falls. Field data was synthesized with a literature review to assess the current state of knowledge about treatment longevity. Many researchers, managers, and field technicians provided invaluable assistance to this project and are listed in the full report. Researchers are currently analyzing field data from the Mission Creek FFS site (box 1) and working on a research article.

Key findings include:

1. Longevity of fuel-reduction benefits differs among treatment types. Thin-and-burn treatments may confer fuel reduction benefits for 20 years or greater. Burn-only treatments may confer fuel reduction benefits for 10-15 years. Thin-only treatments may

be less effective due to short-term surface fuel increases and long-term canopy fuel and ladder fuel recovery. These estimates are based on limited data, so they should be treated as preliminary.

2. Long-term fuel-treatment effects depend on which response metric is considered. Fuel treatments had minimal effects on expected surface fire flame lengths ~15 years after treatment. However, fuel treatments had persistent effects on tree basal area and density, canopy fuel loads, as well as expected crown fire potential ~15 years after treatment. Thus, in locations where maintaining low surface-fuel loads and flame lengths is a high priority — such as defensible space close to homes or fuel breaks — re-treating will likely be needed more frequently. Re-treatment rates can be longer in places where maintaining low crown fire potential, as well as drought resistance, is the priority and moderate flame lengths are acceptable, such as in forested areas farther away from homes.

3. Treatment longevity depends on more than just treatment type. In addition to treatment type, pretreatment condition, treatment intensity, site productivity, and forest type affect treatment longevity. For example, stands with large trees before treatment are more likely to have trees survive wildfire after treatment, for a given treatment type. Treatment intensity (e.g., basal area removed during thinning) is correlated with long-term stand structure and fuel profiles.

   However, the effects of these factors are not well understood, and only very general estimates of treatment longevity are currently possible. Continuing existing long-term monitoring studies, as well as initiating new ones, is needed for reliable prediction of treatment longevity as well as related estimates of long-term treatment need across eastern Washington.

Case Study: The Mission Creek Fire and Fire Surrogates (FFS) Study

This site near Cashmere was part of a national study initiated in the early 2000s to experimentally test the effect of common fuel treatments on stand structure, fuel profiles, and expected fire behavior and severity. Three approximately 25-acre units were treated with each of four treatment types: burn-only, thin-only, thin-plus-burn, and no-treatment control. In the short term, thin-only treatment increased surface fuel loads while decreasing canopy fuel loads, burn-only treatments decreased surface fuel loads with little effect on canopy fuel loads, and thin-plus-burn treatments reduced both surface and canopy fuel loads. In 2019 and 2020, our team resampled units to assess effects 13-18 years after treatment.

Figure 50: Representative stands ~15 years after treatment at the Mission Creek FFS site, showing long-term reductions in stand structure and canopy fuel relative to untreated control stands, especially in thin and thin plus burn stands. Photo credits: Brian Harvey and Michele Buonanduci, UW.

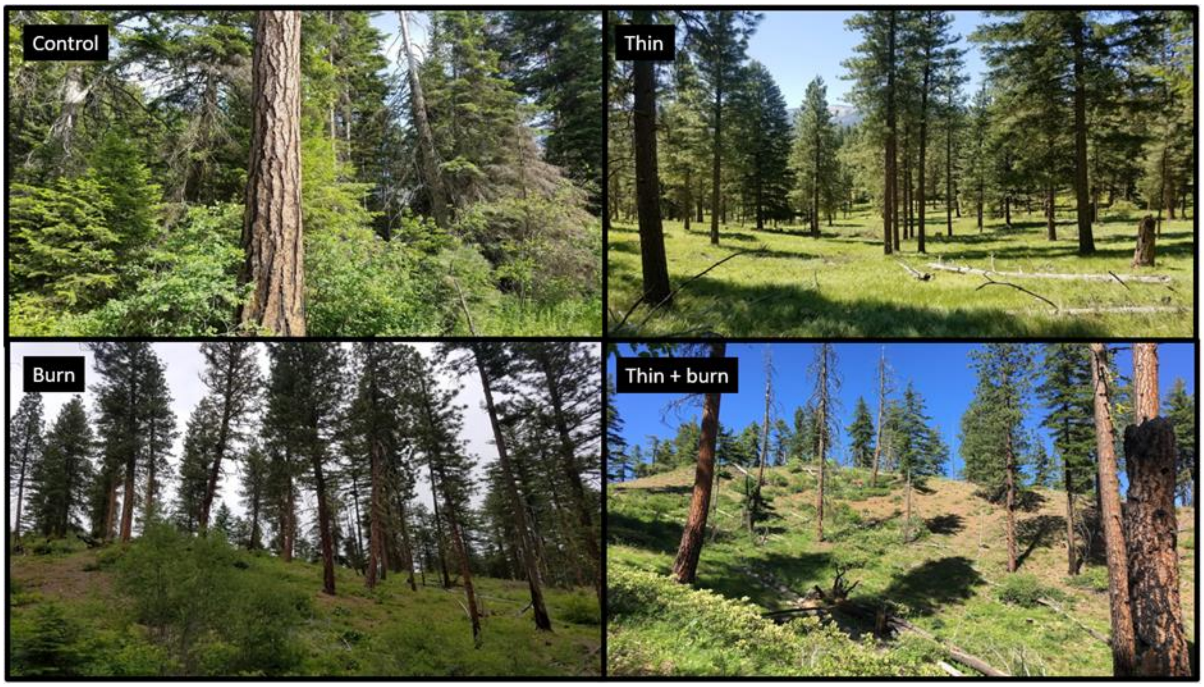
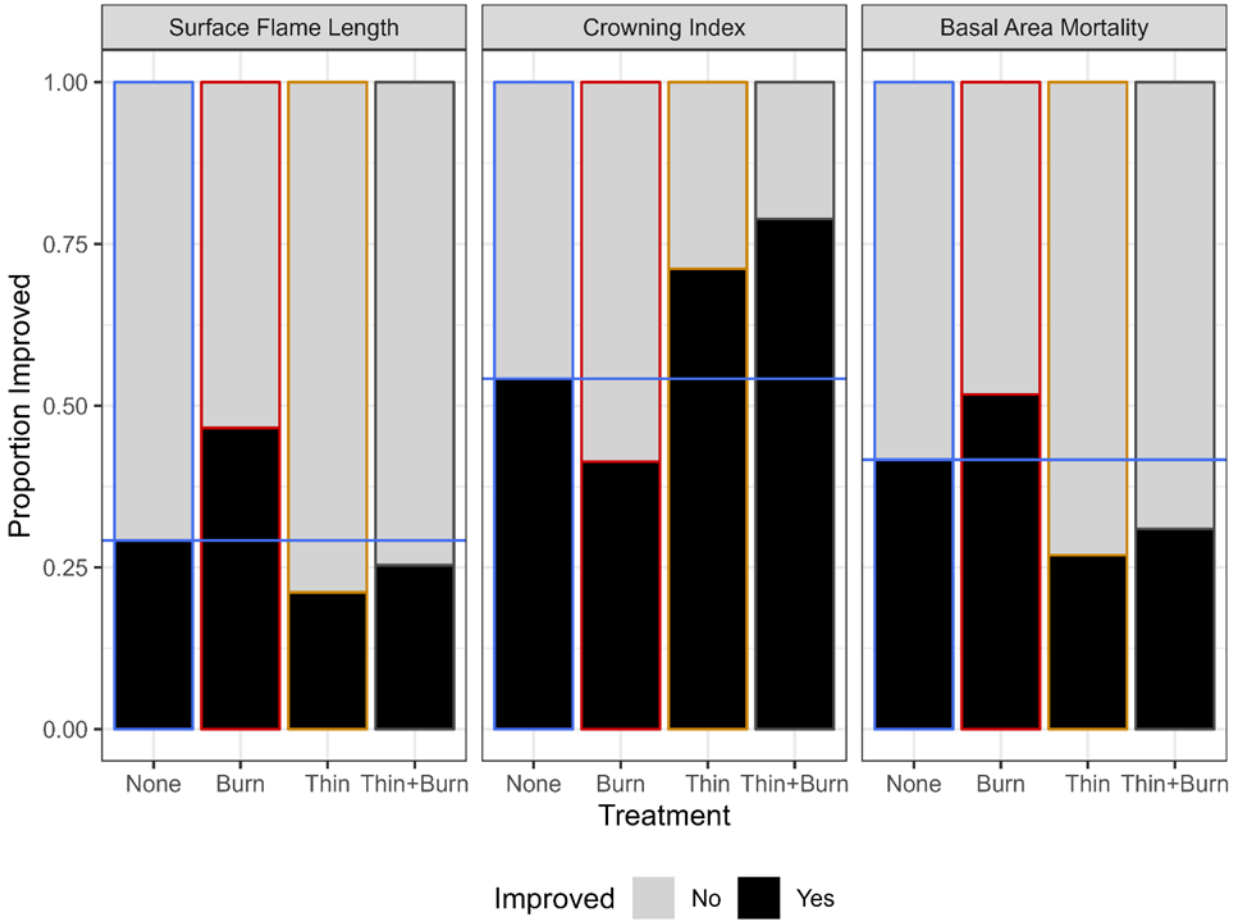


Figure 50 shows examples of what each treatment looked like in 2019, giving a visual representation of long-term reductions in basal area and canopy fuel in treated stands, especially in thin and thin-plus-burn stands. Key findings from long-term sampling included slight increases in expected surface fire intensity and related tree mortality, with decreases in canopy fuel and expected crown fire (Figure 2). This indicates that fuel treatment longevity depends on whether surface fire or crown fire is of greater concern to managers.

Additionally, the pretreatment condition was positively correlated with long-term response of fuel loading and stand structure, suggesting that treatments work within bounds set by stand history and biophysical conditions (climate, topography, soil type). These findings will soon be published in a scientific journal.

Figure 51: Proportion of sample plots for which selected fire intensity and severity metrics improved from pretreatment to long-term sample periods. Blue lines represent the proportion that improved when no treatment was applied. Most sample plots exhibit increases in expected surface fire intensity and related tree mortality after ~15 years, and decreases in canopy fuel loads and expected crown fire (higher crowning index equates to greater resistance to crown fire). This indicates that fuel treatment longevity depends on whether surface fire or crown fire is of greater concern to managers.



Future Work on Fuel Treatment Longevity

The team is continuing to address knowledge gaps highlighted in key finding number 3. Most immediately, they are finishing work on a publication from the Mission Creek FFS project highlighted in box 1. They are also revising the literature review report into a scientific journal format, with the goal of encouraging other research teams to study how pretreatment condition, treatment intensity, site productivity, understory plant composition (shrubs vs. grasses), and other factors affect treatment longevity.

Future projects will likely include analyses of fuel treatment longevity using long-term datasets on the Colville National Forest, and on the Stehekin and Lake Roosevelt National Recreation Areas. Datasets have been cataloged, and data collection continues at each site. The results of these analyses will allow DNR and other land managers to better estimate long-term treatment needs. Improved knowledge of treatment longevity will also help forest managers in Washington State and around the western U.S. schedule fuel treatments more effectively and efficiently.

State Appropriations Request

Released in 2017, the 20-Year Forest Health Strategic Plan laid the foundation and catalyzed action to increase the health and resilience of Washington's fire prone forests and communities in response to fulfilling RCW 76.06.200 and at the pace and scale of the threats facing them. Tremendous progress has been made in the past five years. Looking ahead, there is no doubt there is more work to be done. This report builds on the foundation presented in our 2018 and 2020 legislative reports, and demonstrates the orchestrated impact of leveraged resources under a common vision. DNR remains committed to completing the 20-Year Forest Health Strategic Plan. With strong legislative, scientific, and collaborative support we will meet and exceed our shared goals.

For the 2023-2025 Biennium, DNR is requesting full funding of the Wildfire Response, Forest Restoration, and Community Resilience Account at $125 million. Of this funding, approximately $94.8 million worth of expenditures is maintenance level funding to DNR, while the remaining $30.2 million is for partners implementing our forest health and wildland fire strategic plans including state agencies, federally recognized tribes, local governments, fire and conservation districts, nonprofit organizations, forest collaboratives, and small forest landowners. DNR is well positioned to serve as fiscal and programmatic steward of all funds that are not directly appropriated to other state agencies. DNR assures the legislature that the comprehensive funding package identified in this proposal meets the minimum appropriation thresholds established in legislation that forest health activities funded by the Account shall not be less than 25% and community resilience activities funded by the Account shall not be less than 15% of the biennial appropriated funding.

To accomplish these objectives, DNR is requesting the following funding:

1. **Maintenance-Level Request:** DNR requests maintenance level funding of approximately $94.8 million, which includes just over $34 million specific to implementation of forest health assessments, treatments (including technical assistance to small forest landowners), and progress tracking work consistent with forest restoration and community resilience objectives in our strategic plans.

2. **State Agency Requests:** To facilitate an all-lands, all-hands approach DNR supports a strategy in which direct allocations are provided to those state agencies producing core deliverables consistent with these plans. For the 23-25 Biennium, DNR supports the direct allocation request from the Washington State Conservation Commission (SCC) for $5 million to deliver community resilience and forest restoration projects through conservation districts statewide. DNR also supports the non-account requests for the Washington Department of Fish and Wildlife (DFW) and Washington State Parks (Parks) including DFW's request for approximately $6M from the dedicated capital-funded

Forest Resiliency Account – Hazardous Fuels Reduction and Forest Health (25F), and Parks' request of approximately $1M in capital funding, and $500K as a component of the General Fund operating budget.

3. **Policy Level Pass-Through Request:** To ensure funding is provided in a transparent, consistent, and accessible manner to non-state entities, DNR requests the remaining $25.2 million in available funds from the Account be provided to the agency for direct disbursement through DNR's existing programs that provide ability to pass-through funding to implementation partners.

See DNR's December 1, 2022 RCW 76.04.516 Report to the Governor and the Legislature for further details on this request.

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Appendices

Appendix A: Landscape Evaluation Summaries for 2022 Priority Planning Areas

Appendix B: Virginia Ridge Stand-Level Monitoring Report

Appendix C: Treatment Unit Monitoring Methods

Appendix D: Change Detection Monitoring Methods

Appendix E: Wildfire Emissions Methods

Appendix A: Landscape Evaluation Summaries

Summaries in the following order of priority planning areas:

- Chelan
- Deer Park
- Dollar
- Highway 97
- Little Naches
- Little Pend Orielle
- Mount Spokane
- Touchet Mill

CHELAN PLANNING AREA
LANDSCAPE EVALUATION SUMMARY (2022)

Total Acres	Forested Acres	Treatment Goal (Acres)
98,004	31,342	7,500 - 12,500

Figure 1. Planning area location in eastern WA.

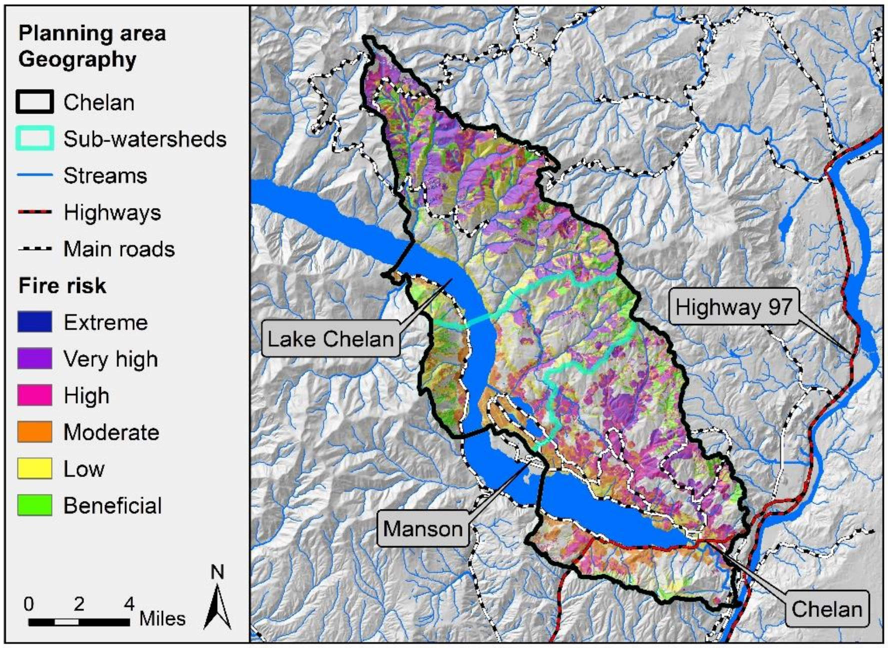

Figure 2. Planning area geography and fire risk, which integrates burn probability, fire intensity, and fire susceptibility of forests, infrastructure, and homes.

Planning Area Highlights

- This planning area includes three sub-watersheds surrounding Lake Chelan and the communities of Chelan and Manson, where recreation, tourism, and orchards are economically important.
- The area is 50% private, 45% US Forest Service, and 5% other land owners.
- Fire risk is very high the northwest portion of the planning area. Fire risk is also high to very high on private property with homes on both sides of Lake Chelan. Lower risk areas include locations that burned within the past 20 years.
- Projected warming over the next 20-40 years will likely shift climate conditions that are currently suitable for dry forest at lower elevations and on south-facing slopes towards conditions that may no longer support forest.
- Treating 24-40% of forested acres is recommended to reduce density in young forests and to maintain open conditions with low fuel loads, thereby increasing resilience. Proactive maintenance, primarily using mechanical and prescribed fire treatments, will also reduce fire risk to communities.
- High priority locations for potential treatments that maximize forest health and wildfire response benefit are concentrated in the northern and eastern portions of the planning area.

LEARN MORE

This landscape evaluation was completed in 2022.
For more details about DNR's priority planning areas please see: **https://www.dnr.wa.gov/ForestHealthPlan**
For data products and methods see: **https://bit.ly/ForestHealthData**

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Overarching Goals

Reduce wildfire risk and protect communities

Substantial areas within and around the planning area have burned in recent decades, including the 2002 Deer Point Fire. Fire risk remains high to very high in central and northern portions of the area. Fire risk is also high to very high on private property with homes on both sides of Lake Chelan (Fig. 2). Fuels treatments are needed to break up patches of young stands with small trees, to reduce the likelihood of large crown fire, and to facilitate protection of private property in the planning area. In some western and eastern portions, fire risk is relatively low due to open forest and fuel conditions.

Increase resilience and prepare for climate change

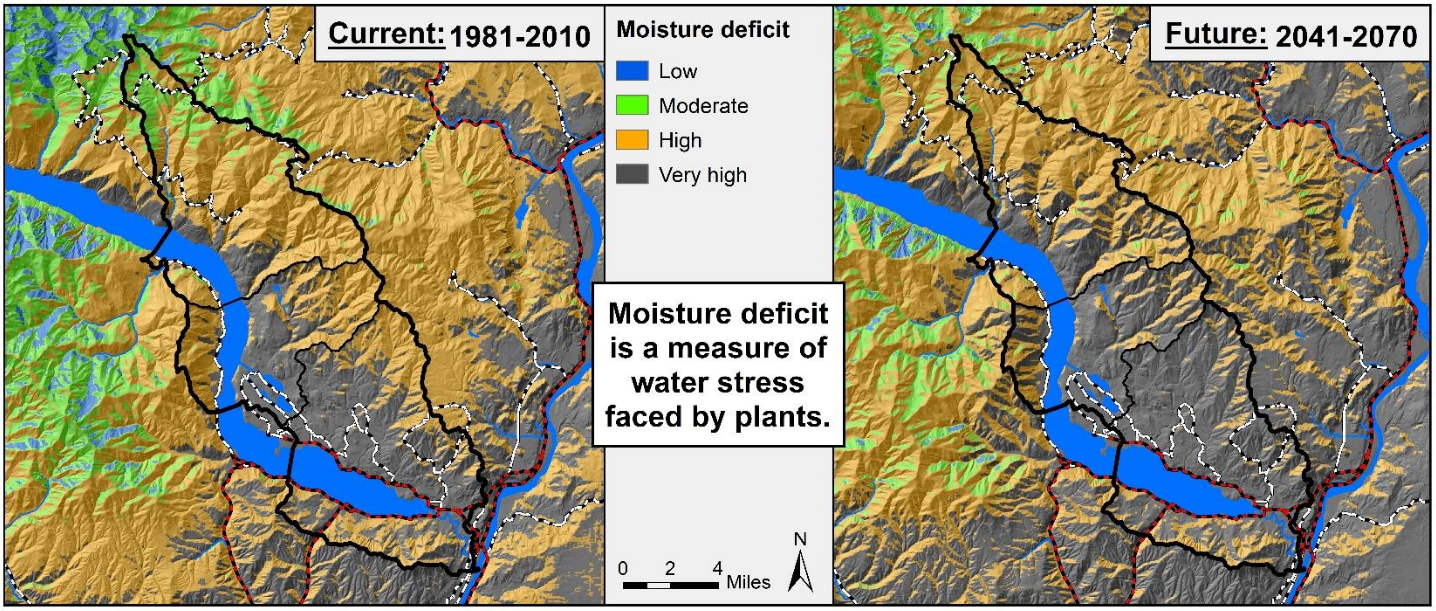
This dry forest landscape has relatively high current and projected future moisture stress. By mid-century, the majority of the planning area is projected to have moisture stress levels that are currently associated woodland/shrub-steppe (Fig. 3). Although non-forest vegetation types (herbland and shrubland) are currently widespread, substantial portions of forested areas within the planning area are projected to shift to non-forest over time. High moisture stress levels associated with dry forest types are projected to remain at higher elevations and on north-facing slopes. Forest health treatments that reduce density and favor drought-tolerant species will support forest persistence into the future.

Sustain wildlife habitat

Dry forests are extensive throughout the planning area, primarily as a mixture of open and closed-canopy patches with small and medium trees. Habitat for dry forest, large tree, open canopy species (e.g. White Headed Woodpecker) is under-represented relative to reference conditions. Habitat for species that depend on moist, closed canopy forest with large trees (e.g. Northern Spotted Owl) is a small component of this planning area. Habitat for cold forest, large-tree, closed canopy species (e.g. American Marten) is also a small component of the planning area. Habitat layers are available in the data products.

Enhance rural economic development

This planning area is a major destination for tourism and recreation in eastern WA. Reducing fire risk will help sustain tourism and recreation while reducing the potential of smoke affecting communities, agricultural lands, and critical infrastructure (road and utility corridors). In terms of wood production, few opportunities exist for commercial treatments due to extensive past fires in and around the planning areas. Projected warming trends and high fire risk will necessitate managing for lower densities and fuel loads. As moisture stress increases and forest cover declines over time, long-term timber production will become more challenging.



Moisture deficit is a measure of water stress faced by plants.

Figure 3. Current (left) and future (right) moisture stress levels based on water balance deficit. Low levels are associated with moist and cold forest types, high with dry forest types, and very high with woodland or shrub-steppe. Future climate is based on a relatively high greenhouse gas emissions scenario (RCP 8.5).

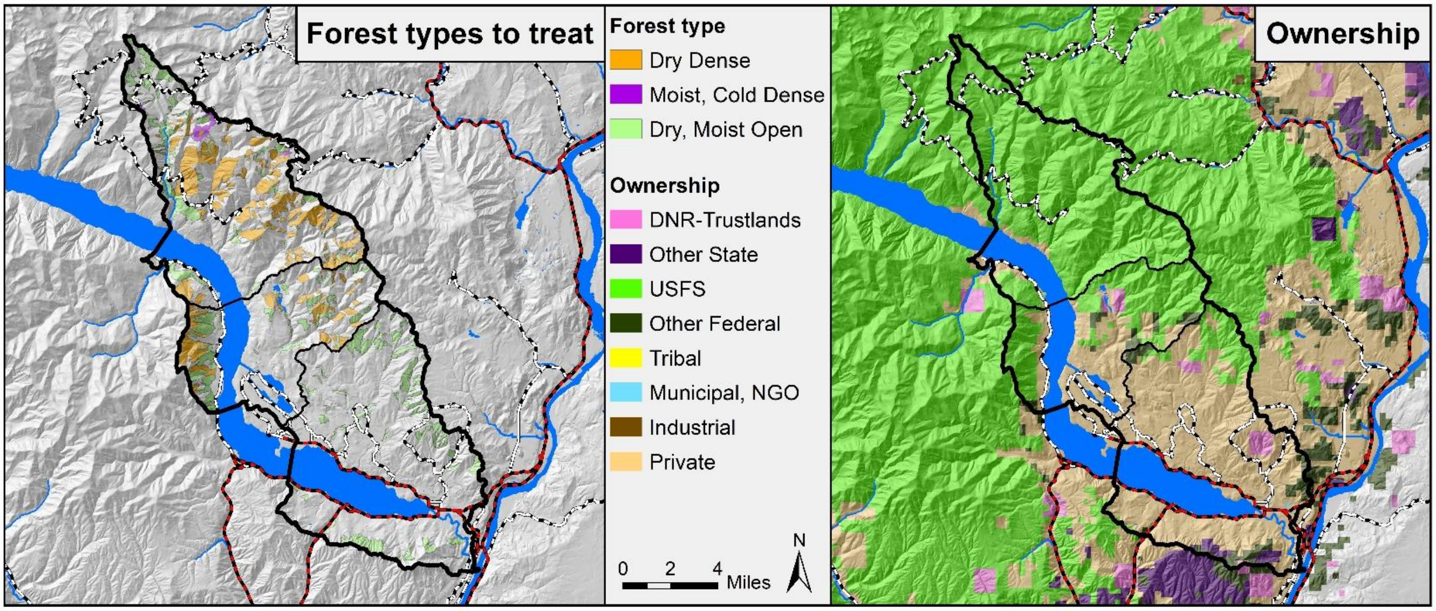
Forest Health Treatment Needs

Treating 7,500 to 12,500 acres is recommended to enhance landscape resilience (24-40% of forested acres; Table 1). This total includes an estimated 1,000-2,250 acres to shift dense to open forest and 6,500-10,250 acres of maintenance treatments in existing open and/or young forest, based on current condition data from 2014 aerial photos. The majority of the treatment need and opportunity is on USFS land, although substantial need exists on private land as well.

Meeting this target range will require multiple treatment types (Table 1). Noncommercial thinning of small trees and prescribed fire are the primary tools available. Managed wildfire under safe conditions will also likely be needed, especially in less accessible locations. Treatment type will depend on road access, logging systems, markets, and other considerations. Individual landowners will conduct their own planning and decision-making processes to determine acres and types of treatments to achieve the landscape goals while meeting their own objectives and regulatory requirements.

Table 1. Summary of forest health treatment needs. ***See methods for details on how the treatment need range is derived.***

Forest conditions to treat		**Treatment need (acres)**	**Current acres by major landowner***			
Type	**Size class**		**USFS**	**Private**	**Federal**	**Other**
Dry Dense	Small	1,000 - 2,000	9,830	739	90	246
Moist + Cold Dense	Small	0 - 250	1,633	0	0	0
Dry + Moist Open	Small, Medium, Large	6,500 - 10,250	4,734	3,558	620	520
Total		**7,500 - 12,500**	**These are current acres, not targets*			
Anticipated treatment type	🟦	Noncommercial thin plus fuels treatment. May be fire only (including prescribed fire or managed wildfire under safe conditions).				
	🟩	Maintenance treatment: prescribed fire, managed wildfire, or mechanical fuels treatment. *Target range corresponds to 50-75% of dry open and 25-50% of moist open forests.*				



Left: Figure 4. Forest structure types that are overabundant relative to targets for a resilient landscape, as well as potential maintenance treatments. Only a portion of the areas shown need to be treated. Right: Figure 5. Current land ownership.

Forest Health Treatment Needs (continued)

Dry dense forest treatment need

On dry sites, dense forest structure is currently over-represented in stands with young trees. Many of these areas experienced high-severity wildfire 20-40 years ago and regenerated naturally or were replanted. These forest conditions create high susceptibility to drought, insects, and stand-replacing wildfire. Treating 1,000-2,000 acres of dry dense forest (Table 1) is recommended to create large patches (~100-1000 ac) of open forest and shift the majority of dry sites to open forest (Fig. 6). Ponderosa pine and other drought-tolerant species will continue to be suitable as climate conditions get warmer and drier.

Moist and cold dense forest treatment need

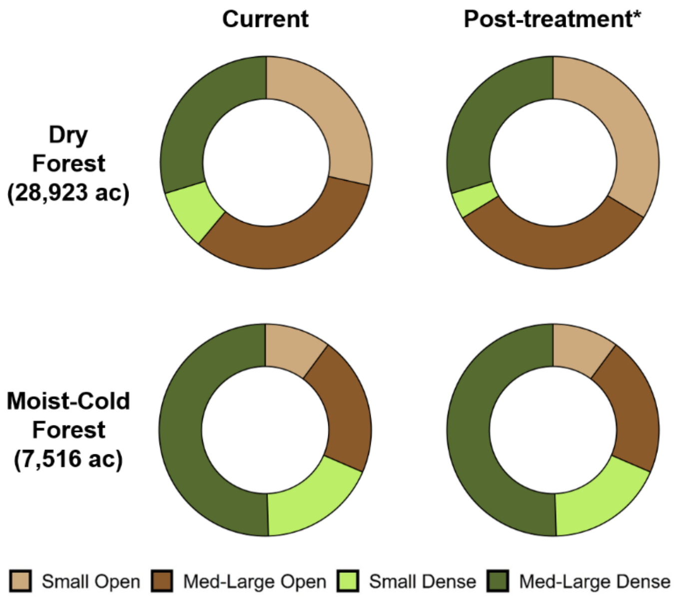
On some moist and cold sites, dense young forest structure exceeds desired ranges. In contrast, open canopy forest with medium to large trees are below desired ranges. Treating 0-250 acres of this type (Table 1, Fig. 4) is recommended to create a mosaic of open, moderate, and dense patches that will reduce risks of large crown fire and insect outbreaks. A range of treatment types will be needed, including thinning, removal of dead trees caused by insect outbreaks and recent wildfires, and prescribed fire. Increasing the relative composition of ponderosa pine and western larch is also needed to help these sites adapt to a warming climate (Fig. 3). The small recommended treatment area means that over 65% of moist and cold forest types will remain dense (>40% canopy cover) (Fig. 6) to meet habitat, wood production and other objectives.

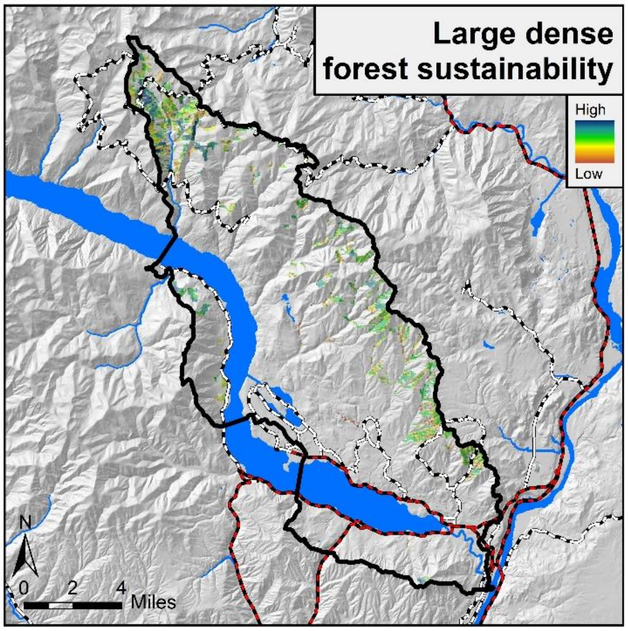
Open forest maintenance treatment need

Maintenance treatments are the most widespread, high-priority treatment type across this planning area. Over the next 15 years, an estimated 6,500-10,250 acres of currently open forests on dry and moist sites will need prescribed fire, managed wildfire, or mechanical methods to maintain open conditions and promote the growth of medium and large trees by reducing surface fuels and small trees. These sites include more open areas where fire is currently predicted to have beneficial effects (Fig. 2), as well as relatively young stands with small trees. Specific maintenance strategies will depend on landowner objectives, time since treatment, and particular conditions in stands dominated by small trees.

Sustainable locations for dense forest with large trees

Locations with low to moderate current and future moisture deficits (Fig. 3) and low fire risk (Fig. 2) offer the most sustainable locations to maintain sufficient area of this habitat type and associated ecosystem functions. Most of the areas with large, dense forest that could potentially persist over time are located in the northwestern corner and at high elevations (Fig. 7). This sustainability map can be used in conjunction with treatment priority (Fig. 9) to select areas to shift to open forest vs. where to maintain and increase large tree, closed canopy patches.





Left: Figure 6. Current and post-treatment proportions of forest types and structure classes. * mid-point of range in Table 1.
Right: Figure 7. Sustainability of current and potential large tree, dense forest based on fire risk and drought vulnerability.

Landscape Treatment Prioritization

Prioritizing for forest health & to reduce fire exposure of homes

Landscape treatment priority integrates three metrics of forest health – forest fire risk (Fig. 2), drought vulnerability (Fig. 3), and presence of overabundant forest structure types (Fig. 4) – with wildfire transmission to homes (Fig. 8). We also recommend incorporating the large dense forest sustainability layer (Fig. 7) as an overlay when selecting treatment locations. Wildfire transmission is high across most of the planning area, indicating that wildfires starting in these locations are expected to expose homes around Lake Chelan and the communities of Chelan and Manson (Fig. 2).

Treatment priorities

Landscape treatment priority is highest in central and northern portions of the planning area (Fig. 9), particularly in dense stands dominated by small trees on US Forest Service lands (Fig. 4, Fig. 5). Medium priority areas occur in forested areas across the planning area on both sides of Lake Chelan. Some low priority areas may need treatment to address species composition, insect and disease risk, or other issues. In addition, fuel reduction treatments, defensible space, and home hardening are needed on private parcels with homes or other structures throughout the planning area.

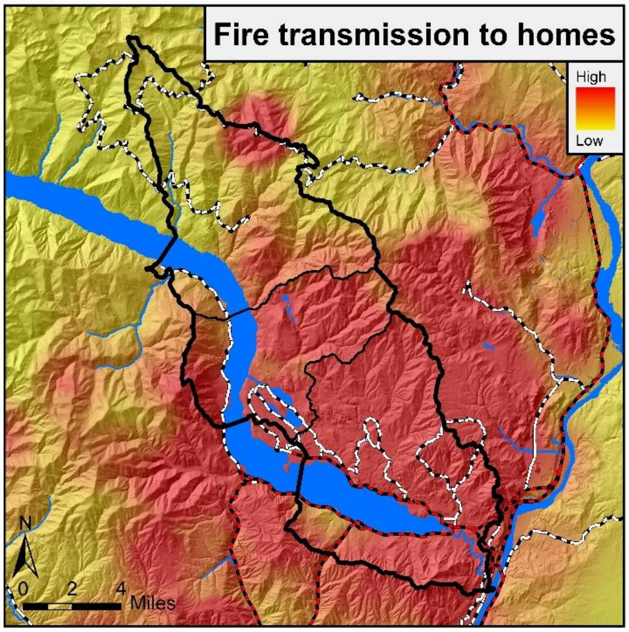


Figure 8. Fire transmission to homes shows where fires that expose structures are most likely to originate. It is based on simulated fire perimeters given contemporary patterns of fuels, topography, and wind.

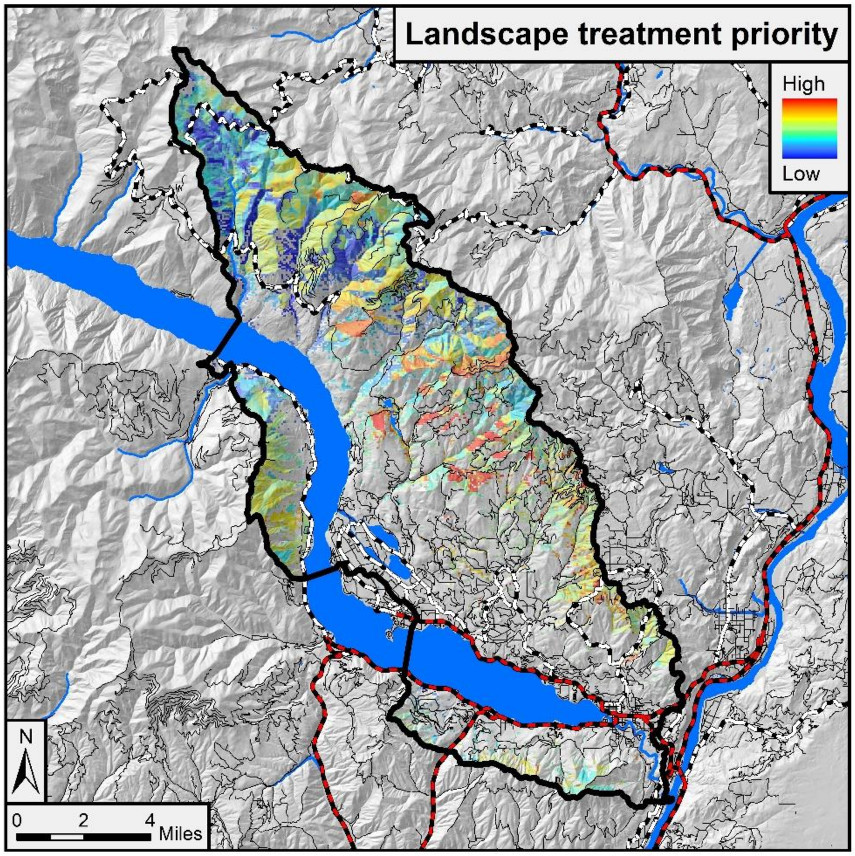


Figure 9. Landscape treatment priority is based on three metrics of forest health – forest fire risk (Fig. 1), drought vulnerability (Fig. 3), overabundant forest structure (Fig. 4) – as well as wildfire transmission to homes (Fig. 8).

Definitions

Vegetation Types

Cold forest: Upper elevation mixed-conifer forests with high-severity fires every 80-200+ years.

Dry forest: Ponderosa pine and Douglas-fir dominated forests that historically had surface fires every 5-25 years.

Moist forest: Forests that historically had mixed-severity fires every 30-100 years and were composed of fire-resistant (western larch, Douglas-fir) and fire-intolerant (grand fir) trees.

Woodland/Steppe: Grass and shrub lands that may have oak woodlands or ≤ 10% conifer cover.

Forest structure

Large tree: Overstory diameter > 20 inches.

Medium tree: Overstory diameter 10-20 inches.

Small tree: Overstory diameter < 10 inches.

Dense canopy: Greater than 40% tree canopy.

Open canopy: Less than 40% tree canopy.

Fuels: Shrubs, grasses, small trees, litter, duff, and dead wood.

Fuels treatments: some combination of mechanical density reduction (commercial or non-commercial) and surface and ladder fuel reduction (prescribed fire, piling & burning, etc.).

Managed wildfire: fire is allowed to burn under safe conditions to achieve management goals but can be suppressed if conditions change.

Wildfire Response Benefit Prioritization

Dual benefits for forest health and wildfire response

It is necessary to conduct treatments to both improve forest health and reduce fire risk to communities as well as provide conditions where firefighters can safely and efficiently conduct fire operations (e.g. suppression, prescribed burning, and managed wildfire). The wildfire response benefit metric (WRB; Fig. 10) identifies and prioritizes locations where values at risk that are more likely to be the focus of fire operations (homes, infrastructure, sources of drinking water, and commercially managed lands) coincide with areas likely to transmit wildfire to homes and generate severe fire behavior. Because there are positive feedbacks between healthy, resilient forests and safe, effective fire operations, the WRB metric also integrates the landscape treatment priority map (Fig. 9).

Where WRB is highest, actions may be needed to create and maintain conditions that provide a tactical advantage for fire operations. These actions will vary with the local context and can include landscape-level forest health and fuel treatments, treatments along fire control lines and escape routes, resident and community fire mitigation activities (e.g. defensible space, home hardening), and improving signage and road conditions. The WRB metric provides a high-level prioritization, and additional work at the local level is required to identify appropriate actions and assess their feasibility. WRB is useful for prioritizing Potential Control Lines (PCLs) for fire operations (Fig. 11). PCLs are a part of Potential Operational Delineations (PODs); see page 7.

In the Chelan planning area, wildfire response benefit is highest on the slopes northeast of Lake Chelan (Fig. 10) due to the high fire risk to homes and infrastructure as well as high transmission to housing units (Fig. 8). Wildfire response benefit is moderate to high in northeastern portions due to a combination of moderate to high landscape treatment priority and high crown fire potential, particularly in the northern end of the planning area.

Definitions (continued)

Wildfire response benefit: Any tactical advantage gained for wildfire response activities from actions on the landscape, including, but not restricted to, identifying and consolidating existing anchor points and control lines and reduction of potential fire behavior. Wildfire response benefit is not restricted to any specific wildfire management strategy and instead is centered on conditions that improve fire operations safety and effectiveness.

Potential Control Lines (PCLs): Boundaries of Potential Operational Delineations (PODs) relevant to fire control operations (e.g. roads, ridgetops, and water bodies).

Potential Operational Delineations (PODs) for wildland fire: Landscape containers whose boundaries are potential control lines (PCLs). PODs are useful for planning strategic response to unplanned ignitions, strategic fuel planning, and prioritizing fuel treatments within PODs.

Commercially managed lands: Commercially managed forestlands include: DNR Trustlands, Tribal forests, industrial forests, non-industrial private forests, and US Forest Service forests where timber is a primary management objective.

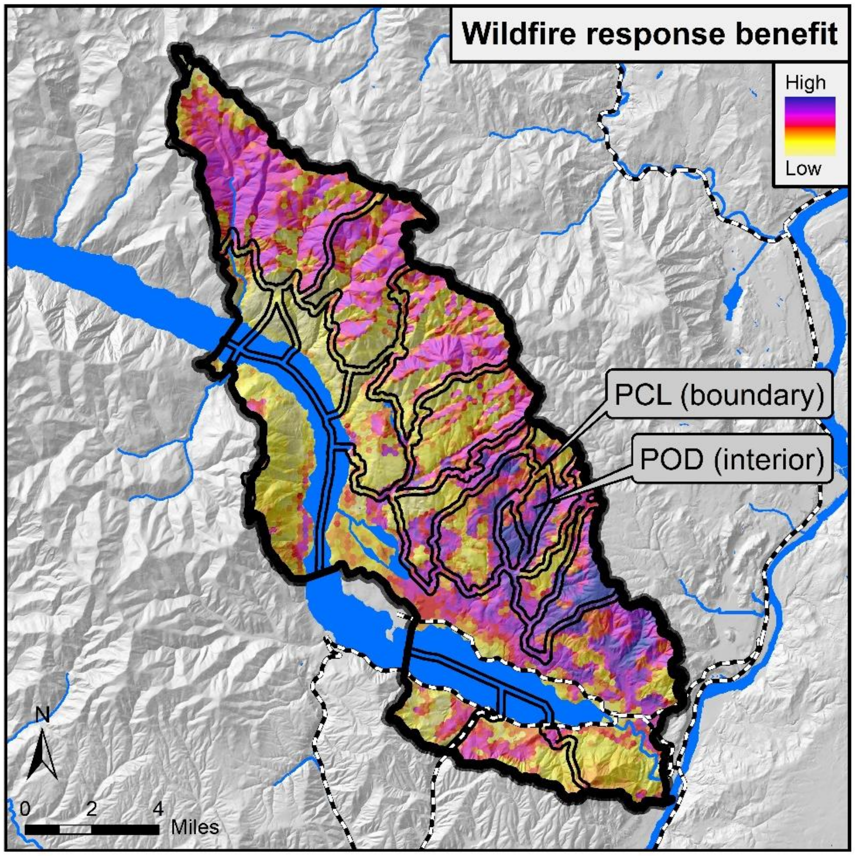


Figure 10. Wildfire response benefit (WRB) integrates multiple fire risk and forest health components. It includes four fire risk metrics representing highly valued resources – risk to homes, infrastructure, drinking water, commercially managed lands – as well as crown fire potential and wildfire transmission to homes (Fig. 8). Combined, these account for 75% of the wildfire response benefit. Landscape treatment priority (Fig. 9) accounts for the remaining 25%. Also shown are PODs: units bounded by PCLs (open black lines). One use of the WRB metric is to prioritize Potential Control Lines (PCLs) for fire operations (Fig. 11).

Prioritizing Landscape Treatments for Dual Benefits

Integration of forest health and wildfire response benefit using PODs

Potential Operational Delineations (PODs) provide a powerful spatial framework to communicate and identify locations that will deliver dual benefits for forest health and wildfire response at the landscape scale. PODs are large landscape areas delimited by Potential Control Lines (PCLs) for fire operations (suppression, prescribed fire, and managed wildfire), delineated by fire operations personnel. PCLs can be roads, ridgelines, or any artificial or natural fuelbreak that provides a strategic opportunity for fire operations. Summarizing landscape treatment priorities (Fig. 9) within PODs and wildfire response benefit priorities (Fig. 10) within PCLs enables planners and managers to identify, at a high level, locations where forest health or fuels treatments can be connected to a high-priority PCL that will support firefighter operations (e.g. ingress/egress route or opportunity for engagement).

Achieving forest health and wildfire response goals will require primarily large, landscape-level treatments across PODs (~100's-1,000's of acres) and, to a lesser extent, targeted treatments along PCLs.

There is important work to do in all Chelan PODs to achieve the forest health treatment targets in Table 1. First priority PODs correspond to areas with moderate to high landscape treatment priority (Fig. 9) in northern portions of the planning area (Fig. 11). Other first priority PODs are located in eastern portions on upper slopes. The easternmost first priority PODs are associated with first priority PCLs, enhancing opportunities for dual benefit treatments. Further work is needed to assess PCLs locally for their condition and detailed treatment needs, which will depend on management goals and values at risk. Ideally, landscape treatments will be implemented adjacent to priority PCLs where feasible to maximize both forest health and wildfire response goals.

Achieving forest health and wildfire response dual benefits will require primarily large, landscape-level treatments across PODs (~100's-1,000's of acres) and, to a lesser extent, targeted treatments along PCLs. These two approaches combined will contribute to restoring and maintaining large portions of the landscape in a resilient condition while providing safe and effective areas for firefighter engagement during suppression, prescribed fire, or managed wildfire operations.

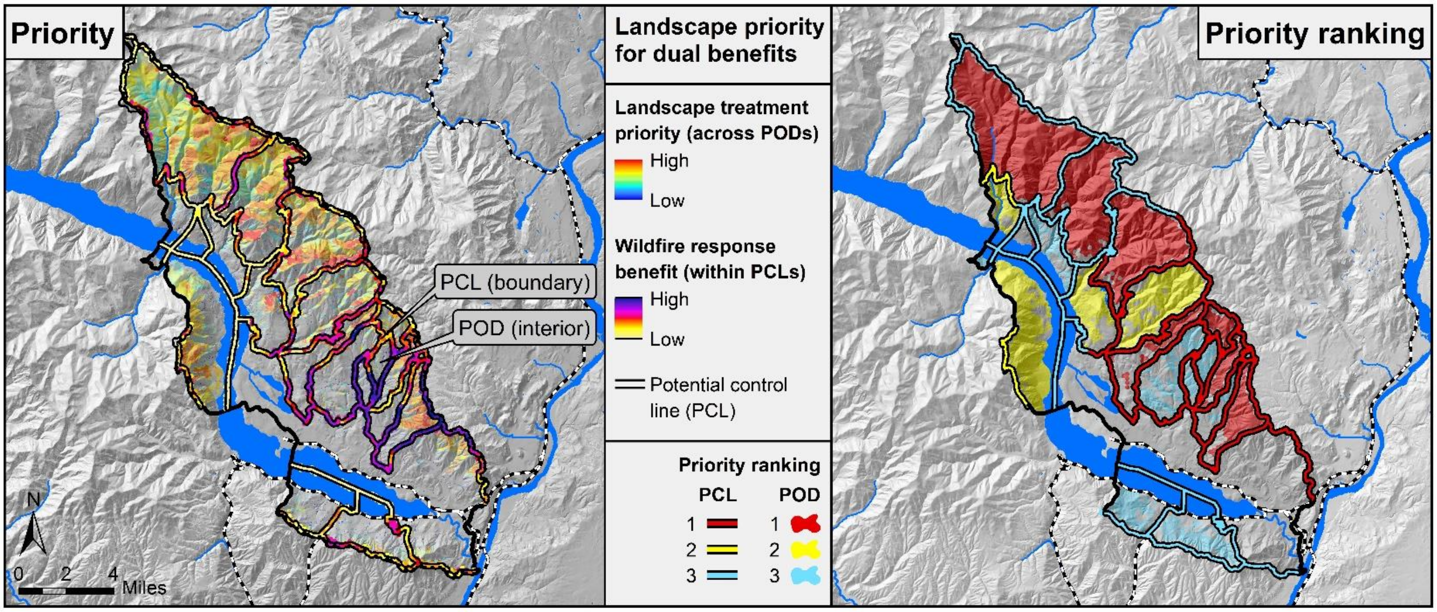


Figure 11. Landscape prioritization of dual benefits using PODs as a spatial framework to summarize treatment priorities. Both maps display landscape treatment priority within PODs and wildfire response benefit within PCLs. The map on the left shows the datasets at the raster level, while the map on the right shows the same information summarized and ranked within PODs and PCLs. PCL width is inflated to display spatial patterns. *PODs shown here are part of an ongoing process towards an all-lands delineation; POD boundaries are subject to change following on-the-ground vetting and continued dialogue among wildfire agencies and stakeholders.*

DEER PARK PLANNING AREA
LANDSCAPE EVALUATION SUMMARY (2022)

Total Acres	Forested Acres	Treatment Goal (Acres)
181,171	90,497	36,000 - 49,000

Figure 1. Planning area location in eastern WA.

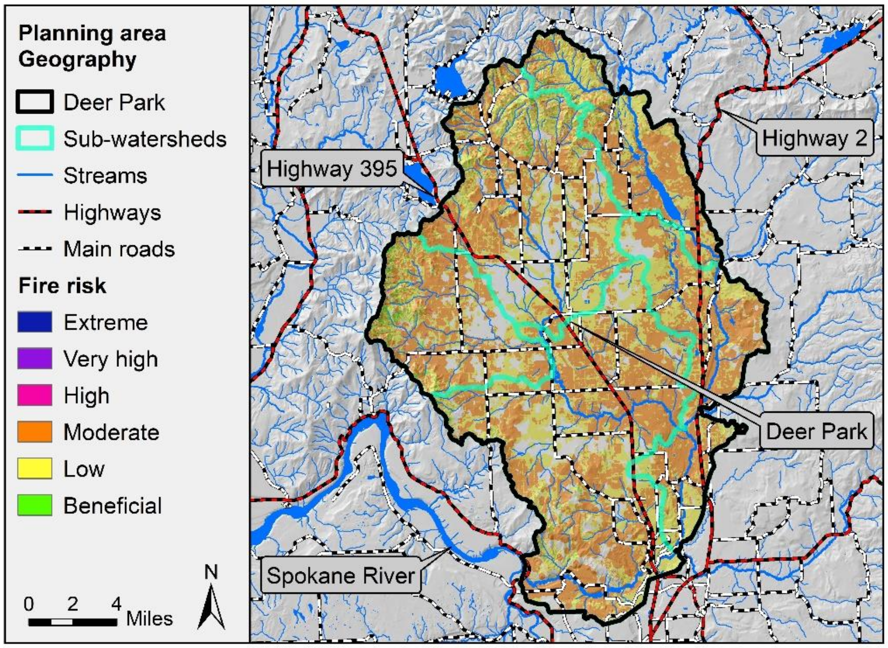


Figure 2. Planning area geography and fire risk, which integrates burn probability, fire intensity, and fire susceptibility of forests, infrastructure, and homes.

Planning Area Highlights

- Ownership is primarily private non-industrial (90%), with the remainder split between industrial forestland, municipal, DNR, and the Washington Department of Fish and Wildlife.
- Only half of the planning area is forested. The other half is mostly agricultural land with some subdivisions in the south.
- Fire risk is highest in the extensive areas of wildland-urban interface throughout the planning area. Fuel loads are high in the forested blocks in northern portions and along the eastern and western boundaries.
- Areas that currently support dry forest, which make up the most the planning area, are projected to become hotter and drier but still be able to support forest in most places. Moist forest sites are projected to be very rare.
- Mechanical and prescribed fire treatments are recommended on 40-54% of forested acres to reduce fire risk to homes, other structures, infrastructure, and forested areas.
- High priority areas for potential treatments that maximize forest health and wildfire response benefit occur throughout the planning area and are concentrated near the western and northern boundaries.

LEARN MORE

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For more details about DNR's priority planning areas please see: **https://www.dnr.wa.gov/ForestHealthPlan**
For data products and methods see: **https://bit.ly/ForestHealthData**

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Overarching Goals

Reduce wildfire risk and protect communities

Fire risk is moderate across most of the planning area (Fig. 2) due to low burn probability. Fire starts have been common, but fire suppression has been highly effective in recent decades. If multiple fires start during a period of hot, dry weather and overwhelm suppression resources, risk is high for private property in the extensive wildland-urban interface areas. High-density housing exists in the south, and most of the planning area is a patchwork of agricultural land and forest with generally low to moderate fuel loading. In addition, larger patches of dense forest in the northern portion and along the eastern and western boundaries have high predicted tree mortality. Without treatments, fire risk is predicted to rise as burn probability increases with projected climate warming. Treatments that integrate risk reduction for communities and forests will reduce the potential for large, destructive fires and increase firefighter safety. This should include treatments around homes and establishing potential control lines.

Increase resilience and prepare for climate change

By mid-century, almost all of planning area is projected to have moisture stress levels that are currently associated with dry forest (Fig. 3). Most areas that currently support dry forest should still be able to support forest, but will likely not be able to support current tree densities due to higher drought stress. The far southern area may transition towards woodland or non-forest over time. Treatments that reduce density and favor drought-tolerant species will the enhance resilience and persistence of forests into the future.

Sustain wildlife habitat

Habitat for dry forest, large tree, open canopy species (e.g. White Headed Woodpecker) is moderately abundant and well distributed in the eastern and northern portions. Patch sizes are generally small, although some moderate patches are present. Treatments that decrease crown fire potential and drought vulnerability by reducing tree density and creating variable spatial patterns will expand this habitat type, especially where larger ponderosa pine exist or will develop over time. Habitat for species that depend on moist, closed canopy forest with large trees (e.g. Northern Goshawk) is low in abundance, and patch sizes are generally small. Given climate change projections and the need to reduce fire risk, maintaining and expanding this habitat type will be limited, although opportunities exist on some north-facing slopes. Habitat for cold forest, large-tree, closed canopy species (e.g. American Marten) is very limited due to the low elevation of this planning area. Habitat layers are available in the data products.

Enhance rural economic development

Almost all of the planning area has road access, and most of the areas needing treatment will likely support commercial treatments. Meeting treatment needs will produce a large amount of forest products and related economic activity. Although warming trends will require managing for more drought-tolerant species and lower densities and fuel loads on relatively dry sites, long-term timber production should be possible in the northern half of the planning area in the relatively larger blocks of forest.

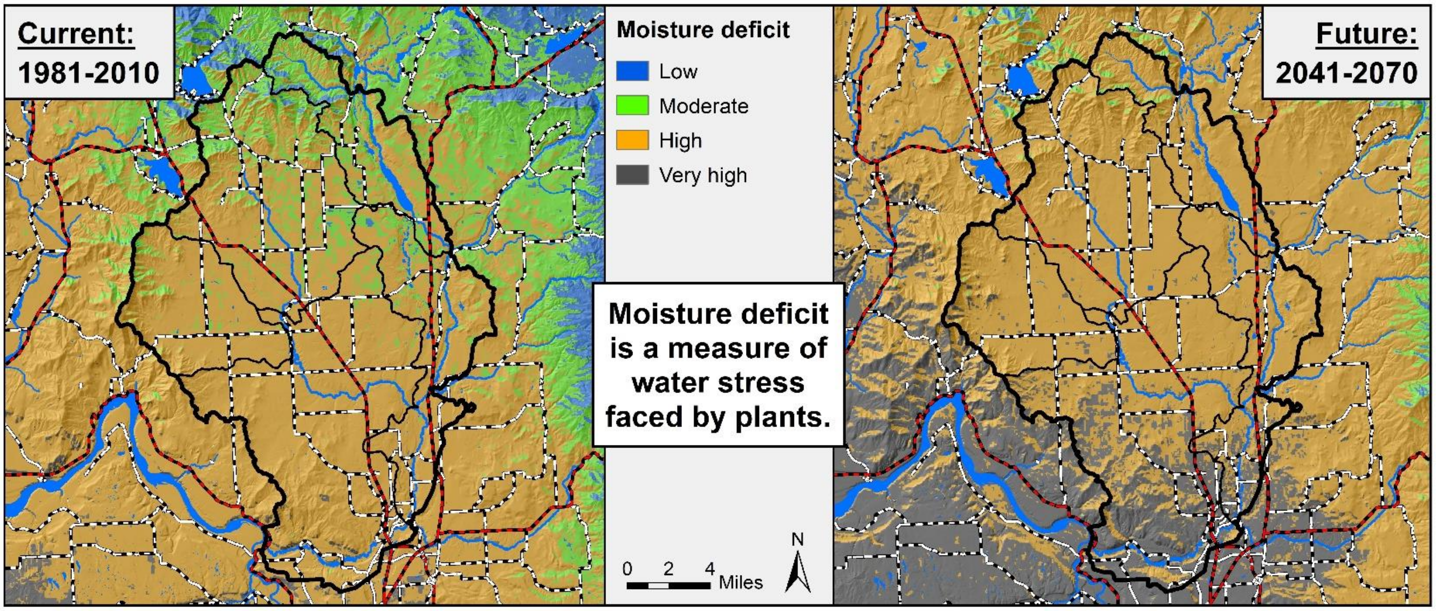


Figure 3. Current (left) and future (right) moisture stress levels based on water balance deficit. Low levels are associated with moist and cold forest types, high with dry forest types, and very high with woodland or shrub-steppe. Future climate is based on a relatively high greenhouse gas emissions scenario (RCP 8.5).

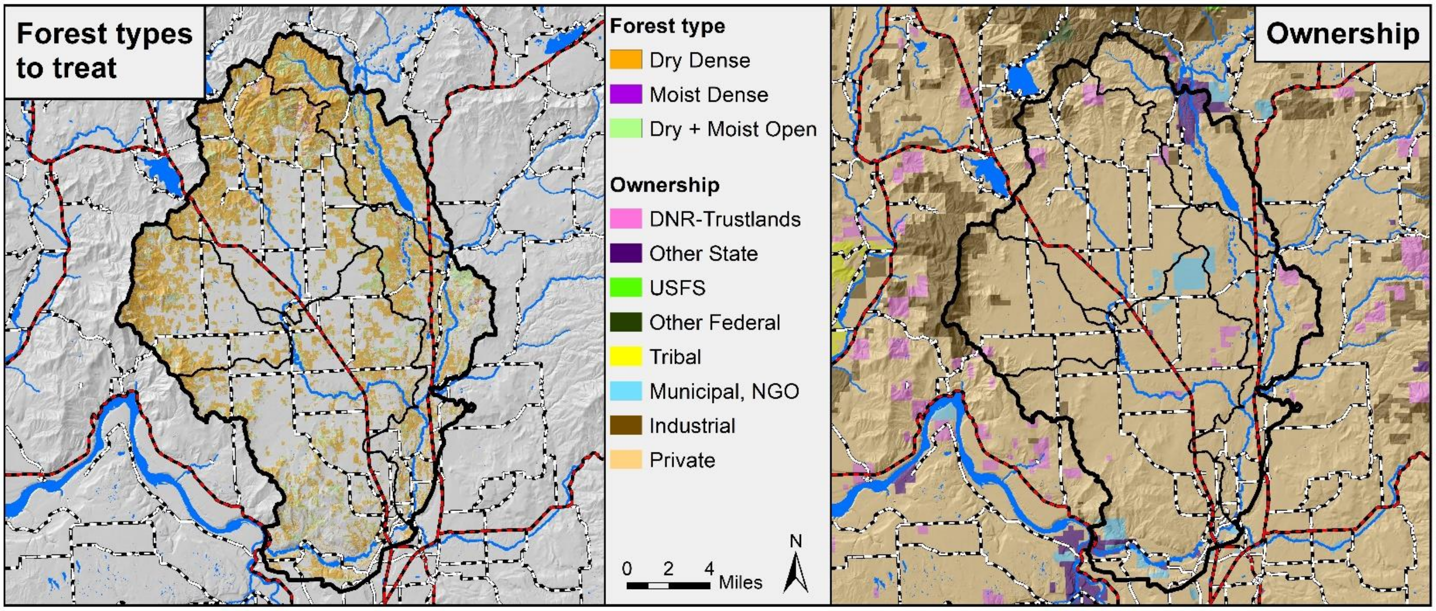
Forest Health Treatment Needs

Treating 36,000 to 49,000 acres is recommended to move the landscape into a resilient condition (40-54% of forested acres; Table 1). This total includes an estimated 28,500-38,000 acres to shift dense to open forest and 7,500-11,000 acres of maintenance treatments in existing open forest (Fig. 4), based on current condition data from 2019 LiDAR imagery. The majority of treatment need is located on private land, but opportunities exist on other ownerships as well. Meeting this target range will require multiple treatment types (Table 1).

Most treatments are likely commercially viable based on tree size, but the small size of ownerships will increase costs in many places. Treatments around homes and in the wildland-urban interface may often be non-commercial. Treatment type will depend on road access, logging systems, markets, and other considerations. Individual landowners will conduct their own planning and decision-making processes to determine acres and types of treatments to achieve the landscape goals while meeting their own objectives and regulatory requirements.

Table 1. Summary of forest health treatment needs. ***See methods for details on how the treatment need range is derived.***

Forest conditions to treat		Treatment need (acres)	Current acres by major landowner*				
Type	Size class		Private	Industrial	City-County	DNR-Trustland	WDFW
Dry Dense	Small	1,500 - 2,500	3,334	437	61	47	30
	Medium-Large	27,000 - 35,000	47,667	3,206	1,341	1,024	938
Moist + Cold Dense	Medium-Large	0 - 500	650	32	5	32	16
Dry + Moist Open	Medium-Large	7,500 - 11,000	12,737	617	568	1,005	568
Total		**36,000 - 49,000**	**These are current acres, not targets*				
Anticipated treatment type	⬜	Noncommercial thin plus fuels treatment. May be fire only (prescribed or managed wildfire).					
	🟦	Commercial thin plus fuels treatment if access exists. May be noncommercial, fire only (prescribed or managed wildfire), or regeneration treatment.					
	🟩	Maintenance treatment: prescribed fire, mechanical fuels treatment, or managed wildfire. *Target range corresponds to 50-75% of dry open and 25-50% of moist open forests.*					



Left: Figure 4. Forest structure types that are overabundant relative to targets for a resilient landscape, as well as potential maintenance treatments. Only a portion of the areas shown need to be treated. Right: Figure 5. Current land ownership.

Forest Health Treatment Needs (continued)

Dry dense forest treatment need

Currently, dense forest structure of all size classes is over-represented on dry sites. Although some large patches are present in the northern and western areas (Fig 4), most forest areas are a mix of small to medium patches of open (<40% cover), moderately closed (40-60% cover), and closed-canopy (>60% cover) forest. Much of the dry forest is also dominated by Douglas-fir. These forests are vulnerable to uncharacteristic levels of high- and mixed-severity fire, as well as a combination of drought stress, root disease, and Douglas-fir beetle. Treating 28,500-37,500 acres of dry dense forest (Table 1) is recommended to create larger patches (~100-1000 ac) of open forest and shift the majority of dry sites to open forest (Fig. 6). As trees grow, the amount open forest with large trees will increase from its current low levels, although the location and extent of this will depend on landowner objectives. Shifting composition toward ponderosa pine is also needed. In places where these species are poorly represented, planting may be needed after gap creation, variable retention harvests, or high-severity fire.

Moist dense forest treatment need

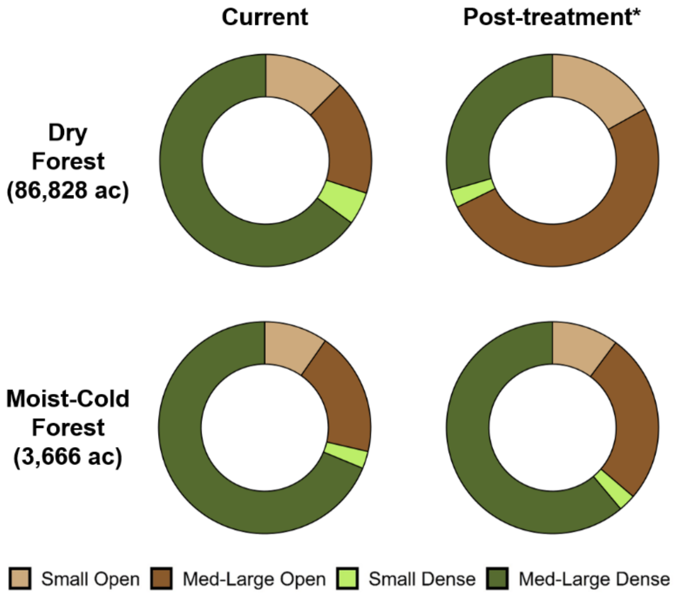
Moist forest occupies only 4% of the total forested area. Within this small area, dense, medium tree forest exceeds desired ranges. Patch sizes are small to moderate but are often connected with dense patches of dry forest patches. Large tree, open and dense forest is below desired ranges. Treating 0-500 acres of this type (Fig. 4) is recommended, especially in larger patches that are connected with dense, dry forest patches. Increasing the relative composition of western larch and ponderosa pine while decreasing grand fir and other fire-intolerant species is also needed, especially on sites projected to shift to dry forest (Fig. 3).

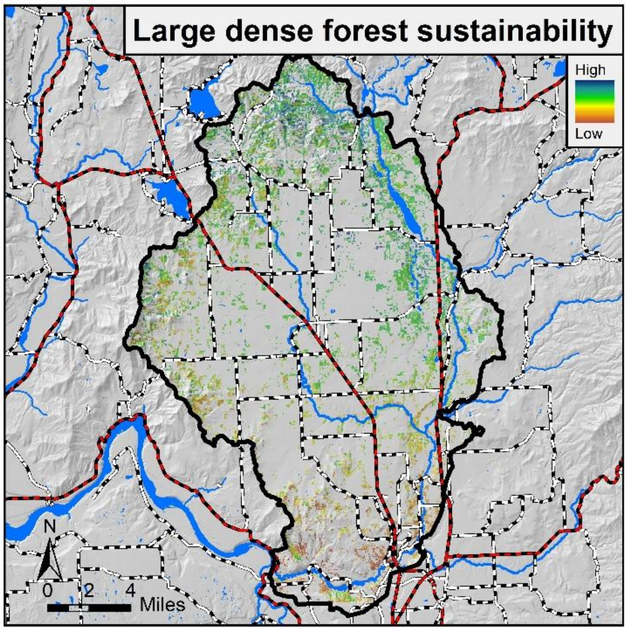
Open forest maintenance treatment need

Over the next 15 years, an estimated 7,500-11,000 acres of currently open forests on dry and moist sites will need prescribed fire or mechanical methods to maintain open conditions by reducing surface fuels and small trees. These sites include recently treated areas and forested areas that are more open due to poor soils where fire is currently predicted to have beneficial effects (Fig. 2). Specific maintenance strategies will depend on landowner objectives and time since treatment.

Sustainable locations for dense forest with large trees

Due to the current prevalence of dry forests and climate projections, sustainable locations to maintain and expand large tree, dense forest are limited in this planning area. However, sustainable locations do exist in northern, more mountainous areas on north-facing slopes, including around and south of Eloika Lake in the northeast portion (Fig. 7). This sustainability map can be used in conjunction with treatment priority (Fig. 9) to select areas to shift to open forest vs. where to maintain and increase large tree, closed canopy patches.





Left: Figure 6. Current and post-treatment proportions of forest types and structure classes. * mid-point of range in Table 1.
Right: Figure 7. Sustainability of current and potential large tree, dense forest based on fire risk and drought vulnerability.

Landscape Treatment Prioritization

Prioritizing for forest health & to reduce fire exposure of homes

Landscape treatment priority integrates three metrics of forest health – forest fire risk (Fig. 2), drought vulnerability (Fig. 3), and presence of overabundant forest structure types (Fig. 4) – with wildfire transmission to homes (Fig. 8). We also recommend incorporating the large dense forest sustainability layer (Fig. 7) as an overlay when selecting treatment locations. Wildfire transmission is moderate to high along the western boundary, indicating that wildfires starting in these locations are expected to expose homes within and adjacent the planning area (Fig. 2).

Treatment priorities

Landscape treatment priority is highest near the western boundary from the central to northern areas on private and some industrial forest land (Fig. 5, Fig. 9). These high priority areas indicate high drought vulnerability, fire transmission to homes, and departed structure types. Moderate priority areas exist in the south and northeast. Some low priority areas may need treatment to address species composition, insect and disease risk, or other issues. In addition, fuel reduction treatments, defensible space, and home hardening are needed on private parcels with homes or other structures throughout the planning area.

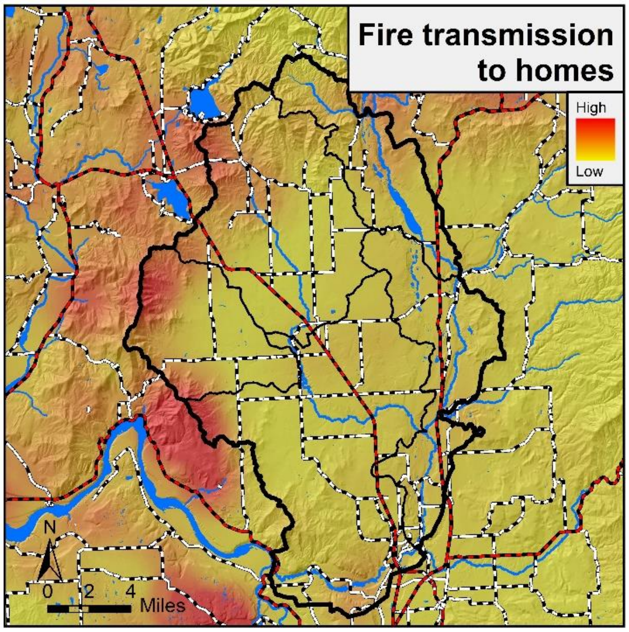


Figure 8. Fire transmission to homes shows where fires that expose structures are most likely to originate. It is based on simulated fire perimeters given contemporary patterns of fuels, topography, and wind.

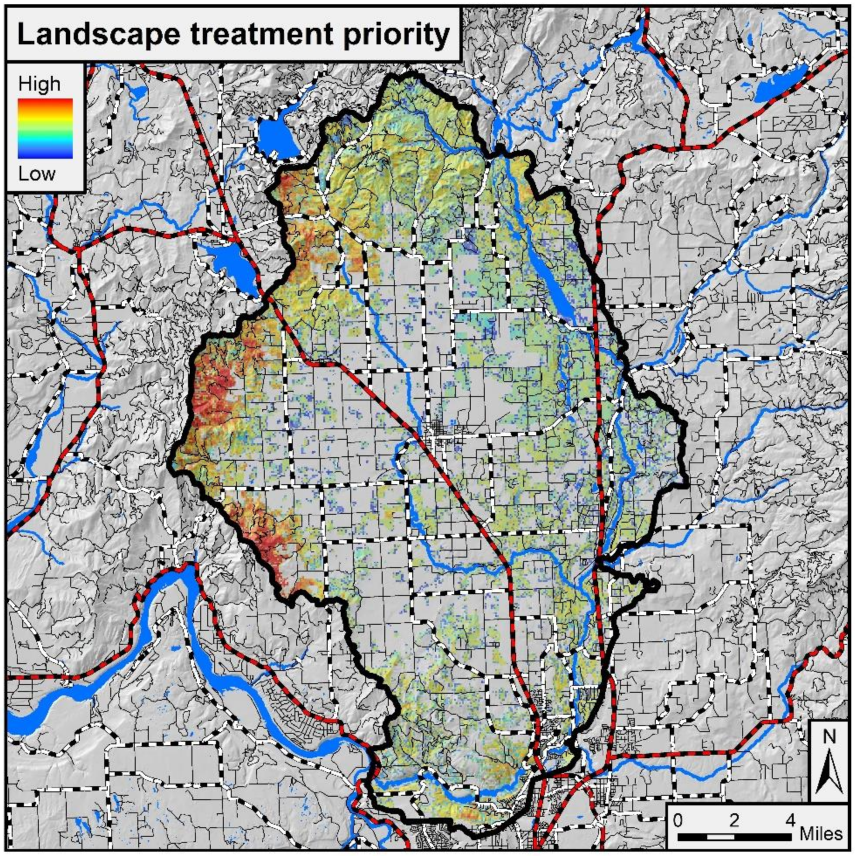


Figure 9. Landscape treatment priority is based on three metrics of forest health – forest fire risk (Fig. 1), drought vulnerability (Fig. 3), overabundant forest structure (Fig. 4) – as well as wildfire transmission to homes (Fig. 8).

Definitions

Vegetation Types

Cold forest: Upper elevation mixed-conifer forests with high-severity fires every 80-200+ years.

Dry forest: Ponderosa pine and Douglas-fir dominated forests that historically had surface fires every 5-25 years.

Moist forest: Forests that historically had mixed-severity fires every 30-100 years and were composed of fire-resistant (western larch, Douglas-fir) and fire-intolerant (grand fir) trees.

Woodland/Steppe: Grass and shrub lands that may have oak woodlands or ≤ 10% conifer cover.

Forest structure

Large tree: Overstory diameter > 20 inches.

Medium tree: Overstory diameter 10-20 inches.

Small tree: Overstory diameter < 10 inches.

Dense canopy: Greater than 40% tree canopy.

Open canopy: Less than 40% tree canopy.

Fuels: Shrubs, grasses, small trees, litter, duff, and dead wood.

Fuels treatments: some combination of mechanical density reduction (commercial or non-commercial) and surface and ladder fuel reduction (prescribed fire, piling & burning, etc.).

Managed wildfire: fire is allowed to burn under safe conditions to achieve management goals but can be suppressed if conditions change.

Wildfire Response Benefit Prioritization

Dual benefits for forest health and wildfire response

It is necessary to conduct treatments to both improve forest health and reduce fire risk to communities as well as provide conditions where firefighters can safely and efficiently conduct fire operations (e.g. suppression, prescribed burning, and managed wildfire). The wildfire response benefit metric (WRB; Fig. 10) identifies and prioritizes locations where values at risk that are more likely to be the focus of fire operations (homes, infrastructure, sources of drinking water, and commercially managed lands) coincide with areas likely to transmit wildfire to homes and generate severe fire behavior. Because there are positive feedbacks between healthy, resilient forests and safe, effective fire operations, the WRB metric also integrates the landscape treatment priority map (Fig. 9).

Where WRB is highest, actions may be needed to create and maintain conditions that provide a tactical advantage for fire operations. These actions will vary with the local context and can include landscape-level forest health and fuel treatments, treatments along fire control lines and escape routes, resident and community fire mitigation activities (e.g. defensible space, home hardening), and improving signage and road conditions. The WRB metric provides a high-level prioritization, and additional work at the local level is required to identify appropriate actions and assess their feasibility. WRB is useful for prioritizing Potential Control Lines (PCLs) for fire operations (Fig. 11). PCLs are a part of Potential Operational Delineations (PODs); see page 7.

In the Deer Park planning area, wildfire response benefit is highest along western portions between Highway 395 and the Spokane River (Fig. 2) due to high wildfire transmission to homes, crown fire potential, and landscape treatment priority (Fig. 9). Pockets of relatively high wildfire response benefit also occur around the forested perimeter of the planning area. Crown fire potential is high in locations with dense, multi-layered forest structure.

Definitions (continued)

Wildfire response benefit: Any tactical advantage gained for wildfire response activities from actions on the landscape, including, but not restricted to, identifying and consolidating existing anchor points and control lines and reduction of potential fire behavior. Wildfire response benefit is not restricted to any specific wildfire management strategy and instead is centered on conditions that improve fire operations safety and effectiveness.

Potential Control Lines (PCLs): Boundaries of Potential Operational Delineations (PODs) relevant to fire control operations (e.g. roads, ridgetops, and water bodies).

Potential Operational Delineations (PODs) for wildland fire: Landscape containers whose boundaries are potential control lines (PCLs). PODs are useful for planning strategic response to unplanned ignitions, strategic fuel planning, and prioritizing fuel treatments within PODs.

Commercially managed lands: Commercially managed forestlands include: DNR Trustlands, Tribal forests, industrial forests, non-industrial private forests, and US Forest Service forests where timber is a primary management objective.

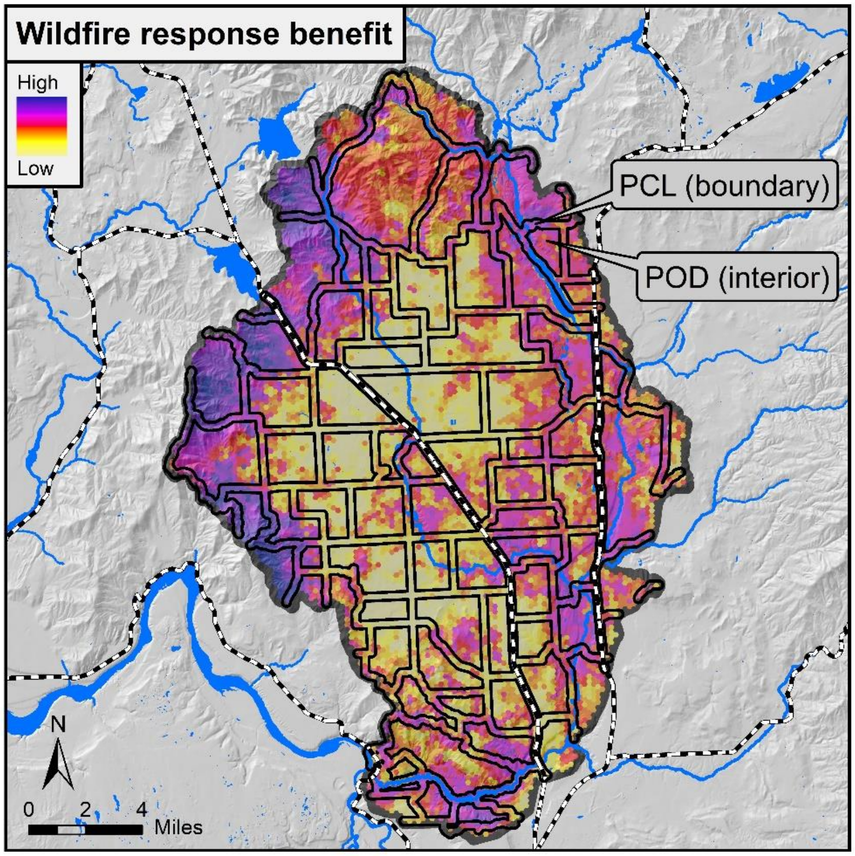


Figure 10. Wildfire response benefit (WRB) integrates multiple fire risk and forest health components. It includes four fire risk metrics representing highly valued resources – risk to homes, infrastructure, drinking water, commercially managed lands – as well as crown fire potential and wildfire transmission to homes (Fig. 8). Combined, these account for 75% of the wildfire response benefit. Landscape treatment priority (Fig. 9) accounts for the remaining 25%. Also shown are PODs: units bounded by PCLs (open black lines). One use of the WRB metric is to prioritize Potential Control Lines (PCLs) for fire operations (Fig. 11).

Prioritizing Landscape Treatments for Dual Benefits

Integration of forest health and wildfire response benefit using PODs

Potential Operational Delineations (PODs) provide a powerful spatial framework to communicate and identify locations that will deliver dual benefits for forest health and wildfire response at the landscape scale. PODs are large landscape areas delimited by Potential Control Lines (PCLs) for fire operations (suppression, prescribed fire, and managed wildfire), delineated by fire operations personnel. PCLs can be roads, ridgelines, or any artificial or natural fuelbreak that provides a strategic opportunity for fire operations. Summarizing landscape treatment priorities (Fig. 9) within PODs and wildfire response benefit priorities (Fig. 10) within PCLs enables planners and managers to identify, at a high level, locations where forest health or fuels treatments can be connected to a high-priority PCL that will support firefighter operations (e.g. ingress/egress route or opportunity for engagement).

Achieving forest health and wildfire response goals will require primarily large, landscape-level treatments across PODs (~100’s-1,000’s of acres) and, to a lesser extent, targeted treatments along PCLs.

There is important work to do in all Deer Park PODs to achieve the forest health treatment targets in Table 1. First and second priority PODs correspond to areas with moderate and high landscape treatment priority (Fig. 9) around the forested perimeter of the planning area (Fig. 11). Most of the first priority PODs are associated with first priority PCLs, particularly in western portions of the planning area, enhancing opportunities for dual benefit treatments. Additional first priority PCLs occur in the southern end near the Spokane River. Further work is needed to assess PCLs locally for their condition and detailed treatment needs, which will depend on management goals and values at risk. Ideally, landscape treatments will be implemented adjacent to priority PCLs where feasible to maximize both forest health and wildfire response goals.

Achieving forest health and wildfire response dual benefits will require primarily large, landscape-level treatments across PODs (~100’s-1,000’s of acres) and, to a lesser extent, targeted treatments along PCLs. These two approaches combined will contribute to restoring and maintaining large portions of the landscape in a resilient condition while providing safe and effective areas for firefighter engagement during suppression, prescribed fire, or managed wildfire operations.

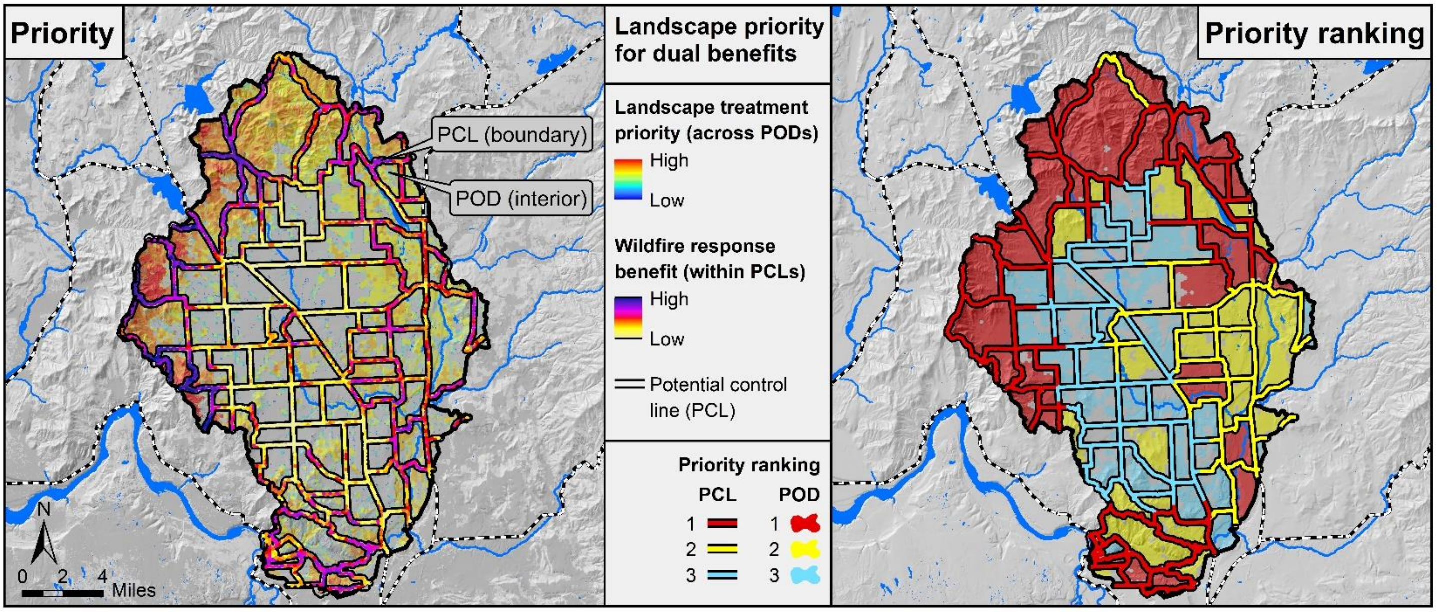


Figure 11. Landscape prioritization of dual benefits using PODs as a spatial framework to summarize treatment priorities. Both maps display landscape treatment priority within PODs and wildfire response benefit within PCLs. The map on the left shows the datasets at the raster level, while the map on the right shows the same information summarized and ranked within PODs and PCLs. PCL width is inflated to display spatial patterns. *PODs shown here are part of an ongoing process towards an all-lands delineation; POD boundaries are subject to change following on-the-ground vetting and continued dialogue among wildfire agencies and stakeholders.*

DOLLAR PLANNING AREA LANDSCAPE EVALUATION SUMMARY (2022)

Total Acres	Forested Acres	Treatment Goal (Acres)
61,328	50,767	18,600 - 27,700

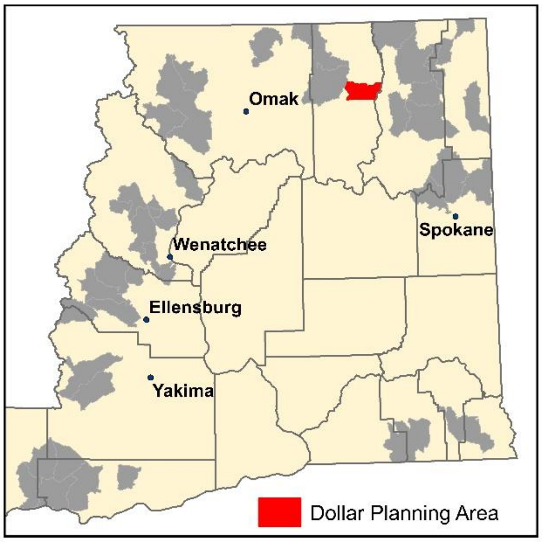


Figure 1. Planning area location in eastern WA.

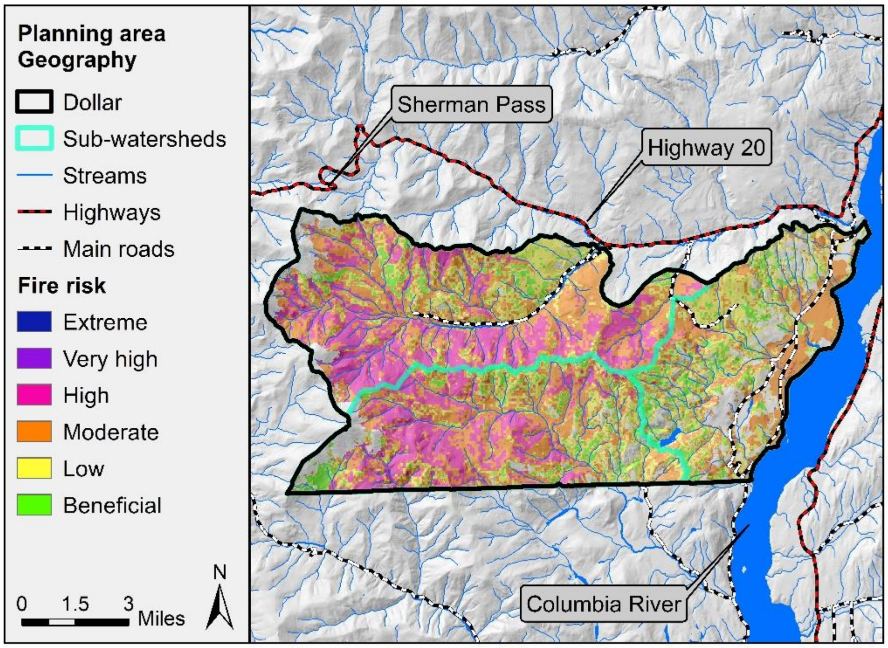


Figure 2. Planning area geography and fire risk, which integrates burn probability, fire intensity, and fire susceptibility of forests, infrastructure, and homes.

Planning Area Highlights

- Ownership is primarily Colville National Forest (84%), including 21,500 acres (42%) located in inventoried roadless area. Small private owners (13%) occupy the far eastern portion. Various other landowners occupy the remaining area (3%).
- Treating 37-55% of forested acres is recommended to increase resilience and reduce fire risk to communities using a combination of mechanical, prescribed fire, and managed wildfire treatments.
- Fire risk is highest in the western half of the planning area, especially on north-facing slopes with high fuel loads. Burn probability is low to moderate, but is increasing due to warmer and drier spring and summer conditions.
- Drought vulnerability is high on south-facing slopes with dense forest, as well as in the far eastern portion that is vulnerable to transitioning to non-forest due to climate change.
- High priority areas for potential treatments that maximize forest health and wildfire response benefit are concentrated in western and southern portions of the planning area.
- The Colville National Forest is planning a landscape restoration project in this area. The Environmental Assessment is planned for release in 2023.

LEARN MORE

This landscape evaluation was completed in 2022.
For more details about DNR's priority planning areas please see: **https://www.dnr.wa.gov/ForestHealthPlan**
For data products and methods see: **https://bit.ly/ForestHealthData**

CONTACT

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Overarching Goals

Reduce wildfire risk and protect communities

Fire risk is moderate to high across most of the western two thirds of the planning area due to high fuel loads, especially on north-facing slopes (Fig. 2). Rocky balds and small patches of low-density forest break up contiguous dense forest. In contrast, the eastern third of the area has low to moderate fire risk. Rocky balds and grassland dominate this portion, with small to medium patches of forest interspersed. Fire risk is moderate on private parcels with homes along the eastern edge (Fig. 2). Burn probability is low to moderate, increasing from east to west. Without treatments, fire risk is predicted to increase as burn probability continues to rise with climate warming. Landscape treatments will reduce the risk of large, high-severity fires. Over time, a restored landscape will facilitate use of managed wildfire, especially in the 21,500 acres of inventoried roadless area. Implementing treatments around homes and establishing potential control lines will increase firefighter safety and help protect communities.

Increase resilience and prepare for climate change

By mid-century, the majority of the planning area is projected to have moisture stress levels that are currently associated with dry forest (Fig. 3). Drought vulnerability is high on south-facing slopes that have dense forests. The far eastern portion is likely to transition to non-forest. North-facing slopes in the western two thirds will still likely be able to support moist and cold forest types. Treatments, as well as managed wildfires in less accessible areas, that reduce density and favor drought-tolerant species will enhance resilience into the future.

Sustain wildlife habitat

Habitat abundance is low for large tree, open canopy, dry forest species (e.g. White Headed Woodpecker), although moderately sized patches exist in the eastern third. Habitat abundance for species that require dry to moist, closed canopy forest with large trees (e.g. Northern Goshawk) is low to moderate, and patch sizes are generally small. Habitat for cold forest, large-tree, closed canopy species (e.g. American Marten) is abundant. As the planning area is dominated by large patches of medium-tree, dense forest (Fig. 4), existing patches of open canopy habitat can be expanded through treatments on south-facing slopes. Conversely, patches of closed-forest, large-tree habitat can be expanded on north-facing slopes, riparian draws, and other sustainable locations (Fig. 7). This will reduce crown fire potential and drought vulnerability across the landscape while expanding habitat in more sustainable locations over time. Sustaining habitat for Canada Lynx by reducing risk of large patches of high-severity fire is another consideration in this planning area. Habitat layers are available in the data products.

Enhance rural economic development

Meeting restoration treatment needs will produce a large amount of forest products and related economic activity. Although warming trends will necessitate managing for more drought-tolerant species and lower densities and fuel loads on current and future dry sites, long-term timber production should be possible in a significant portion of the area that has road access.

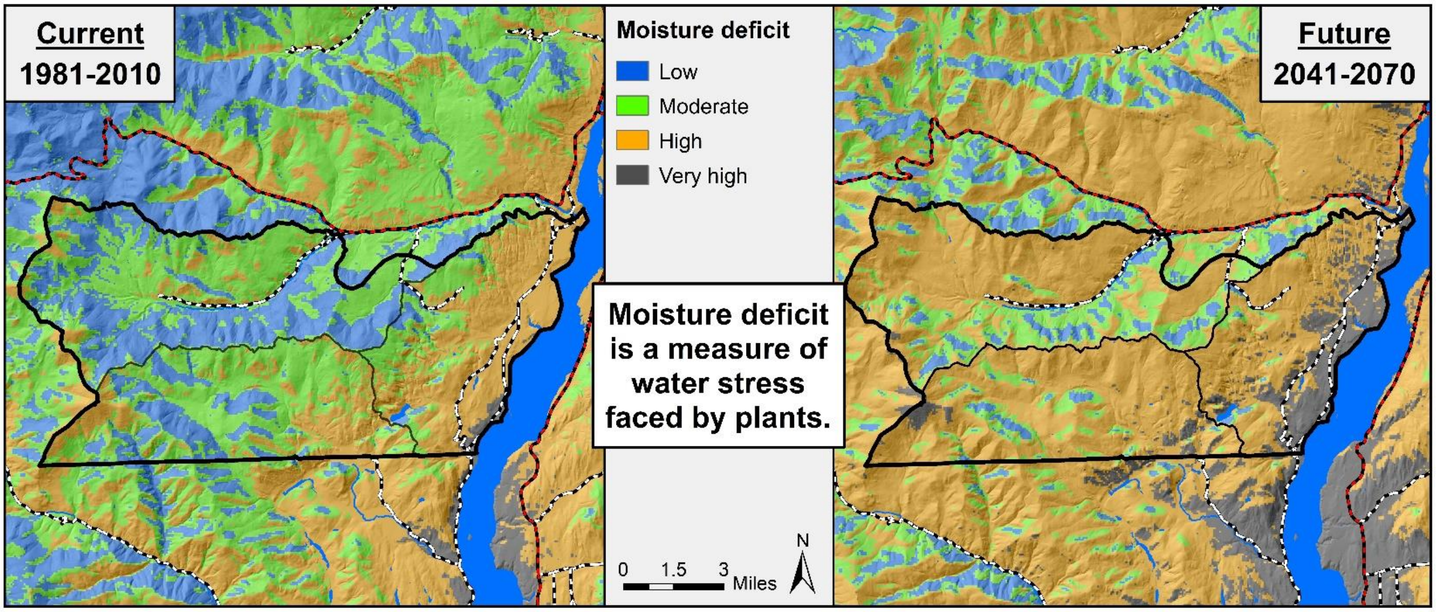


Figure 3. Current (left) and future (right) moisture stress levels based on water balance deficit. Low levels are associated with moist and cold forest types, high with dry forest types, and very high with woodland or shrub-steppe. Future climate is based on a relatively high greenhouse gas emissions scenario (RCP 8.5).

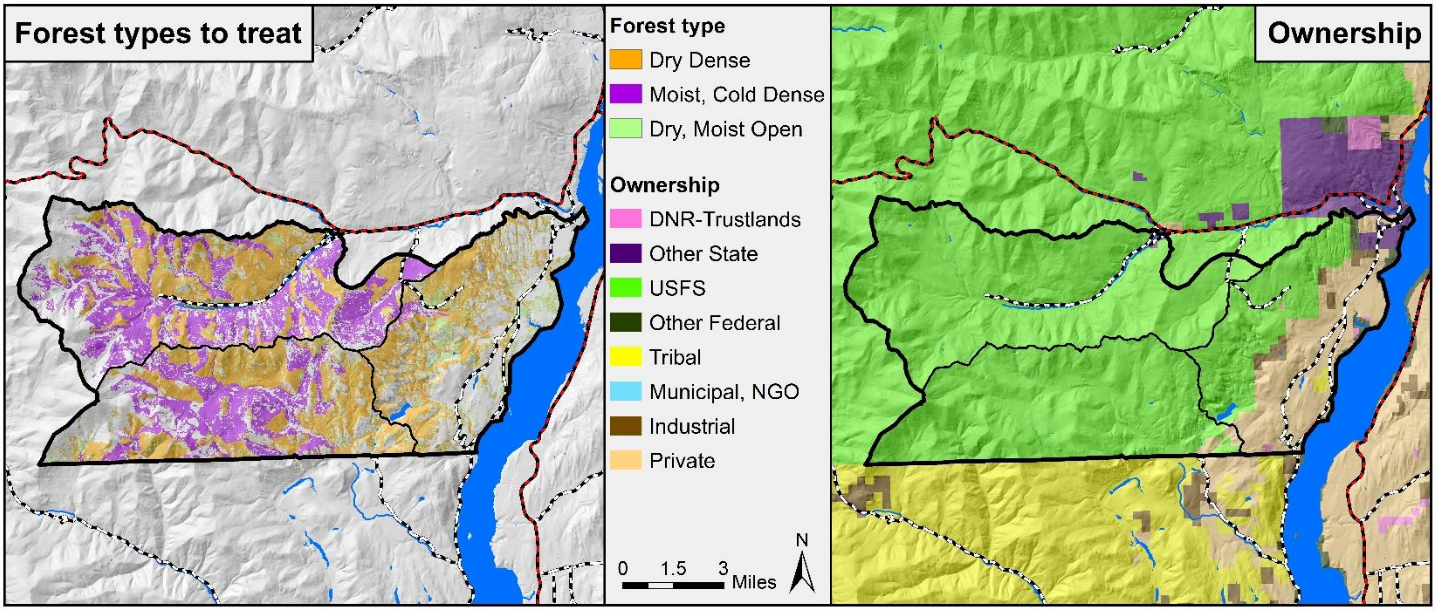
Forest Health Treatment Needs

Treating 18,600 to 27,700 acres is recommended to move the landscape into a resilient condition (37-55% of forested acres; Table 1). This total includes an estimated 16,000-24,000 acres to shift dense to open forest and 2,600-3,700 acres of maintenance treatments in existing open forest, based on current condition data from 2015 and 2008 LiDAR imagery. The great majority of treatment need is located on USFS land, and will be met to a significant degree by a project that is currently being planned by the Colville National Forest. Opportunities also exist on private land, the Sherman Creek State Wildlife Area, and the Lake Roosevelt National Recreation Area Wildlife Area.

Meeting this target range will require multiple treatment types (Table 1). Managed wildfire under safe conditions will be needed to meet treatment targets, especially in Inventoried Roadless Areas. Most treatments are commercially viable based on tree size. Treatment type will depend on road access, logging systems, markets, and other considerations. Individual landowners will conduct their own planning and decision-making processes to determine acres and types of treatments to achieve the landscape goals while meeting their own objectives and regulatory requirements.

Table 1. Summary of forest health treatment needs. ***See methods for details on how treatment need is derived.***

Forest conditions to treat		Treatment need (acres)	Current acres by major landowner*				
Type	**Size class**		**USFS**	**Private**	**WDFW**	**Other federal**	**Industrial**
Dry Dense	Medium-Large	11,000 - 16,000	17,516	1,912	123	146	180
Moist Dense	Medium-Large	5,000 - 8,000	15,379	3	34	0	0
Dry + Moist Open	Medium-Large	2,600 - 3,700	2,826	1,064	165	76	166
Total		**18,600 - 27,700**	*These are current acres, not targets				
Anticipated treatment type	🟦	Commercial thin plus fuels treatment if access exists. May be noncommercial, fire only (prescribed or managed wildfire), or regeneration treatment.					
	🟩	Maintenance treatment: prescribed fire, managed wildfire, or mechanical fuels treatment. *Target range corresponds to 50-75% of dry open and 25-50% of moist open forests.*					



Left: Figure 4. Forest structure types that are overabundant relative to targets for a resilient landscape, as well as potential maintenance treatments. Only a portion of the areas shown need to be treated. Right: Figure 5. Current land ownership.

Forest Health Treatment Needs (continued)

Dry dense forest treatment need

Medium tree, dense forest structure is very over-represented on dry sites. Patch sizes are large, although they are somewhat broken up by rocky balds, especially in the eastern third (Fig. 4). Large tree forest with >60% canopy cover is also over-represented. Much of the dry forest is also dominated by Douglas-fir. Given climate change projections (Fig. 3), these forests are vulnerable to drought stress and Douglas-fir beetle, as well as uncharacteristic levels of high- severity fire. Treating 11,000-16,000 acres of dry dense forest (Table 1) is recommended to create large patches (~100-1000 ac) of open forest and shift the majority of dry sites to open forest (Fig. 6). As the retained trees grow over time, much of the dry forest will shift to large tree, open forest, which is currently very low. Shifting composition toward ponderosa pine and western larch is also needed. In places where these species are poorly represented, planting may be needed after gap creation, variable retention harvests, or high-severity fire.

Moist and cold dense forest treatment need

Dense, medium tree forest on moist sites exceeds desired ranges for both moist and cold forests. Patch sizes are large, which increases the risk of large patches of high-severity fire. Open and moderate canopy cover (40-60%) forest with large trees is below desired ranges, as is small open and close forest. Treating 5,000-8,000 acres of moist and cold forest (Table 1, Fig. 4) is recommended to create a mosaic of open, moderate, and dense patches that will reduce risks of large crown fire and insect outbreaks.

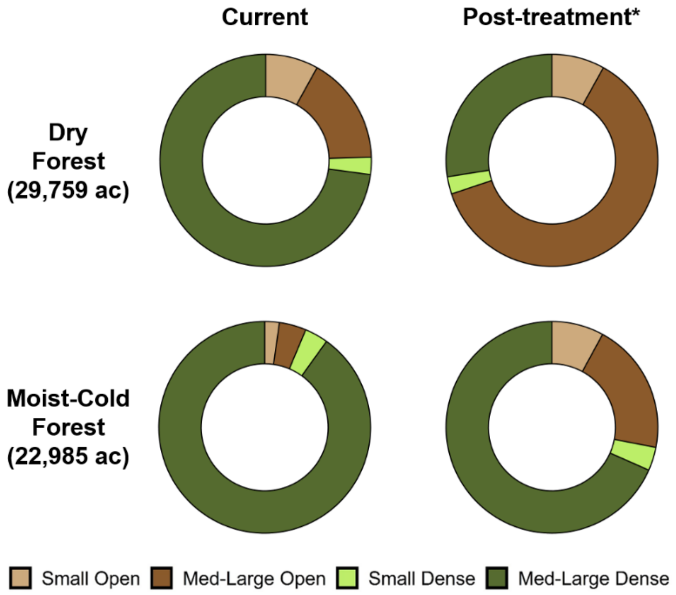
A range of treatment types will be needed, including moderate to heavy thinning, regeneration treatments, and fire. Increasing the relative composition of western larch and ponderosa pine is also needed, especially on sites projected to shift to dry forest (Fig. 3). If landscape treatment targets are achieved, over 70% of the total moist and cold forest area will remain dense (>40% canopy cover) (Fig. 6) to meet habitat, wood production, and other objectives.

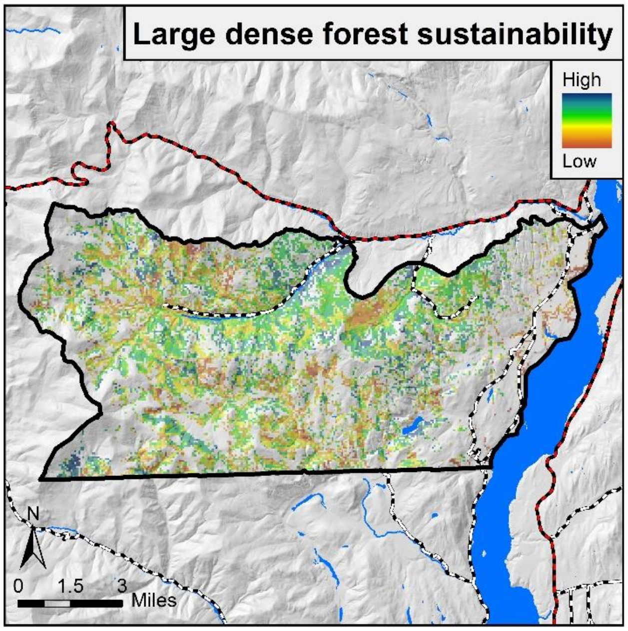
Open forest maintenance treatment need

Over the next 15 years, an estimated 2,600-3,700 acres of currently open forests on dry and moist sites will need prescribed fire, managed wildfire, or mechanical methods to maintain open conditions by reducing surface fuels and small trees. Specific maintenance strategies will depend on landowner objectives and time since treatment.

Sustainable locations for dense forest with large trees

Locations with low to moderate current and future moisture deficits (Fig. 3) and low fire risk (Fig. 2) offer the most sustainable locations to maintain sufficient area and patch sizes of this habitat type and associated ecosystem functions. Sustainable locations are found mostly on north-facing slopes, riparian draws, and areas with ash-capped soils (Fig. 7). This sustainability map can be used in conjunction with treatment priority (Fig. 9) to select areas to shift to open forest vs. where to maintain and increase large tree, closed canopy patches.





Left: Figure 6. Current and post-treatment proportions of forest types and structure classes. * mid-point of range in Table 1.
Right: Figure 7. Sustainability of current and potential large tree, dense forest based on fire risk and drought vulnerability.

Landscape Treatment Prioritization

Prioritizing for forest health & to reduce fire exposure of homes

Landscape treatment priority integrates three metrics of forest health – forest fire risk (Fig. 2), drought vulnerability (Fig. 3), and presence of overabundant forest structure types (Fig. 4) – with wildfire transmission to homes (Fig. 8). We also recommend incorporating the large dense forest sustainability layer (Fig. 7) as an overlay when selecting treatment locations. Wildfire transmission is low to moderate in the eastern half of the planning area, indicating that wildfires starting in these locations may reach homes near Lake Roosevelt, within and outside the planning area (Fig. 2).

Treatment priorities

High priority treatment areas are interspersed with moderate and low priority patches throughout the planning area, and are located almost entirely on USFS land (Fig. 5, Fig. 9). Some of the highest priority areas for treatments lie within inventoried roadless areas with high fire risk, drought vulnerability, and departed forest structure. Some low priority areas may need treatment to address species composition, insect and disease risk, or other issues. In addition, fuel reduction treatments, defensible space, and home hardening are needed on private parcels with homes or other structures in the far eastern portion of the planning area.

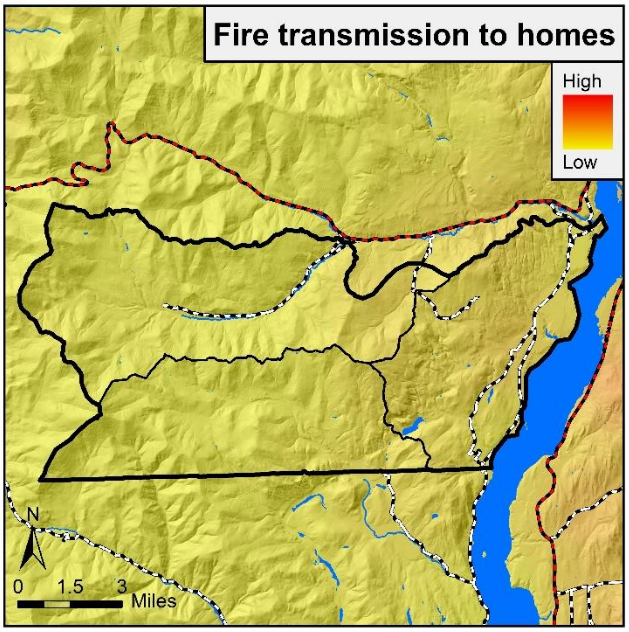


Figure 8. Fire transmission to homes shows where fires that expose structures are most likely to originate. It is based on simulated fire perimeters given contemporary patterns of fuels, topography, and wind.

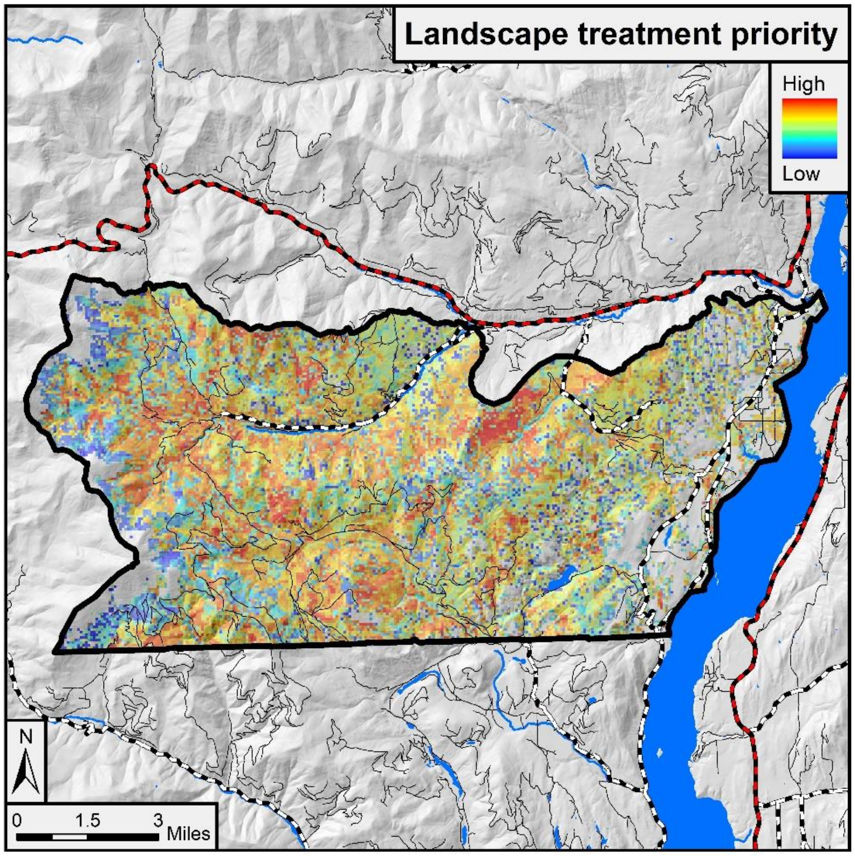


Figure 9. Landscape treatment priority is based on three metrics of forest health – forest fire risk (Fig. 1), drought vulnerability (Fig. 3), overabundant forest structure (Fig. 4) – as well as wildfire transmission to homes (Fig. 8).

Definitions

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Woodland/Steppe: Grass and shrub lands that may have oak woodlands or ≤ 10% conifer cover.

Forest structure

Large tree: Overstory diameter > 20 inches.

Medium tree: Overstory diameter 10-20 inches.

Small tree: Overstory diameter < 10 inches.

Dense canopy: Greater than 40% tree canopy.

Open canopy: Less than 40% tree canopy.

Fuels: Shrubs, grasses, small trees, litter, duff, and dead wood.

Fuels treatments: some combination of mechanical density reduction (commercial or non-commercial) and surface and ladder fuel reduction (prescribed fire, piling & burning, etc.).

Managed wildfire: fire is allowed to burn under safe conditions to achieve management goals but can be suppressed if conditions change.

Wildfire Response Benefit Prioritization

Dual benefits for forest health and wildfire response

It is necessary to conduct treatments to both improve forest health and reduce fire risk to communities as well as provide conditions where firefighters can safely and efficiently conduct fire operations (e.g. suppression, prescribed burning, and managed wildfire). The wildfire response benefit metric (WRB; Fig. 10) identifies and prioritizes locations where values at risk that are more likely to be the focus of fire operations (homes, infrastructure, sources of drinking water, and commercially managed lands) coincide with areas likely to transmit wildfire to homes and generate severe fire behavior. Because there are positive feedbacks between healthy, resilient forests and safe, effective fire operations, the WRB metric also integrates the landscape treatment priority map (Fig. 9).

Where WRB is highest, actions may be needed to create and maintain conditions that provide a tactical advantage for fire operations. These actions will vary with the local context and can include landscape-level forest health and fuel treatments, treatments along fire controls lines and escape routes, resident and community fire mitigation activities (e.g. defensible space, home hardening), and improving signage and road conditions. The WRB metric provides a high-level prioritization, and additional work at the local level is required to identify appropriate actions and assess their feasibility. WRB is useful for prioritizing Potential Control Lines (PCLs) for fire operations (Fig. 11). PCLs are a part of Potential Operational Delineations (PODs); see page 7.

In the Dollar planning area, wildfire response benefit is highest in the eastern portion (Fig. 10) due to the concentration of higher wildfire risk to homes and infrastructure combined with high wildfire transmission to structures. Wildfire response benefit is relatively lower in the uninhabited western portion. Crown fire potential is high throughout the planning area in locations with dense, multi-layered forest structure.

Definitions (continued)

Wildfire response benefit: Any tactical advantage gained for wildfire response activities from actions on the landscape, including, but not restricted to, identifying and consolidating existing anchor points and control lines and reduction of potential fire behavior. Wildfire response benefit is not restricted to any specific wildfire management strategy and instead is centered on conditions that improve fire operations safety and effectiveness.

Potential Control Lines (PCLs): Boundaries of Potential Operational Delineations (PODs) relevant to fire control operations (e.g. roads, ridgetops, and water bodies).

Potential Operational Delineations (PODs) for wildland fire: Landscape containers whose boundaries are potential control lines (PCLs). PODs are useful for planning strategic response to unplanned ignitions, strategic fuel planning, and prioritizing fuel treatments within PODs.

Commercially managed lands: Commercially managed forestlands include: DNR Trustlands, Tribal forests, industrial forests, non-industrial private forests, and US Forest Service forests where timber is a primary management objective.

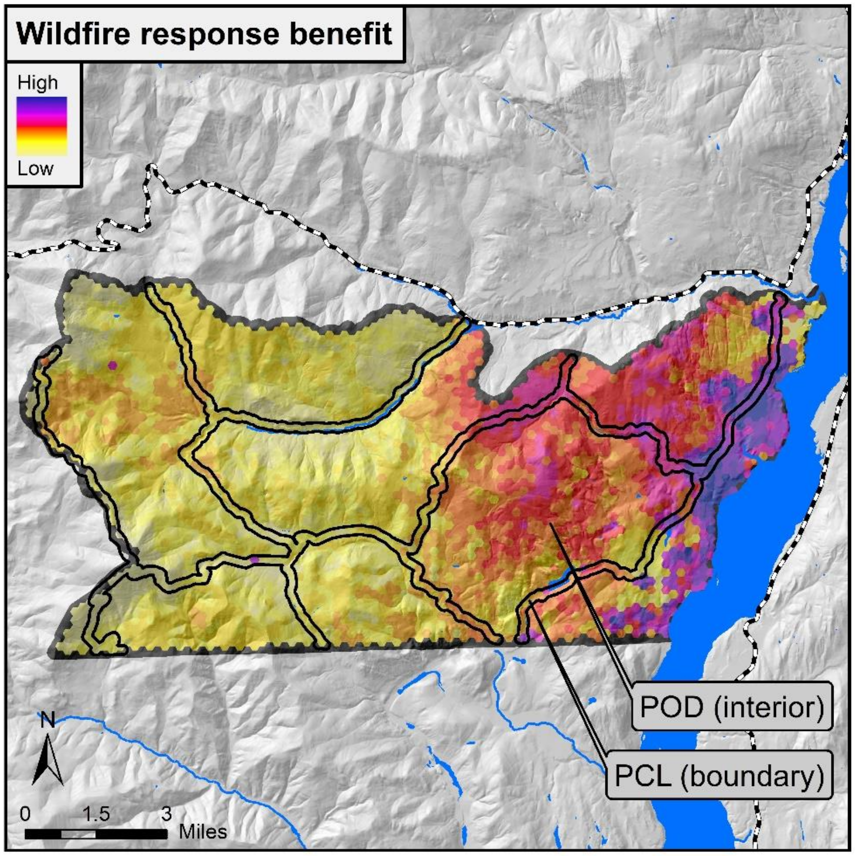

Figure 10. Wildfire response benefit (WRB) integrates multiple fire risk and forest health components. It includes four fire risk metrics representing highly valued resources – risk to homes, infrastructure, drinking water, commercially managed lands – as well as crown fire potential and wildfire transmission to homes (Fig. 8). Combined, these account for 75% of the wildfire response benefit. Landscape treatment priority (Fig. 9) accounts for the remaining 25%. Also shown are PODs: units bounded by PCLs (open black lines). One use of the WRB metric is to prioritize Potential Control Lines (PCLs) for fire operations (Fig. 11).

Prioritizing Landscape Treatments for Dual Benefits

Integration of forest health and wildfire response benefit using PODs

Potential Operational Delineations (PODs) provide a powerful spatial framework to communicate and identify locations that will deliver dual benefits for forest health and wildfire response at the landscape scale. PODs are large landscape areas delimited by Potential Control Lines (PCLs) for fire operations (suppression, prescribed fire, and managed wildfire), delineated by fire operations personnel. PCLs can be roads, ridgelines, or any artificial or natural fuelbreak that provides a strategic opportunity for fire operations. Summarizing landscape treatment priorities (Fig. 9) within PODs and wildfire response benefit priorities (Fig. 10) within PCLs enables planners and managers to identify, at a high level, locations where forest health or fuels treatments can be connected to a high-priority PCL that will support firefighter operations (e.g. ingress/egress route or opportunity for engagement).

Achieving forest health and wildfire response goals will require primarily large, landscape-level treatments across PODs (~100's-1,000's of acres) and, to a lesser extent, targeted treatments along PCLs.

There is important work to do in all Dollar PODs to achieve the forest health treatment targets in Table 1. First priority PODs correspond to areas with relatively high landscape treatment priority (Fig. 9) in western and southern portions of the planning area (Fig. 11). Most of the first priority PODs are associated with first priority PCLs, enhancing opportunities for dual benefit treatments. Additional first priority PCLs occur in the eastern portion due to their proximity to communities. Further work is needed to assess PCLs locally for their condition and detailed treatment needs, which will depend on management goals and values at risk. Ideally, landscape treatments will be implemented adjacent to priority PCLs where feasible to maximize both forest health and wildfire response goals.

Achieving forest health and wildfire response dual benefits will require primarily large, landscape-level treatments across PODs (~100's-1,000's of acres) and, to a lesser extent, targeted treatments along PCLs. These two approaches combined will contribute to restoring and maintaining large portions of the landscape in a resilient condition while providing safe and effective areas for firefighter engagement during suppression, prescribed fire, or managed wildfire operations.

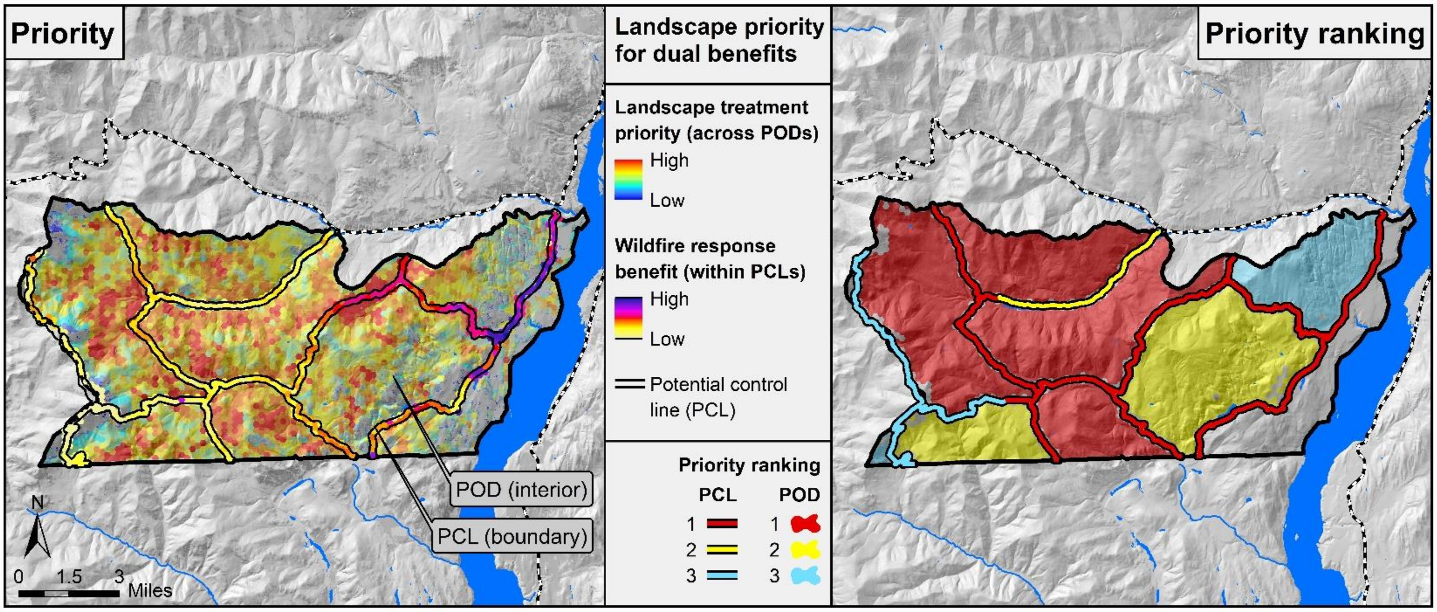

Figure 11. Landscape prioritization of dual benefits using PODs as a spatial framework to summarize treatment priorities. Both maps display landscape treatment priority within PODs and wildfire response benefit within PCLs. The map on the left shows the datasets at the raster level, while the map on the right shows the same information summarized and ranked within PODs and PCLs. PCL width is inflated to display spatial patterns. *PODs shown here are part of an ongoing process towards an all-lands delineation; POD boundaries are subject to change following on-the-ground vetting and continued dialogue among wildfire agencies and stakeholders.*

HIGHWAY 97 PLANNING AREA LANDSCAPE EVALUATION SUMMARY (2022)

Total Acres	Forested Acres	Treatment Goal (Acres)
60,398	37,415	11,000 - 16,500

Figure 1. Planning area location in eastern WA.

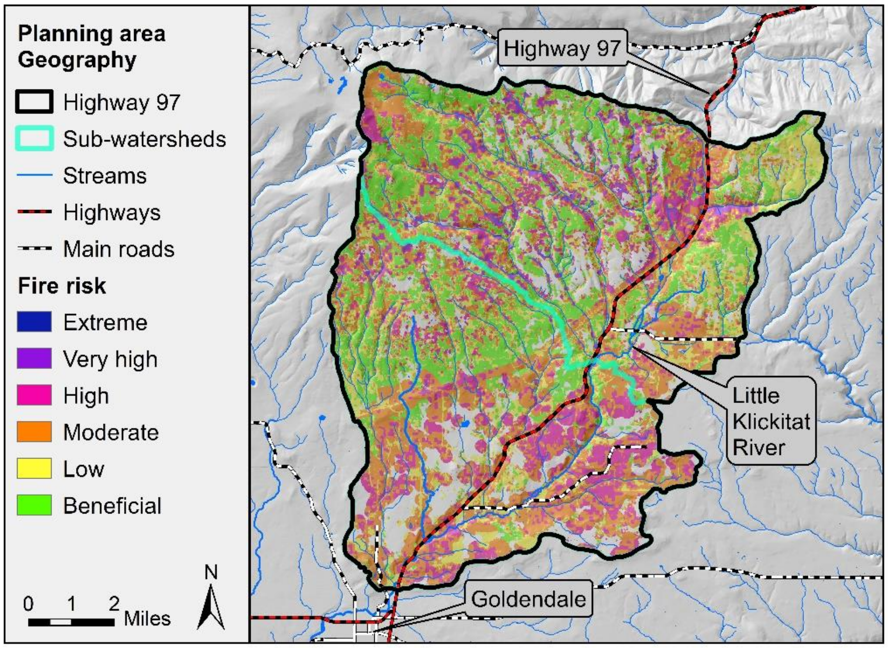

Figure 2. Planning area geography and fire risk, which integrates burn probability, fire intensity, and fire susceptibility of forests, infrastructure, and homes.

Planning Area Highlights

- This planning area is primarily dry forest land surrounding Highway 97 north of Goldendale, and it includes the city's water supply. Non-forest vegetation is an important component of eastern and southern portions.
- Unlike most DNR priority planning areas in eastern Washington, the land ownership is almost all private, with 56% private industrial and 41% private non-industrial land.
- Fire risk is highest in southern portions of the planning area and along the Highway 97 corridor (Fig. 2). In some central and northern portions, fire risk is relatively low due to open forest conditions.
- Projected warming over the next 20-40 years will likely shift climate conditions that are currently suitable for dry forest towards widespread conditions that may no longer support forest.
- Treating 29-44% of forested acres is recommended to increase resilience and reduce fire risk to communities using a combination of mechanical treatments, prescribed fire, and maintenance treatments.
- High priority areas for potential treatments that maximize forest health and wildfire response benefit include locations in the western, central, and eastern portions of the planning area.

LEARN MORE

This landscape evaluation was completed in 2022.
For more details about DNR's priority planning areas please see: **https://www.dnr.wa.gov/ForestHealthPlan**
For data products and methods see: **https://bit.ly/ForestHealthData**

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Overarching Goals

Reduce wildfire risk and protect communities

Fire risk is high to very high in southern portions of the planning area, where homes and private property are concentrated. Fire risk is also high in the northwest corner and along the Highway 97 corridor due to high fuel loads (Fig. 2). Fuels treatments are needed to break up large patches of dense forest to reduce the likelihood of large crown fire and to facilitate protection of private property throughout the planning area. In addition, implementing fuel reduction treatments around homes and establishing potential control lines will increase firefighter safety and help protect communities.

Increase resilience and prepare for climate change

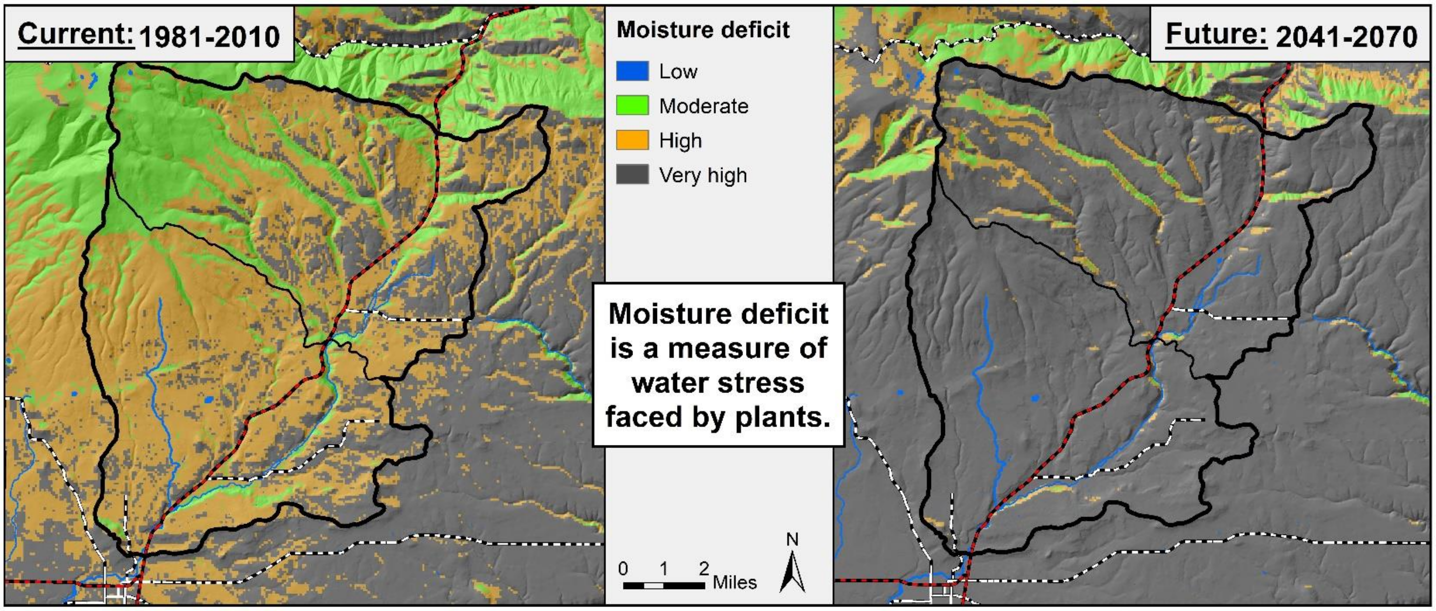
This landscape has some of the highest current and projected future moisture stress among all DNR planning areas in eastern WA. By mid-century, the vast majority of the planning area is projected to have moisture stress levels that are currently associated with oak woodland and shrub-steppe (Fig. 3). Although non-forest vegetation types (herbland, shrubland) are currently widespread, substantial portions of forested areas within the planning area are projected to shift to non-forest over time, driven mainly by wildfires. High moisture stress levels associated with dry forest types are projected to remain on north-facing slopes in valley bottoms. Forest health treatments that reduce density and favor drought-tolerant species will support forest persistence into the future.

Sustain wildlife habitat

Dry forests are extensive throughout the northern half of the planning area as a mixture of open and closed-canopy patches with medium trees. Habitat for dry forest, large tree, open canopy species (e.g. White Headed Woodpecker) is under-represented relative to reference conditions. Habitat for species that depend on moist, closed canopy forest with large trees (e.g. Northern Spotted Owl) is a minor component, and habitat for cold forest, large-tree, closed canopy species (e.g. American Marten) is not a component of the planning area. Oak woodland habitat for western gray squirrel is an important consideration in this area, particularly east of Highway 97 and in areas where conifers have been removed to favor oaks. Habitat layers are available in the data products.

Enhance rural economic development

Most of the higher priority areas for commercial treatments have road access and are capable of producing timber volume. Projected warming trends and high fire risk will necessitate managing for lower densities and fuel loads, as well as fire- and drought-tolerant species. As moisture stress increases and forest cover declines over time, long-term timber production will likely become increasingly challenging. Reducing fire risk will help sustain recreation and tourism while reducing the potential of smoke affecting nearby communities and critical infrastructure (roads and utility corridors, Goldendale water supply, and observatory managed by State Parks).



Moisture deficit is a measure of water stress faced by plants.

Figure 3. Current (left) and future (right) moisture stress levels based on water balance deficit. Low levels are associated with moist and cold forest types, high with dry forest types, and very high with woodland or shrub-steppe. Future climate is based on a relatively high usual greenhouse gas emissions scenario (RCP 8.5).

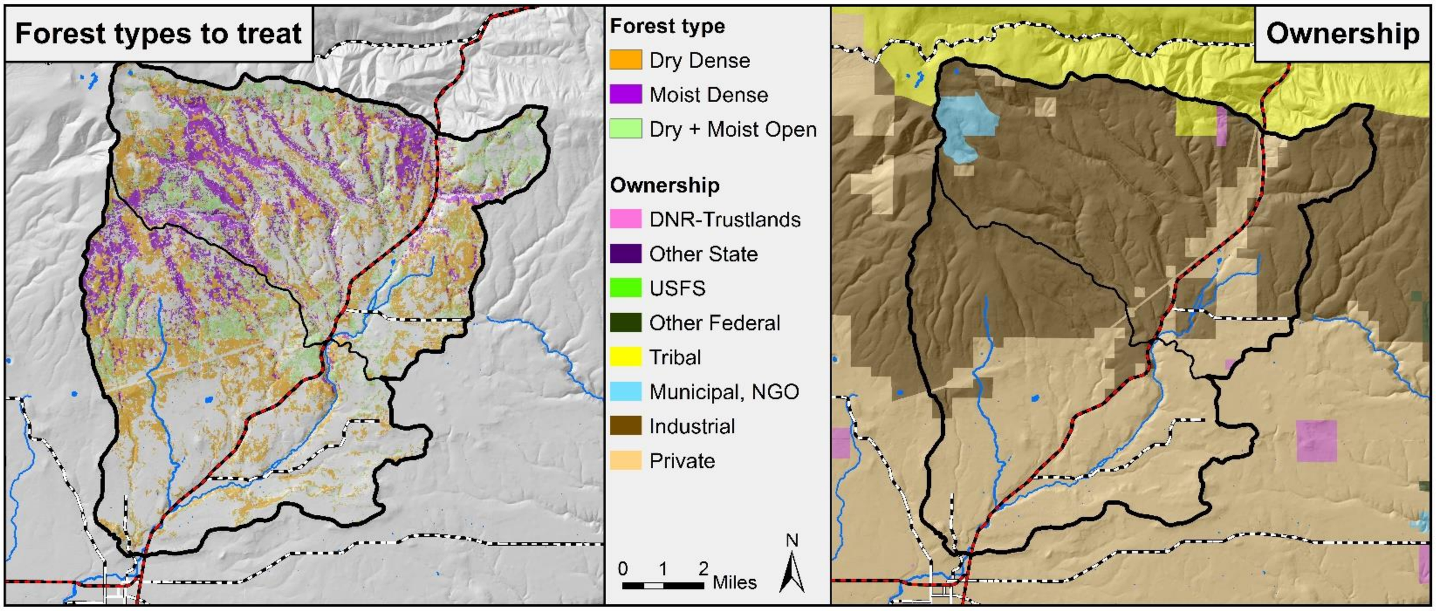
Forest Health Treatment Needs

Treating 11,000 to 16,500 acres is recommended to move the landscape into a resilient condition (29-44% of forested acres; Table 1). This total includes an estimated 7,500-11,500 acres to shift dense to open forest and 3,500-5,000 acres of maintenance treatments in existing open forest, based on current condition data from 2019 LiDAR imagery and 2017 aerial photos.

Meeting this target range will require multiple treatment types (Table 1). Most treatments are commercially viable based on tree size. Treatment type will depend on road access, logging systems, markets, and other considerations. Individual landowners will conduct their own planning and decision-making processes to determine acres and types of treatments to achieve the landscape goals while meeting their own objectives and regulatory requirements.

Table 1. Summary of forest health treatment needs. ***See methods for details on how the treatment need range is derived.***

Forest conditions to treat		Treatment need (acres)	Current acres by major landowner*				
Type	**Size class**		**Industrial**	**Private**	**City-County**	**Tribal**	**DNR-Trustlands**
Dry Dense	Medium-Large	6,000 - 8,500	8,508	5,060	279	153	25
Moist Dense	Medium-Large	1,500 - 3,000	6,162	351	16	123	51
Dry + Moist Open	Medium-Large	3,500 - 5,000	5,826	1,345	73	78	11
Total	**11,000 - 16,500**		**These are current acres, not targets*				
Anticipated treatment type	🟦	Commercial thin plus fuels treatment if access exists. May be noncommercial, fire only (primarily prescribed fire), or regeneration treatment.					
	🟩	Maintenance treatment: prescribed fire or mechanical fuels treatment. *Target range corresponds to 50-75% of dry open and 25-50% of moist open forests.*					



Left: Figure 4. Forest structure types that are overabundant relative to targets for a resilient landscape, as well as potential maintenance treatments. Only a portion of the areas shown need to be treated. Right: Figure 5. Current land ownership.

Forest Health Treatment Needs (continued)

Dry dense forest treatment need

On dry sites, dense forest structure of all size classes is currently over-represented. The large, contiguous patches of these forest conditions create high susceptibility to drought, insects, and stand-replacing wildfire. Treating 6,000-8,500 acres of dry dense forest (Table 1) is recommended to create large patches (~100-1000 ac) of open forest and shift the majority of dry sites to open forest (Fig. 6). Ponderosa pine, oak woodlands, and other fire- and drought-tolerant species will continue to be suitable as climate conditions get warmer and drier.

Moist and cold dense forest treatment need

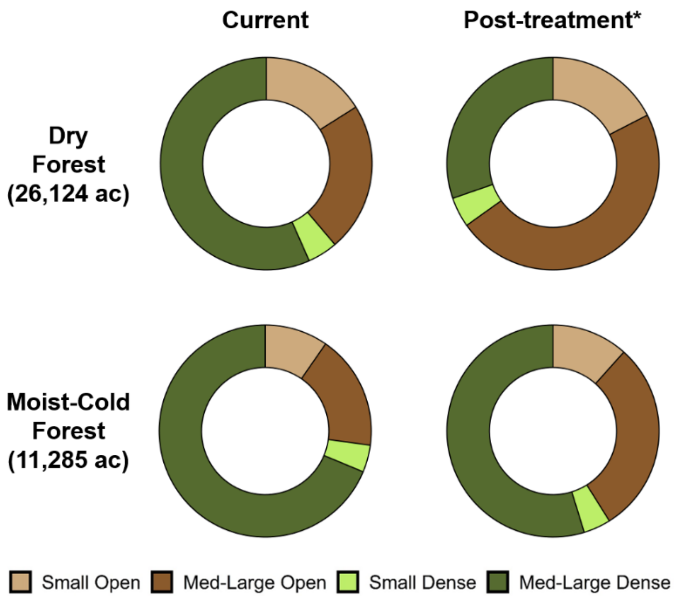
On moist sites, dense, multistory forest structure exceeds desired ranges. Patches are aggregated and concentrated in northern portions of the planning area. In contrast, open canopy forest with medium to large trees, as well as open forest with small trees, are below desired ranges. Treating 1,500-3,000 acres of this type (Table 1, Fig. 4) is recommended to create a mosaic of open, moderate, and dense patches that will reduce risks of large crown fire and insect outbreaks. A range of treatment types will be needed, including thinning, regeneration treatments, and prescribed fire. Increasing the relative composition of ponderosa pine is also needed to help these sites adapt to a warming climate (Fig. 3). If landscape treatment targets are achieved, over 55% of the total moist and cold forest area will remain dense (>40% canopy cover) (Fig. 6) to meet habitat, wood production, and other objectives.

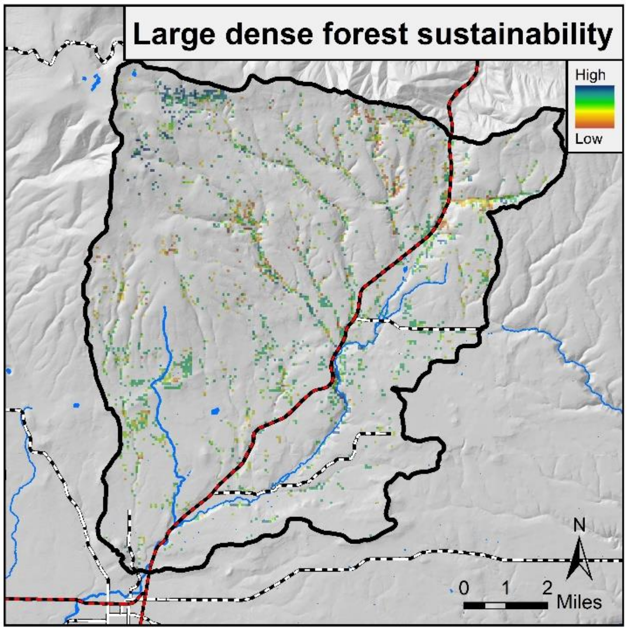
Open forest maintenance treatment need

Over the next 15 years, an estimated 3,500-5,000 acres of currently open forests on dry and moist sites will need prescribed fire and/or mechanical methods to maintain open conditions by reducing surface fuels and small tree density. These sites include more open and recently treated areas where fire is currently predicted to have beneficial effects (Fig. 2). Other high priority sites include western gray squirrel habitat in oak woodlands where recent management has reduced conifer abundance. Specific maintenance strategies will depend on landowner objectives and time since treatment.

Sustainable locations for dense forest with large trees

Locations with low to moderate current and future moisture deficits (Fig. 3) and low fire risk (Fig. 2) offer the most sustainable locations to maintain sufficient area and patch sizes of this habitat type and associated ecosystem functions. Sustainable locations occur in the northwestern portion and in valley bottoms, as well as some dry sites in the southwestern portion (Fig. 7). This sustainability map can be used in conjunction with treatment priority (Fig. 9) to select areas to shift to open forest vs. where to maintain and increase large tree, closed canopy patches.





Left: Figure 6. Current and post-treatment proportions of forest types and structure classes. * mid-point of range in Table 1.
Right: Figure 7. Sustainability of current and potential large tree, dense forest based on fire risk and drought vulnerability.

Landscape Treatment Prioritization

Prioritizing for forest health & to reduce fire exposure of homes

Landscape treatment priority integrates three metrics of forest health – forest fire risk (Fig. 2), drought vulnerability (Fig. 3), and presence of overabundant forest structure types (Fig. 4) – with wildfire transmission to homes (Fig. 8). We also recommend incorporating the large dense forest sustainability layer (Fig. 7) as an overlay when selecting treatment locations. Wildfire transmission is moderate to high in the southern half of the planning area, indicating that wildfires starting in these locations are expected to expose homes in and around the Highway 97 corridor (Fig. 2).

Treatment priorities

Landscape treatment priority is highest in the southwestern portion of the planning area (Fig. 9) mostly on small private and some industrial land (Fig. 5). These areas have high fire risk, drought vulnerability, and fire transmission to homes. Medium and high priority areas occur throughout the planning area. Some low priority areas may need treatment to address species composition, insect and disease risk, or other issues. In addition, fuel reduction treatments, defensible space, and home hardening are needed on private parcels with homes or other structures throughout the planning area.

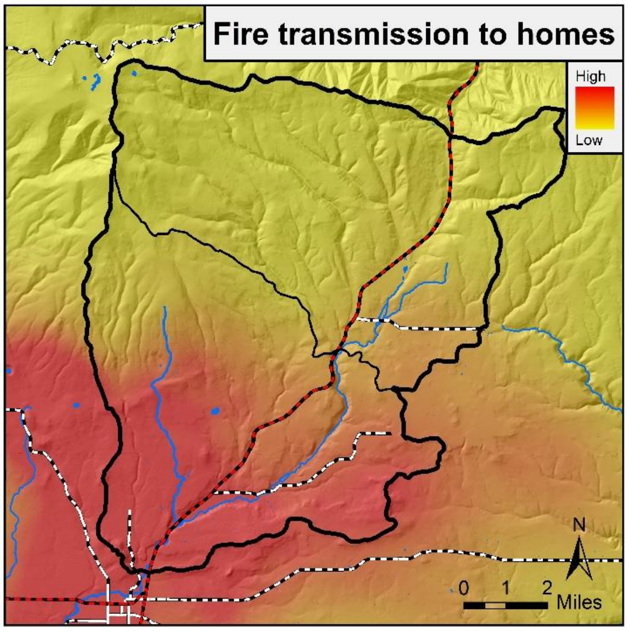


Figure 8. Fire transmission to homes shows where fires that expose structures are most likely to originate. It is based on simulated fire perimeters given contemporary patterns of fuels, topography, and wind.

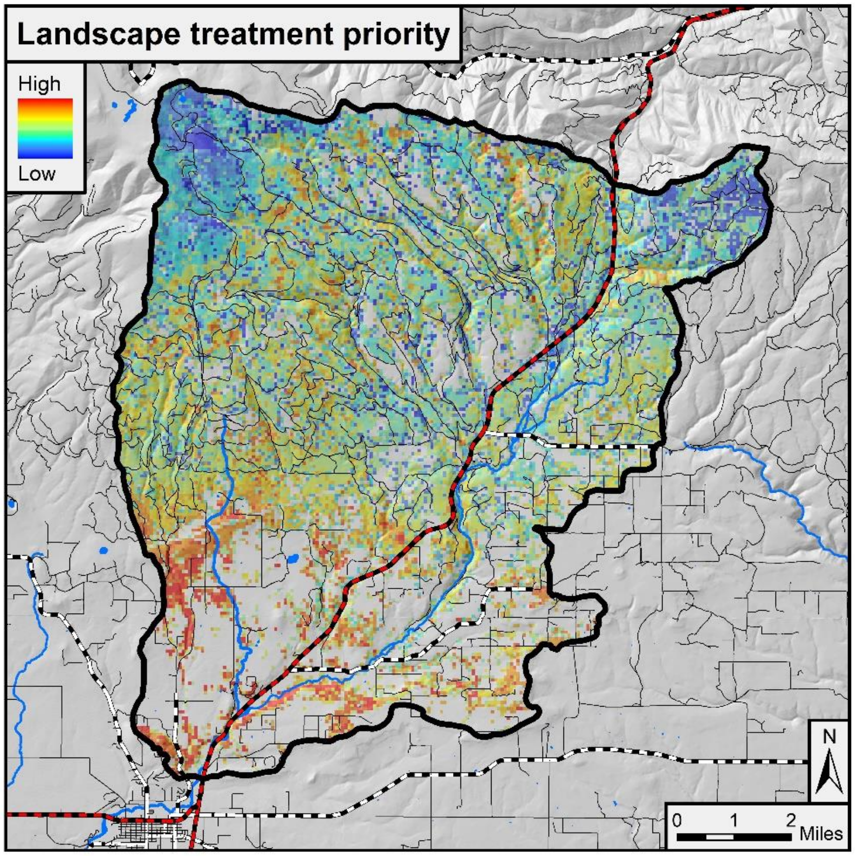


Figure 9. Landscape treatment priority is based on three metrics of forest health – forest fire risk (Fig. 1), drought vulnerability (Fig. 3), overabundant forest structure (Fig. 4) – as well as wildfire transmission to homes (Fig. 8).

Definitions

Vegetation Types

Cold forest: Upper elevation mixed-conifer forests with high-severity fires every 80-200+ years.

Dry forest: Ponderosa pine and Douglas-fir dominated forests that historically had surface fires every 5-25 years.

Moist forest: Forests that historically had mixed-severity fires every 30-100 years and were composed of fire-resistant (western larch, Douglas-fir) and fire-intolerant (grand fir) trees.

Woodland/Steppe: Grass and shrub lands that may have oak woodlands or ≤ 10% conifer cover.

Forest structure

Large tree: Overstory diameter > 20 inches.

Medium tree: Overstory diameter 10-20 inches.

Small tree: Overstory diameter < 10 inches.

Dense canopy: Greater than 40% tree canopy.

Open canopy: Less than 40% tree canopy.

Fuels: Shrubs, grasses, small trees, litter, duff, and dead wood.

Fuels treatments: some combination of mechanical density reduction (commercial or non-commercial) and surface and ladder fuel reduction (prescribed fire, piling & burning, etc.).

Managed wildfire: fire is allowed to burn under safe conditions to achieve management goals but can be suppressed if conditions change.

Wildfire Response Benefit Prioritization

Dual benefits for forest health and wildfire response

It is necessary to conduct treatments to both improve forest health and reduce fire risk to communities as well as provide conditions where firefighters can safely and efficiently conduct fire operations (e.g. suppression, prescribed burning, and managed wildfire). The wildfire response benefit metric (WRB; Fig. 10) identifies and prioritizes locations where values at risk that are more likely to be the focus of fire operations (homes, infrastructure, sources of drinking water, and commercially managed lands) coincide with areas likely to transmit wildfire to homes and generate severe fire behavior. Because there are positive feedbacks between healthy, resilient forests and safe, effective fire operations, the WRB metric also integrates the landscape treatment priority map (Fig. 9).

Where WRB is highest, actions may be needed to create and maintain conditions that provide a tactical advantage for fire operations. These actions will vary with the local context and can include landscape-level forest health and fuel treatments, treatments along fire control lines and escape routes, resident and community fire mitigation activities (e.g. defensible space, home hardening), and improving signage and road conditions. The WRB metric provides a high-level prioritization, and additional work at the local level is required to identify appropriate actions and assess their feasibility. WRB is useful for prioritizing Potential Control Lines (PCLs) for fire operations (Fig. 11). PCLs are a part of Potential Operational Delineations (PODs); see page 7.

In the Highway 97 planning area, wildfire response benefit is highest in southwestern portions due to interspersed homes, commercially managed lands, infrastructure, and the municipal water source for Goldendale (Fig. 2). The Highway 97 corridor in the northern portion also has very high wildfire response benefit. Crown fire potential is high throughout the planning area in locations with dense forest structure.

Definitions (continued)

Wildfire response benefit: Any tactical advantage gained for wildfire response activities from actions on the landscape, including, but not restricted to, identifying and consolidating existing anchor points and control lines and reduction of potential fire behavior. Wildfire response benefit is not restricted to any specific wildfire management strategy and instead is centered on conditions that improve fire operations safety and effectiveness.

Potential Control Lines (PCLs): Boundaries of Potential Operational Delineations (PODs) relevant to fire control operations (e.g. roads, ridgetops, and water bodies).

Potential Operational Delineations (PODs) for wildland fire: Landscape containers whose boundaries are potential control lines (PCLs). PODs are useful for planning strategic response to unplanned ignitions, strategic fuel planning, and prioritizing fuel treatments within PODs.

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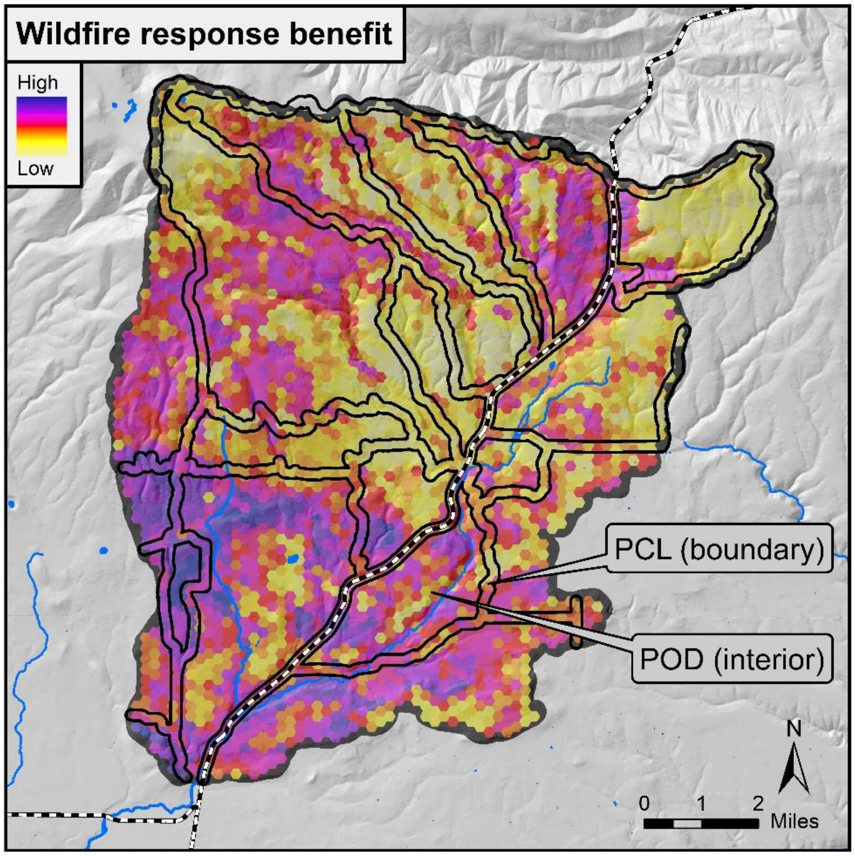


Figure 10. Wildfire response benefit (WRB) integrates multiple fire risk and forest health components. It includes four fire risk metrics representing highly valued resources – risk to homes, infrastructure, drinking water, commercially managed lands – as well as crown fire potential and wildfire transmission to homes (Fig. 8). Combined, these account for 75% of the wildfire response benefit. Landscape treatment priority (Fig. 9) accounts for the remaining 25%. Also shown are PODs: units bounded by PCLs (open black lines). One use of the WRB metric is to prioritize Potential Control Lines (PCLs) for fire operations (Fig. 11).

Prioritizing Landscape Treatments for Dual Benefits

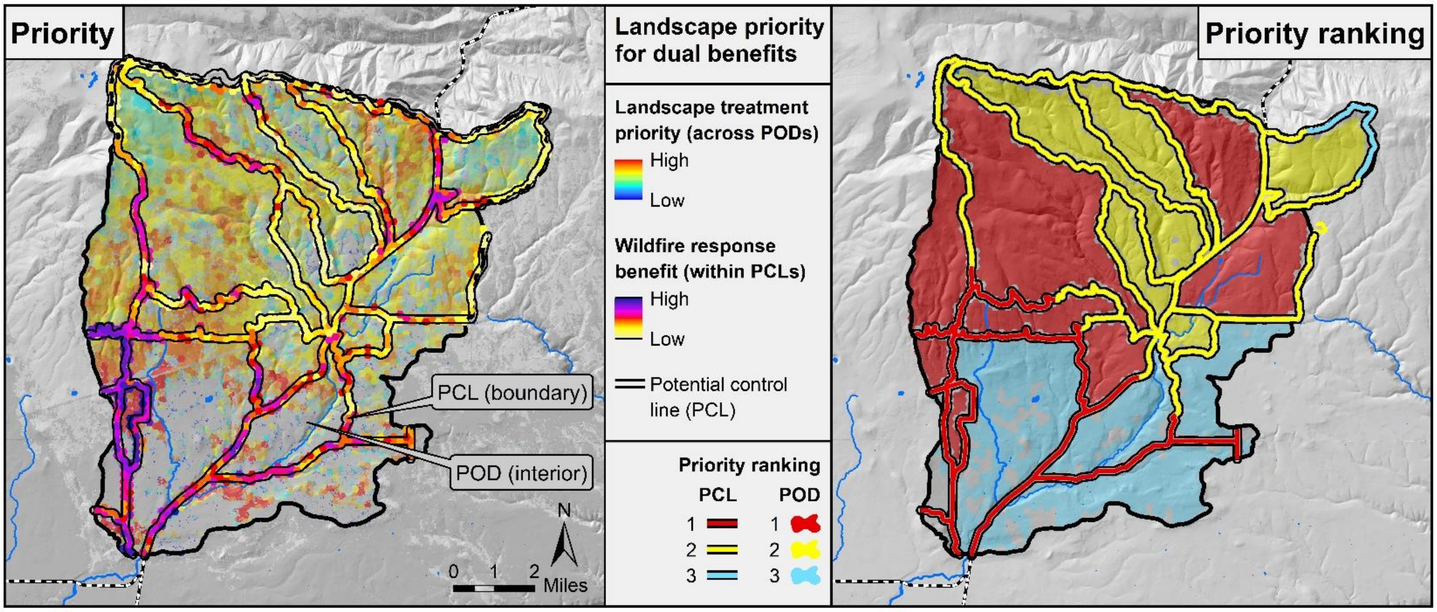
Integration of forest health and wildfire response benefit using PODs

Potential Operational Delineations (PODs) provide a powerful spatial framework to communicate and identify locations that will deliver dual benefits for forest health and wildfire response at the landscape scale. PODs are large landscape areas delimited by Potential Control Lines (PCLs) for fire operations (suppression, prescribed fire, and managed wildfire), delineated by fire operations personnel. PCLs can be roads, ridgelines, or any artificial or natural fuelbreak that provides a strategic opportunity for fire operations. Summarizing landscape treatment priorities (Fig. 9) within PODs and wildfire response benefit priorities (Fig. 10) within PCLs enables planners and managers to identify, at a high level, locations where forest health or fuels treatments can be connected to a high-priority PCL that will support firefighter operations (e.g. ingress/egress route or opportunity for engagement).

Achieving forest health and wildfire response goals will require primarily large, landscape-level treatments across PODs (~100's-1,000's of acres) and, to a lesser extent, targeted treatments along PCLs.

There is important work to do in all Highway 97 PODs to achieve the forest health treatment targets in Table 1. First priority PODs correspond to areas with moderate to high landscape treatment priority (Fig. 9) in western and northeastern portions of the planning area (Fig. 11). Most of the first priority PODs are associated with first or second priority PCLs, enhancing opportunities for dual benefit treatments. Additional first priority PCLs occur in the southern portion around the Highway 97 corridor (Fig. 10). Further work is needed to assess PCLs locally for their condition and detailed treatment needs, which will depend on management goals and values at risk. Ideally, landscape treatments will be implemented adjacent to priority PCLs where feasible to maximize both forest health and wildfire response goals.

Achieving forest health and wildfire response dual benefits will require primarily large, landscape-level treatments across PODs (~100's-1,000's of acres) and, to a lesser extent, targeted treatments along PCLs. These two approaches combined will contribute to restoring and maintaining large portions of the landscape in a resilient condition while providing safe and effective areas for firefighter engagement during suppression, prescribed fire, or wildfire operations.



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LITTLE NACHES PLANNING AREA LANDSCAPE EVALUATION SUMMARY (2022)

Total Acres	Forested Acres	Treatment Goal (Acres)
95,331	92,914	25,500 - 43,000

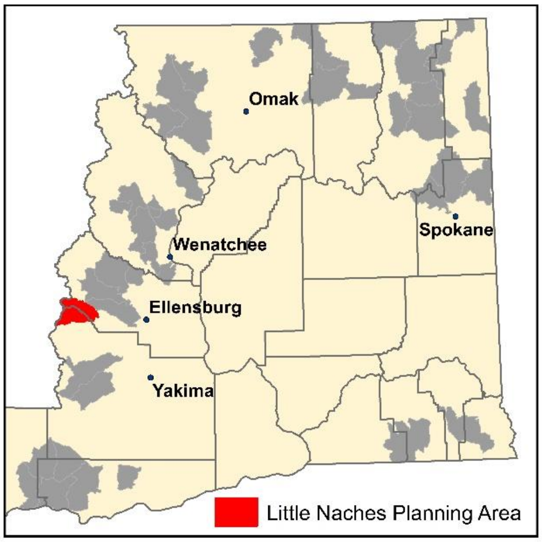

Figure 1. Planning area location in eastern WA.

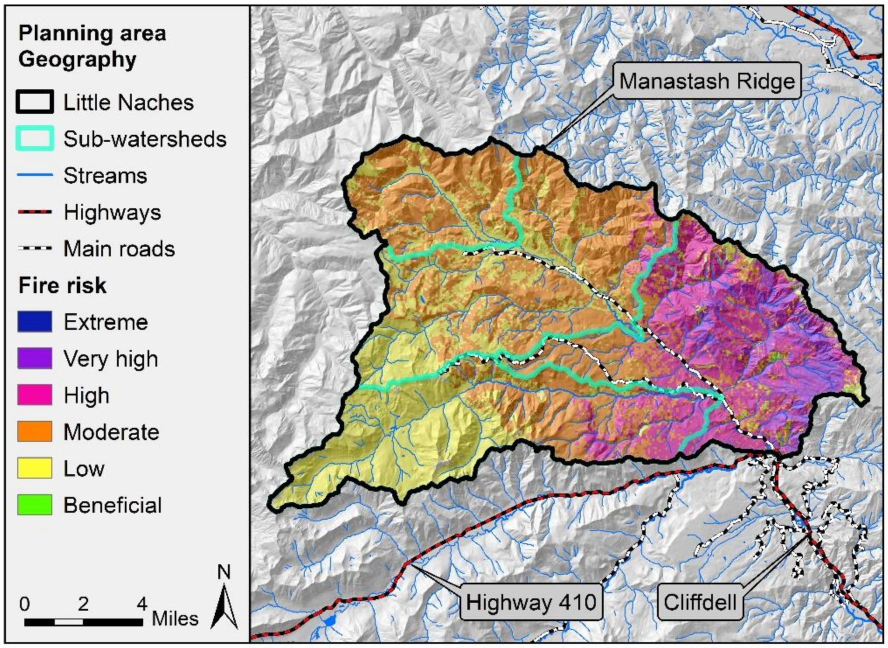

Figure 2. Planning area geography and fire risk, which integrates burn probability, fire intensity, and fire susceptibility of forests, infrastructure, and homes.

Planning Area Highlights

- This planning area extends from the Cascade Crest down to the Naches Valley. Forests are primarily moist and cold types with higher capacity to sustain dense forests than other DNR priority planning areas.
- Ownership is 94% US Forest Service, and the remaining 6% is former industrial private land that is being transferred from The Nature Conservancy to the USFS.
- Fire risk is highest in the eastern portion of the planning area (Fig. 2). Fire risk is relatively low in the southwestern portion due to the 2017 Norse Peak Fire.
- Projected warming over the next 20-40 years will likely shift climate conditions suitable for moist and cold forest towards conditions suitable for dry forest.
- Treating 27-46% of forested acres is recommended to increase resilience and reduce fire risk to communities using a combination of mechanical, prescribed fire, and managed wildfire treatments. Recent and planned USFS treatments are distributed throughout the central portion of the planning area.
- High priority areas for potential treatments that maximize forest health and wildfire response benefit include locations throughout the southern and eastern portions of the planning area.

LEARN MORE

This landscape evaluation was completed in 2022.
For more details about DNR's priority planning areas please see: **https://www.dnr.wa.gov/ForestHealthPlan**
For data products and methods see: **https://bit.ly/ForestHealthData**

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Overarching Goals

Reduce wildfire risk and protect communities

Fire risk is high to very high in eastern portions of the planning area due to high fuel loads and burn probability. Fire risk is moderate throughout the central portion (Fig. 2). Fuels treatments are needed to break up large patches of dense forest to reduce the likelihood of large crown fire and to facilitate protection of private property throughout the planning area. Fire risk is relatively low in the southwestern portion due to the effect of the 2017 Norse Peak Fire on fuels and predicted flame lengths. In addition, implementing fuel reduction treatments around homes and establishing potential control lines will increase firefighter safety and help protect communities.

Increase resilience and prepare for climate change

By mid-century, portions of the planning area that are currently moist forests are projected to have moisture stress levels that are currently associated with dry forest (Fig. 3). Moderate and low moisture stress levels are projected to remain throughout the planning area, indicating lower drought vulnerability than some of the DNR priority planning areas in drier locations. Treatments, as well as managed wildfires in roadless and other inaccessible areas, that reduce density and favor drought-tolerant species will support forest persistence into the future.

Sustain wildlife habitat

Habitat for dry forest, large tree, open canopy species (e.g. White Headed Woodpecker) is concentrated in dry forest patches at lower elevations and is a relatively minor component. Habitat for species that depend on moist, closed canopy forest with large trees (e.g. Northern Spotted Owl) is in the middle to upper end of desired ranges, although it is overly abundant in the northwestern portion. In high fire risk locations, reducing tree density and canopy cover will reduce crown fire potential and drought vulnerability, help maintain habitat in the most sustainable locations (Fig. 7), and broaden the spatial distribution of open canopy habitat. Habitat for cold forest, large-tree, closed canopy species (e.g. American Marten) is abundant but concentrated in large patches at higher elevations in the western part of the planning area. Habitat layers are available in the data products.

Enhance rural economic development

Most of the higher priority areas for commercial treatments have road access and are capable of producing significant timber volume. Although warming trends and high fire risk will necessitate managing for lower densities and drought-tolerant species, long-term timber production will likely be possible. Reducing fire risk will help sustain recreation and tourism while reducing the potential of smoke affecting nearby communities.

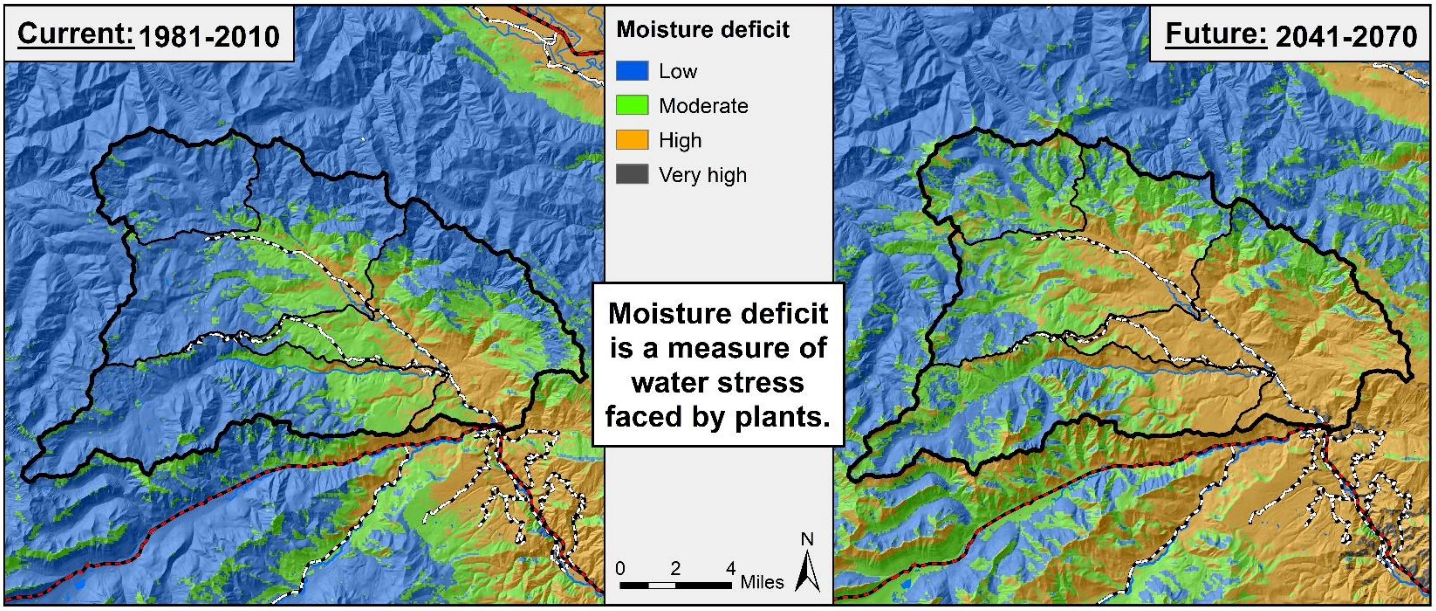


Figure 3. Current (left) and future (right) moisture stress levels based on water balance deficit. Low levels are associated with moist and cold forest types, high with dry forest types, and very high with woodland or shrub-steppe. Future climate is based on relatively high greenhouse gas emissions scenario (RCP 8.5).

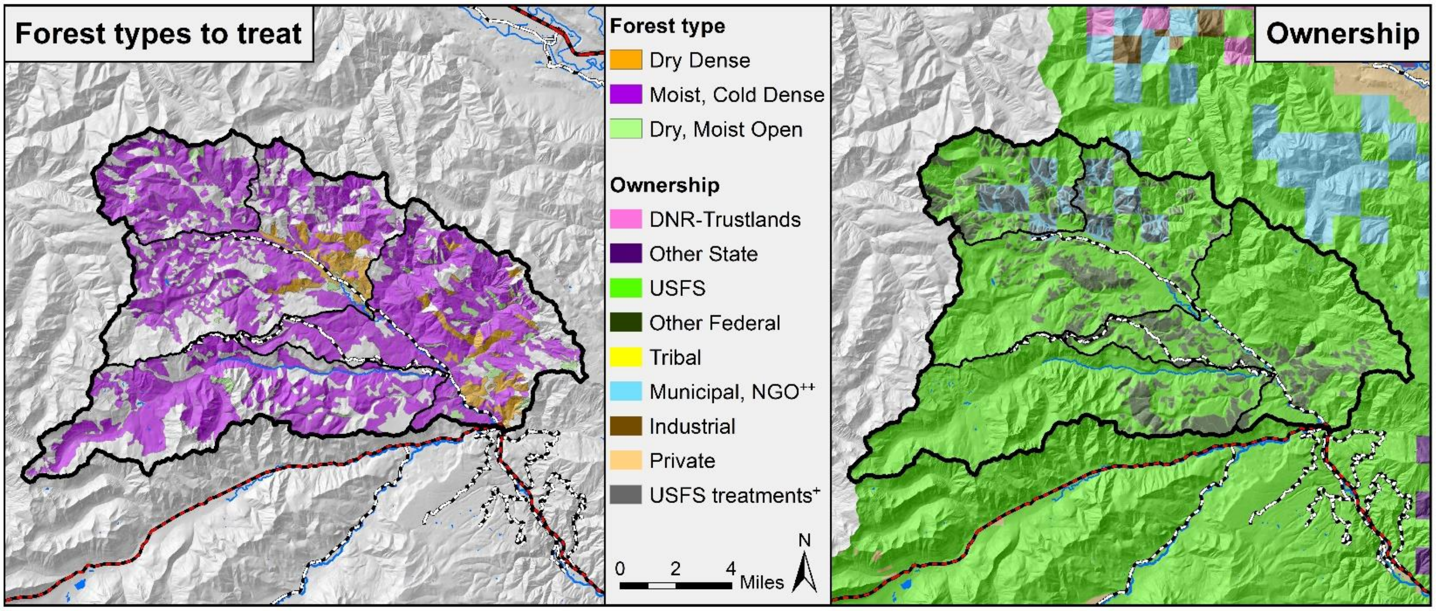
Forest Health Treatment Needs

Treating 25,500 to 43,000 acres is recommended to move the landscape into a resilient condition (27-46% of forested acres; Table 1). This total includes an estimated 25,000-41,500 acres to shift dense to open forest and 500-1,500 acres of maintenance treatments in existing open forest, based on current condition data from 2012 and 2019 aerial photos. Recent and planned management activities by the US Forest Service include commercial, noncommercial, and prescribed fire treatments (gray polygons in Fig. 5 based on data from USFS).

Meeting this target range will require multiple treatment types (Table 1). Managed wildfire under safe conditions will be needed, especially in less accessible locations. Most treatments are commercially viable based on tree size. Treatment type will depend on road access, logging systems, markets, and other considerations. Individual landowners will conduct their own planning and decision-making processes to determine acres and types of treatments to achieve the landscape goals while meeting their own objectives and regulatory requirements.

Table 1. Summary of forest health treatment needs. *See methods for details on how the treatment need range is derived.*

Forest conditions to treat		Treatment need (acres)	Current acres by major landowner*		
Type	**Size class**		**USFS**	**TNC****	**Other**
Dry Dense	Medium-Large	3,000 - 4,500	4,988	138	0
Moist + Cold Dense	Small	2,000 - 3,000	6,409	2,725	21
	Medium-Large	20,000 - 34,000	57,777	1,644	5
Dry + Moist Open	Medium-Large	500 - 1,500	1,870	74	0
Total		**25,500 - 43,000**	**These are current acres, not targets **Transfer to USFS*		
Anticipated treatment type	⬜	Noncommercial thin plus fuels treatment. May be fire only (prescribed or managed wildfire).			
	🟦	Commercial thin plus fuels treatment if access exists. May be noncommercial, fire only (prescribed or managed wildfire), or regeneration treatment.			
	🟩	Maintenance treatment: prescribed fire, managed wildfire, or mechanical fuels treatment. *Target range corresponds to 50-75% of dry open and 25-50% of moist open forests.*			



Left: Figure 4. Forest structure types that are overabundant relative to targets for a resilient landscape, as well as potential maintenance treatments. Only a portion of the areas shown need to be treated. Right: Figure 5. Current land ownership. ⁺⁺Note that blue land within the planning area is being transferred to USFS. ⁺Gray areas indicate recent or planned treatments.

Forest Health Treatment Needs (continued)

Dry dense forest treatment need

Currently, dense, multistory forest structure is over-represented on dry sites, especially sites dominated by Douglas-fir. The large, numerous patches of this forest type create high susceptibility to defoliating insects, bark beetles, and crown fire. Treating 3,000-4,500 acres of this type (Table 1) is recommended to create large patches (~100-1000 ac) of open forest with a component of large trees (Fig. 4), flipping the majority of dry sites from closed to open forest (Fig. 6). Shifting composition toward ponderosa pine and reducing grand fir, silver fir, and Douglas-fir is also recommended.

Moist and cold dense forest treatment need

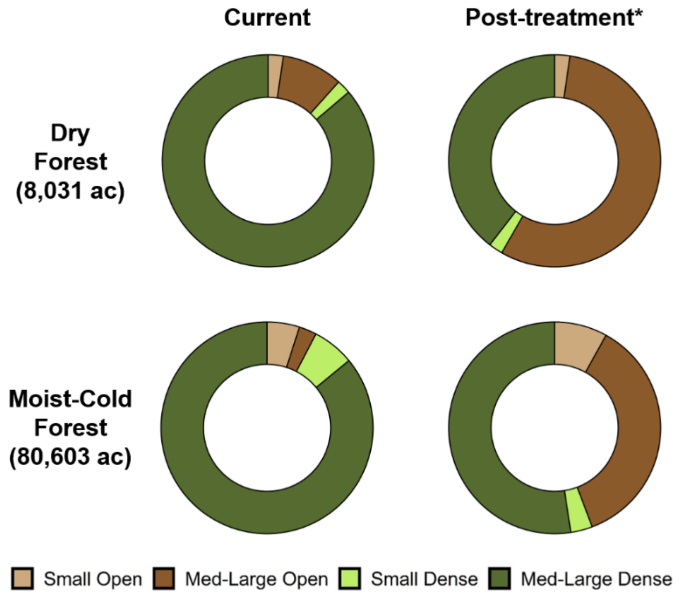
Dense, multistory mixed-conifer forests on moist and cold sites exceed or are at the upper end of desired ranges throughout higher elevations of the planning area. In contrast, open canopy forest with medium to large trees are below or at the low end of desired ranges. Treating 22,000-37,000 (Table 1, Fig. 4) is recommended to create a mosaic of open and dense forest that will reduce the risk of large crown fire and insect outbreaks, which are occurring in the eastern portion near Manastash Ridge. A range of treatment types will be needed, including thinning, regeneration treatments, and managed wildfire in roadless areas. Increasing the relative composition of ponderosa pine and western larch is also recommended to help these sites adapt to a warming climate. If landscape treatment targets are achieved, over 55% of the total moist and cold forest area will remain dense (>40% canopy cover) (Fig. 6) to meet habitat, wood production, and other objectives.

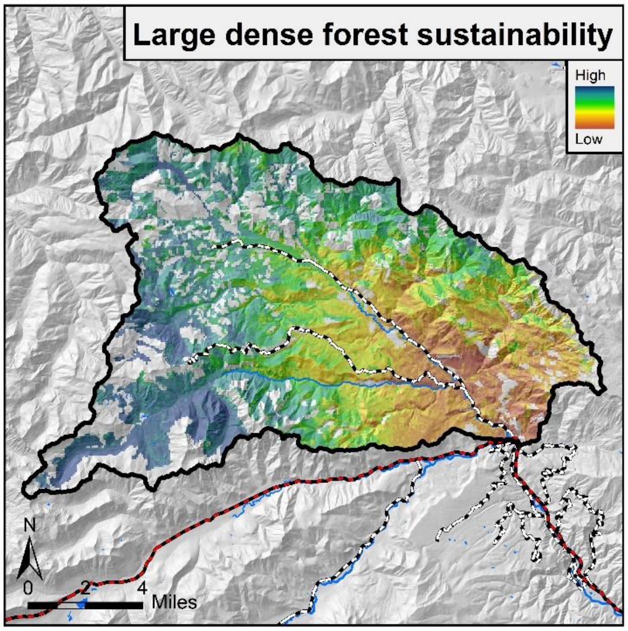
Open forest maintenance treatment need

Over the next 15 years, an estimated 500-1,500 acres of currently open forests on dry and moist sites will need prescribed fire, managed wildfire, or mechanical methods to maintain open conditions by reducing surface fuels and small trees. Specific maintenance strategies depend on site conditions and time since treatment.

Sustainable locations for dense forest with large trees

Locations with low to moderate current and future moisture deficits (Fig. 3) and low fire risk (Fig. 2) offer the most sustainable locations to maintain sufficient area and patch sizes of this forest habitat type and associated ecosystem functions. Sustainable locations include western and northern portions of the planning area, as well as upper slopes in the central portion (Fig. 7). The large tree, dense forest sustainability map can be used in conjunction with treatment priority (Fig. 9) to select areas to promote open forest vs. where to maintain and build large tree closed canopy patches.





Left: Figure 6. Current and post-treatment proportions of forest types and structure classes. * mid-point of range in Table 1.
Right: Figure 7. Sustainability of current and potential large tree, dense forest based on fire risk and drought vulnerability.

Landscape Treatment Prioritization

Prioritizing for forest health & to reduce fire exposure of homes

Landscape treatment priority integrates three metrics of forest health – forest fire risk (Fig. 2), drought vulnerability (Fig. 3), and presence of overabundant forest structure types (Fig. 4) – with wildfire transmission to homes (Fig. 8). We also recommend incorporating the large dense forest sustainability layer (Fig. 7) as an overlay when selecting treatment locations. Wildfire transmission is moderate in southern and eastern locations, indicating that wildfires starting in these locations are expected to expose homes in the Highway 410 corridor (Fig. 2).

Treatment priorities

Landscape treatment priority is highest in the southeastern portion of the planning area (Fig. 9). These high priority locations exhibit high fire risk, drought vulnerability, fire transmission to homes, and departed forest structure. Medium and high priority areas occur throughout the planning area. Some low priority areas may need treatment to address species composition, insect and disease risk, or other issues. In addition, fuel reduction treatments, defensible space, and home hardening are needed on private parcels with homes or other structures throughout the planning area.

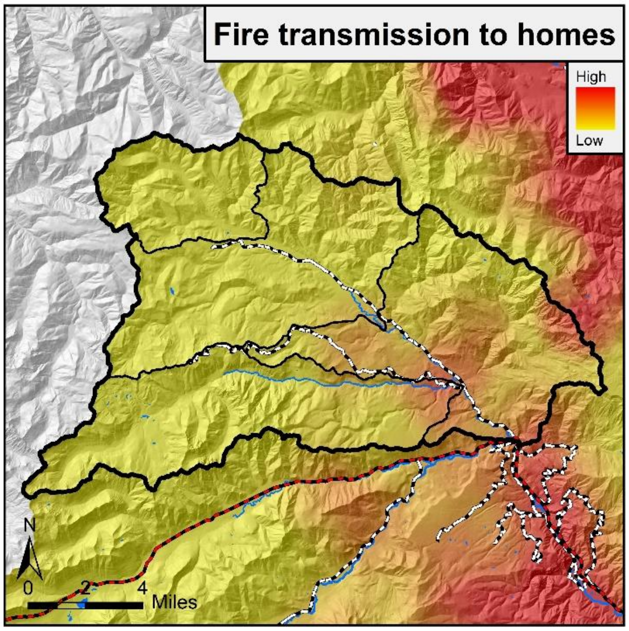


Figure 8. Fire transmission to homes shows where fires that expose structures are most likely to originate. It is based on simulated fire perimeters given contemporary patterns of fuels, topography, and wind.

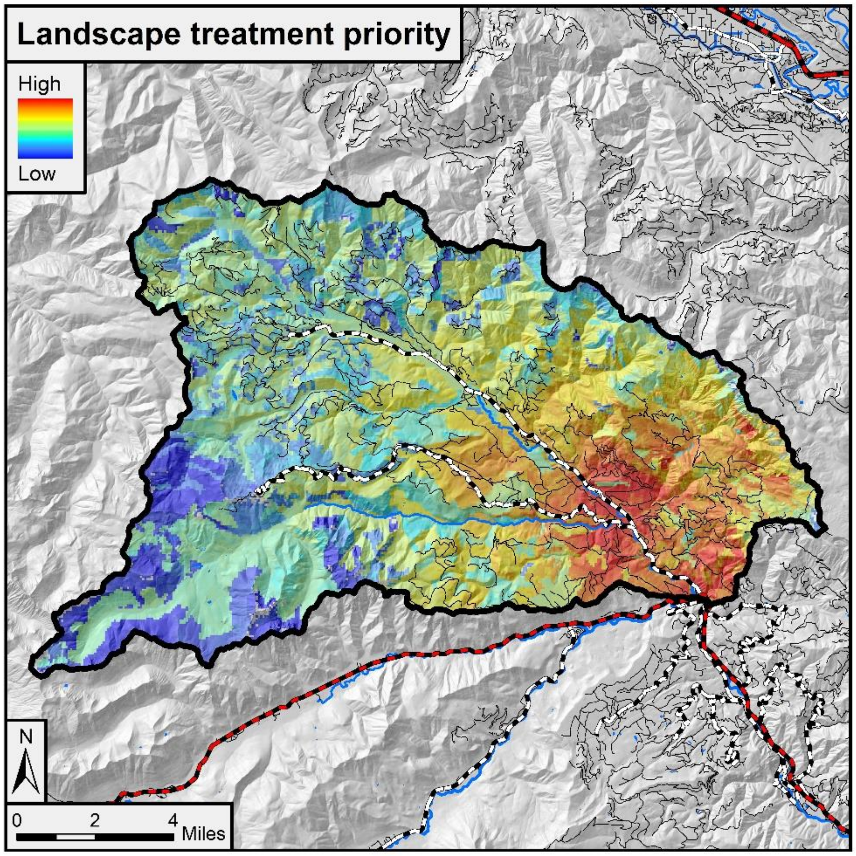


Figure 9. Landscape treatment priority is based on three metrics of forest health – forest fire risk (Fig. 1), drought vulnerability (Fig. 3), overabundant forest structure (Fig. 4) – as well as wildfire transmission to homes (Fig. 8).

Definitions

Vegetation Types

Cold forest: Upper elevation mixed-conifer forests with high-severity fires every 80-200+ years.

Dry forest: Ponderosa pine and Douglas-fir dominated forests that historically had surface fires every 5-25 years.

Moist forest: Forests that historically had mixed-severity fires every 30-100 years and were composed of fire-resistant (western larch, Douglas-fir) and fire-intolerant (grand fir) trees.

Woodland/Steppe: Grass and shrub lands that may have oak woodlands or ≤ 10% conifer cover.

Forest structure

Large tree: Overstory diameter > 20 inches.

Medium tree: Overstory diameter 10-20 inches.

Small tree: Overstory diameter < 10 inches.

Dense canopy: Greater than 40% tree canopy.

Open canopy: Less than 40% tree canopy.

Fuels: Shrubs, grasses, small trees, litter, duff, and dead wood.

Fuels treatments: some combination of mechanical density reduction (commercial or non-commercial) and surface and ladder fuel reduction (prescribed fire, piling & burning, etc.).

Managed wildfire: fire is allowed to burn under safe conditions to achieve management goals but can be suppressed if conditions change.

Wildfire Response Benefit Prioritization

Dual benefits for forest health and wildfire response

It is necessary to conduct treatments to both improve forest health and reduce fire risk to communities as well as provide conditions where firefighters can safely and efficiently conduct fire operations (e.g. suppression, prescribed burning, and managed wildfire). The wildfire response benefit metric (WRB; Fig. 10) identifies and prioritizes locations where values at risk that are more likely to be the focus of fire operations (homes, infrastructure, sources of drinking water, and commercially managed lands) coincide with areas likely to transmit wildfire to homes and generate severe fire behavior. Because there are positive feedbacks between healthy, resilient forests and safe, effective fire operations, the WRB metric also integrates the landscape treatment priority map (Fig. 9).

Where WRB is highest, actions may be needed to create and maintain conditions that provide a tactical advantage for fire operations. These actions will vary with the local context and can include landscape-level forest health and fuel treatments, treatments along fire control lines and escape routes, resident and community fire mitigation activities (e.g. defensible space, home hardening), and improving signage and road conditions. The WRB metric provides a high-level prioritization, and additional work at the local level is required to identify appropriate actions and assess their feasibility. WRB is useful for prioritizing Potential Control Lines (PCLs) for fire operations (Fig. 11). PCLs are a part of Potential Operational Delineations (PODs); see page 7.

In the Little Naches planning area, wildfire response benefit is highest in the southeastern portion at relatively low elevations. These hotspots of wildfire response benefit are due to a combination of high landscape treatment priority (Fig. 9), high crown fire potential in the southeastern half of the planning area, and high wildfire transmission to homes and structures in the Naches Valley along the Highway 410 corridor (Fig. 8).

Definitions (continued)

Wildfire response benefit: Any tactical advantage gained for wildfire response activities from actions on the landscape, including, but not restricted to, identifying and consolidating existing anchor points and control lines and reduction of potential fire behavior. Wildfire response benefit is not restricted to any specific wildfire management strategy and instead is centered on conditions that improve fire operations safety and effectiveness.

Potential Control Lines (PCLs): Boundaries of Potential Operational Delineations (PODs) relevant to fire control operations (e.g. roads, ridgetops, and water bodies).

Potential Operational Delineations (PODs) for wildland fire: Landscape containers whose boundaries are potential control lines (PCLs). PODs are useful for planning strategic response to unplanned ignitions, strategic fuel planning, and prioritizing fuel treatments within PODs.

Commercially managed lands: Commercially managed forestlands include: DNR Trustlands, Tribal forests, industrial forests, non-industrial private forests, and US Forest Service forests where timber is a primary management objective.

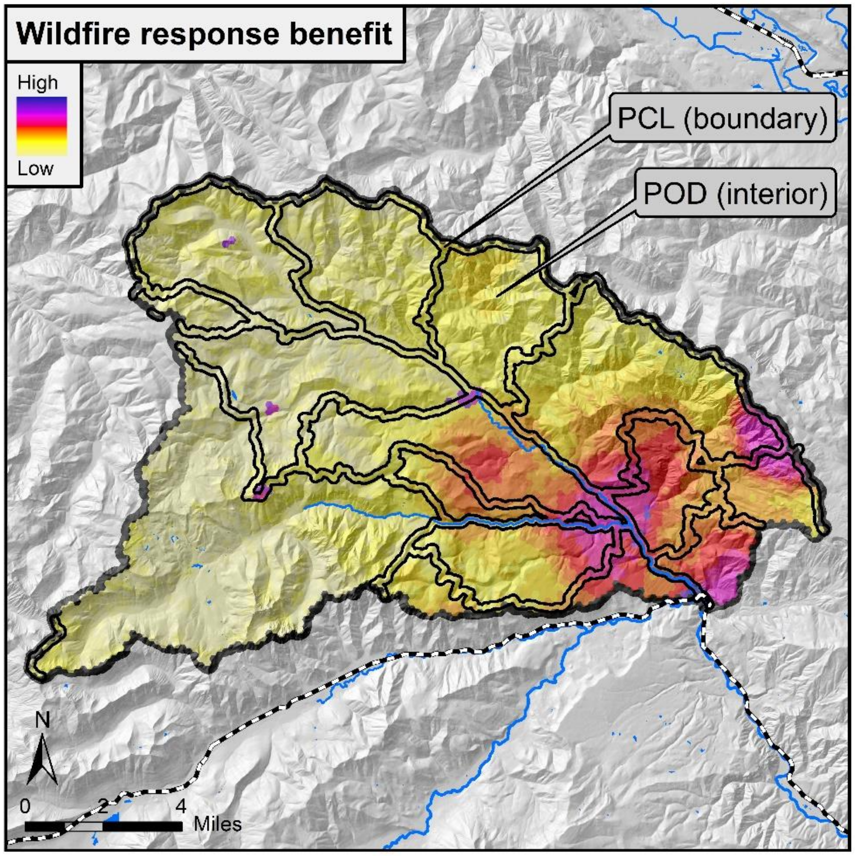


Figure 10. Wildfire response benefit (WRB) integrates multiple fire risk and forest health components. It includes four fire risk metrics representing highly valued resources – risk to homes, infrastructure, drinking water, commercially managed lands – as well as crown fire potential and wildfire transmission to homes (Fig. 8). Combined, these account for 75% of the wildfire response benefit. Landscape treatment priority (Fig. 9) accounts for the remaining 25%. Also shown are PODs: units bounded by PCLs (open black lines). One use of the WRB metric is to prioritize Potential Control Lines (PCLs) for fire operations (Fig. 11).

Prioritizing Landscape Treatments for Dual Benefits

Integration of forest health and wildfire response benefit using PODs

Potential Operational Delineations (PODs) provide a powerful spatial framework to communicate and identify locations that will deliver dual benefits for forest health and wildfire response at the landscape scale. PODs are large landscape areas delimited by Potential Control Lines (PCLs) for fire operations (suppression, prescribed fire, and managed wildfire), delineated by fire operations personnel. PCLs can be roads, ridgelines, or any artificial or natural fuelbreak that provides a strategic opportunity for fire operations. Summarizing landscape treatment priorities (Fig. 9) within PODs and wildfire response benefit priorities (Fig. 10) within PCLs enables planners and managers to identify, at a high level, locations where forest health or fuels treatments can be connected to a high-priority PCL that will support firefighter operations (e.g. ingress/egress route or opportunity for engagement).

Achieving forest health and wildfire response goals will require primarily large, landscape-level treatments across PODs (~100's-1,000's of acres) and, to a lesser extent, targeted treatments along PCLs.

There is important work to do in all Little Naches PODs to achieve the forest health treatment targets in Table 1. First priority PODs correspond to areas with moderate and high landscape treatment priority (Fig. 9) in eastern and southern portions of the planning area (Fig. 11). All of the first priority PODs are associated with first priority PCLs, enhancing opportunities for dual benefit treatments. Further work is needed to assess PCLs locally for their condition and detailed treatment needs, which will depend on management goals and values at risk. Ideally, landscape treatments will be implemented adjacent to priority PCLs where feasible to maximize both forest health and wildfire response goals.

Achieving forest health and wildfire response dual benefits will require primarily large, landscape-level treatments across PODs (~100's-1,000's of acres) and, to a lesser extent, targeted treatments along PCLs. These two approaches combined will contribute to restoring and maintaining large portions of the landscape in a resilient condition while providing safe and effective areas for firefighter engagement during suppression, prescribed fire, or managed wildfire operations.

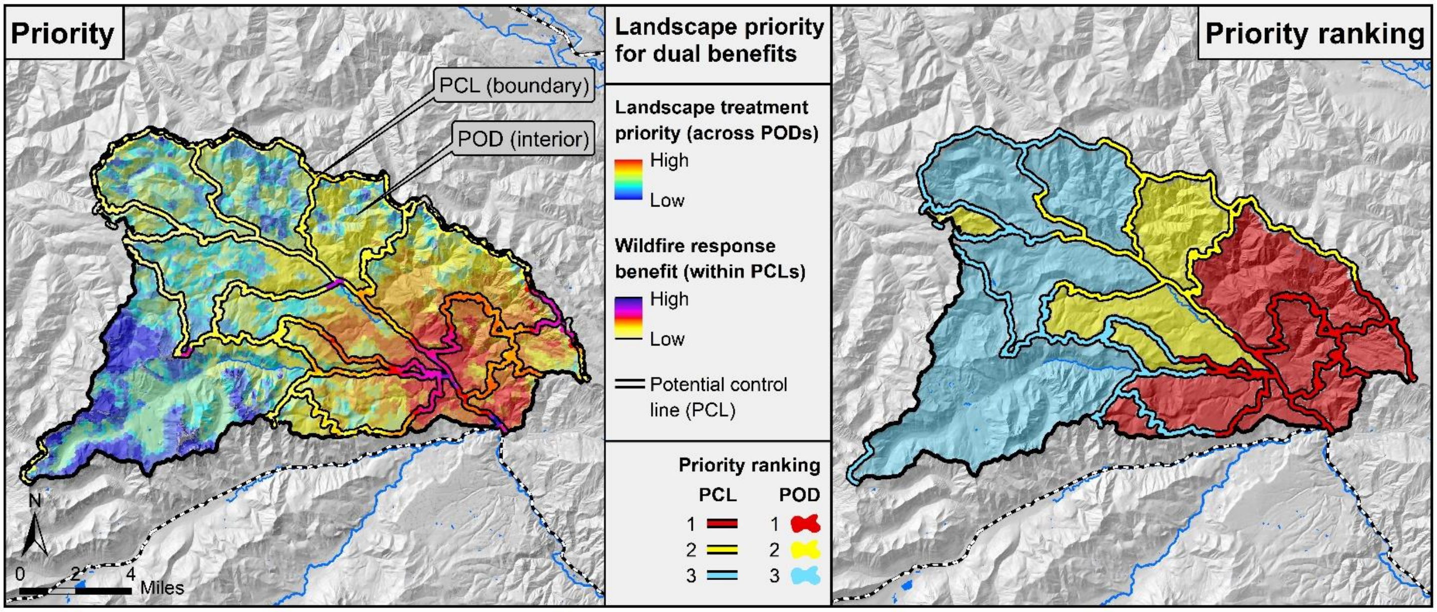


Figure 11. Landscape prioritization of dual benefits using PODs as a spatial framework to summarize treatment priorities. Both maps display landscape treatment priority within PODs and wildfire response benefit within PCLs. The map on the left shows the datasets at the raster level, while the map on the right shows the same information summarized and ranked within PODs and PCLs. PCL width is inflated to display spatial patterns. *PODs shown here are part of an ongoing process towards an all-lands delineation; POD boundaries are subject to change following on-the-ground vetting and continued dialogue among wildfire agencies and stakeholders.*

LITTLE PEND OREILLE PLANNING AREA LANDSCAPE EVALUATION SUMMARY (2022)

Total Acres	Forested Acres	Treatment Goal (Acres)
92,986	81,145	30,250 - 43,500

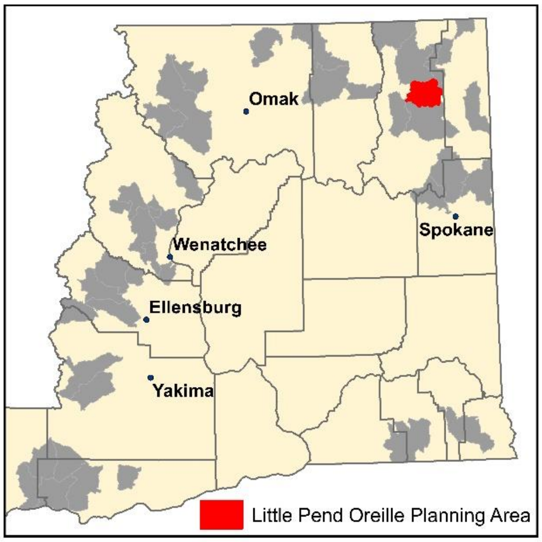


Figure 1. Planning area location in eastern WA.

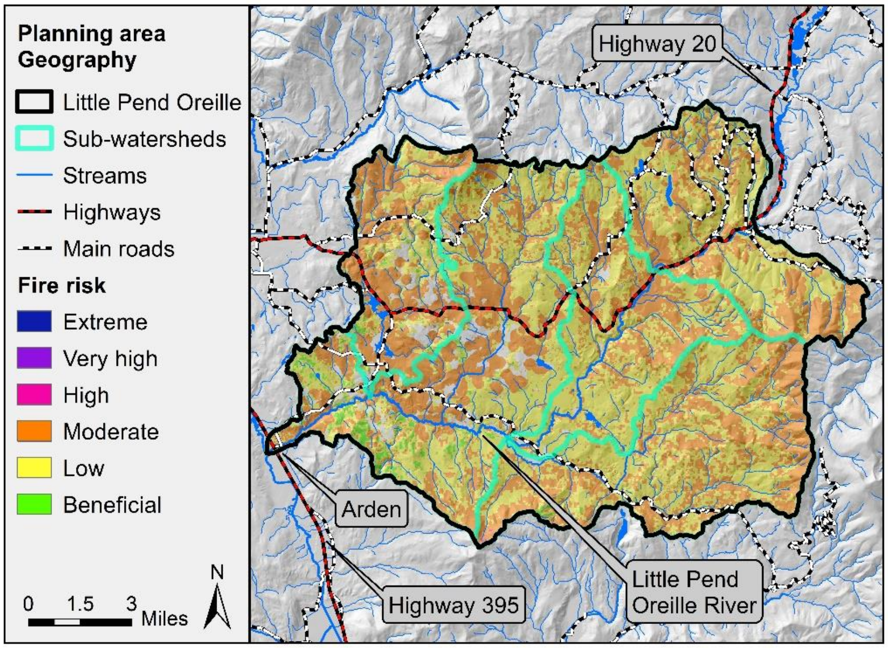


Figure 2. Planning area geography and fire risk, which integrates burn probability, fire intensity, and fire susceptibility of forests, infrastructure, and homes.

Planning Area Highlights

- Ownership is split primarily between the Little Pend Oreille National Wildlife Refuge (41%), small private land (27%), DNR Trustlands (16%), and industrial forestland (14%). The planning area boundary increased from an earlier version.
- Burn probability and fire risk are highest in the western half of the planning area where private property with homes is concentrated. Patches with high fuel loads in the eastern half also have moderate risk.
- Much of the existing moist and cold forests are projected to shift towards climate conditions that support dry forest.
- Treating 37-54% of forested acres is recommended to increase resilience and reduce fire risk to communities using a combination of mechanical, prescribed fire, and managed wildfire treatments where compatible with landowner goals.
- High priority locations for potential treatments that maximize forest health and wildfire response benefit are concentrated in western and southern portions of the planning area. These areas will require a mix of fuel reduction and defensible space treatments, as well as home hardening, to protect homes and restore resilient forests.
- High priority treatment areas are also present across the National Wildlife Refuge and on some blocks of DNR land. Recent and planned treatments on the National Wildlife Refuge and DNR lands are addressing risk reduction needs.

LEARN MORE

This landscape evaluation was completed in 2022.
For more details about DNR's priority planning areas please see: **https://www.dnr.wa.gov/ForestHealthPlan**
For data products and methods see: **https://bit.ly/ForestHealthData**

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Overarching Goals

Reduce wildfire risk and protect communities

Overall fire risk is low to moderate across the planning area (Fig. 2) due to burn fire probability, which is based on large fires from 1992-2015. If a fire does occur, however, predicted fire risk is highest in the western half and along the Little Pend Oreille River where private property with homes is concentrated. This area is a patchwork of agricultural land and forest with mostly low to moderate fuel loading. Large to moderate patches with high fuel loading and predicted high fire severity exist in the eastern half, as well as in the northwest and southwest portions. These patches are dissected by past treatments and non-forest. Without treatments, fire risk is predicted to increase as burn probability increases with projected warming. Landscape treatments will reduce the risk of large, high-severity fires. In addition, implementing treatments around homes and establishing potential control lines will increase firefighter safety and help keep fires from moving west towards the communities of Arden and Colville.

Increase resilience and prepare for climate change

By mid-century, most of the areas that currently support moist and cold forest are projected to have moisture stress levels currently associated with dry forest (Fig. 3). Treatments that reduce density and favor drought-tolerant species will reduce vulnerability to drought mortality, and are especially important on south-facing slopes and areas with droughty soils in the western portion of the planning area. North-facing slopes and higher elevation areas in the eastern half, as well near Old Dominion Mountain, are projected to support moist and cold forest.

Sustain wildlife habitat

Habitat for dry forest, large tree, open canopy species (e.g. White Headed Woodpecker) is moderately abundant in the western half, but patches are concentrated on the National Wildlife Refuge and DNR land where treatments have created larger patches. Habitat for species that depend on dry to moist, closed canopy forest with large trees (e.g. Northern Goshawk) is very abundant on the Wildlife Refuge, with moderate to large patches. On the Refuge and DNR land, opportunities exist for further expanding White Headed Woodpecker habitat in dense forests with high drought vulnerability and fire risk. These treatments would reduce risk of a large crown fire and thus help sustain all habitat types. Habitat for cold forest, large-tree, closed canopy species (e.g. American Marten) is also very abundant on the Refuge. Sustaining habitat for Canada Lynx in the face of warming temperatures and increasing fire probability is a significant challenge in this planning area. Current Lynx management affects the amount and types of treatment that are currently possible. Habitat layers are available in the data products.

Enhance rural economic development

Meeting treatment needs will produce a large volume of forest products and economic activity. Although warming trends will necessitate managing for more drought-tolerant species and lower densities and fuel loads on current and future dry sites, long-term timber production will likely be possible on DNR Trustlands and private land. Reducing fire risk will help sustain recreation while reducing the potential of smoke affecting communities.

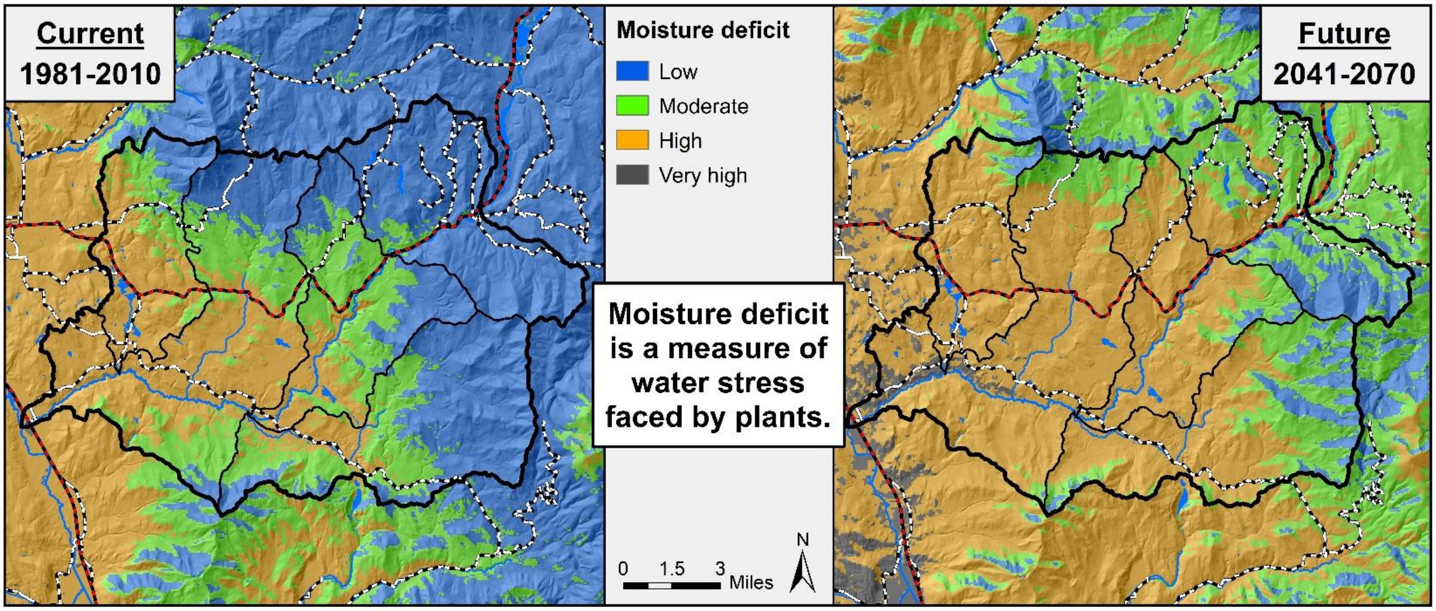


Figure 3. Current (left) and future (right) moisture stress levels based on water balance deficit. Low levels are associated with moist and cold forest types, high with dry forest types, and very high with woodland or shrub-steppe. Future climate is based on a relatively high greenhouse gas emissions scenario (RCP 8.5).

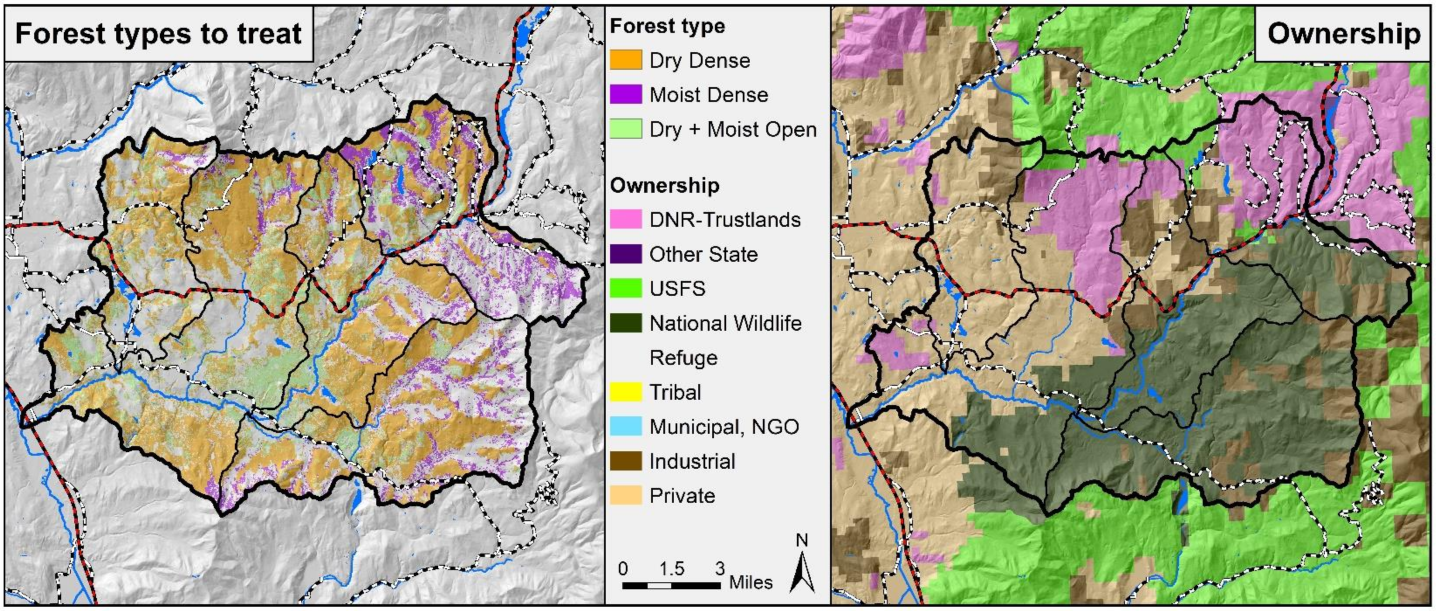
Forest Health Treatment Needs

Treating 30,250 to 43,500 acres is recommended to move the landscape into a resilient condition (37-54% of forested acres; Table 1). This total includes an estimated 24,500-34,500 acres to shift dense to open forest and 5,750-9,000 acres of maintenance treatments in existing open forest, based on current condition data from 2016 LiDAR imagery. Treatments completed after the 2016 LiDAR acquisition on National Wildlife Refuge and DNR land have already met some of this treatment need. Treatment need exists across ownerships, although the Wildlife Refuge has the highest amount.

Meeting this target range will require multiple treatment types (Table 1). Almost all treatments are commercially viable based on tree size. Large prescribed fires and/or managed wildfire under safe conditions will likely be needed to accomplish forest health objectives in portions of the Wildlife Refuge that do not have road access. Treatment type will depend on road access, logging systems, markets, and other considerations. Individual landowners will conduct their own planning and decision-making processes to determine acres and types of treatments to achieve the landscape goals while meeting their own objectives and regulatory requirements.

Table 1. Summary of forest health treatment needs. ***See methods for details on how the treatment need range is derived.***

Forest conditions to treat		Treatment need (acres)	Current acres by major landowner*				
Type	**Size class**		**Nat. Wildlife Refuge**	**Private**	**DNR-Trustlands**	**Industrial**	**USFS**
Dry Dense	Medium-Large	21,000 - 28,000	16,403	8,208	7,808	3,474	835
Moist Dense	Medium-Large	3,500 - 6,500	10,723	724	2,358	1,869	742
Dry + Moist Open	Medium-Large	5,750 - 9,000	3,680	3,128	2,403	1,377	116
Total	**30,250 - 43,500**		**These are current acres, not targets*				
Anticipated treatment type	🟦	Commercial thin plus fuels treatment if access exists. May be noncommercial, fire only (prescribed or managed wildfire), or regeneration treatment.					
	🟩	Maintenance treatment: prescribed fire, managed wildfire, or mechanical fuels treatment. *Target range corresponds to 50-75% of dry open and 25-50% of moist open forests.*					



Left: Figure 4. Forest structure types that are overabundant relative to targets for a resilient landscape, as well as potential maintenance treatments. Only a portion of the areas shown need to be treated. Right: Figure 5. Current land ownership.

Forest Health Treatment Needs (continued)

Dry dense forest treatment need

Medium tree, dense forest structure is over-represented on dry sites. Large patches are present (Fig. 4). Large tree forest with >60% canopy cover is also significantly over-represented on the National Wildlife Refuge. Much of the dry forest is also dominated by Douglas-fir. These forests are vulnerable to uncharacteristic levels of high- and mixed-severity fire, as well as a combination of drought stress, root disease, and Douglas-fir beetle. Treating 21,000-28,000 acres of dry dense forest (Table 1) is recommended to create large patches (~100-1000+ ac) of open forest and shift the majority of dry sites to open forest (Fig. 6). Thinning treatments in large tree, dense forests will create large tree, open forest, which is currently very low. In dense forests with medium trees, treatments plus subsequent growth will increase large tree, open forest. Shifting composition toward ponderosa pine and western larch is also needed in some locations; planting may be needed after treatments or high-severity fire.

Moist and cold dense forest treatment need

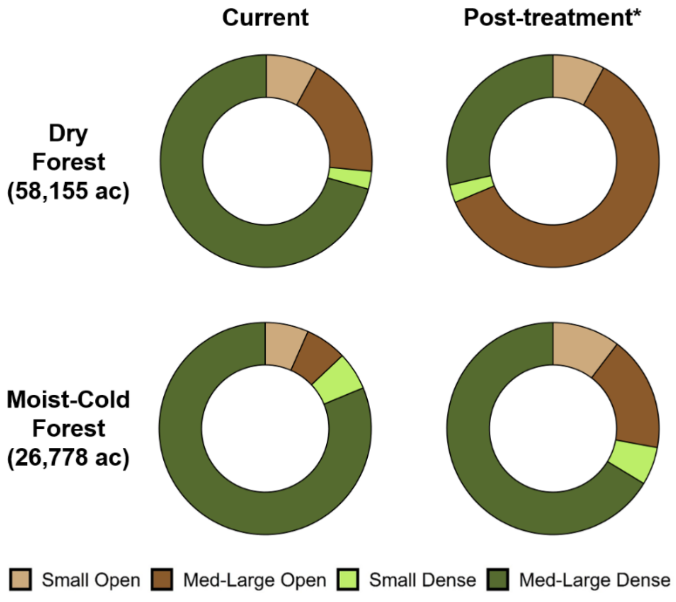
Medium tree, dense forest on moist sites exceeds desired ranges. Patch sizes moderate to small, but are often connected with dense, dry forest patches. Large tree forest with >60% canopy cover is also over-represented on the National Wildlife Refuge. Large tree, open and moderate canopy cover (40-60%) is below desired ranges. Treating 3,500-6,500 acres of this type (Table 1, Fig. 4) is recommended, especially in larger patches that are connected with dense, dry forest patches and are projected to support dry forest in the future (Fig. 3). This will enhance the mosaic of open, moderate, and dense patches and reduce risks of large crown fire and insect outbreaks. Increasing the relative composition of western larch and ponderosa pine is also needed, especially on sites projected to shift to dry forest (Fig. 3). If landscape treatment targets are achieved, over 70% of the total moist and cold forest area will remain dense (>40% canopy cover) (Fig. 6) to meet habitat, wood production, and other objectives.

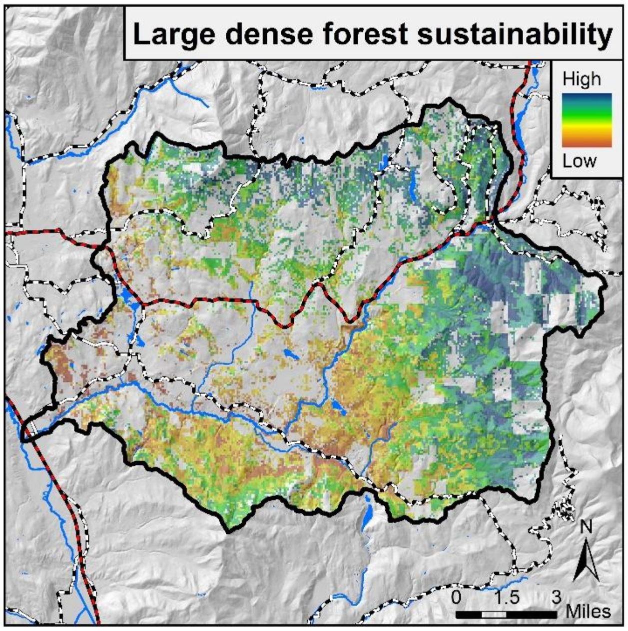
Open forest maintenance treatment need

Over the next 15 years, an estimated 5,750-9,000 acres of currently open forests on dry and moist sites will need maintenance treatments. These sites are mostly areas that have been treated. Maintenance treatments include prescribed fire, mechanical fuel reduction, or managed wildfire where compatible with landowner objectives. Specific maintenance strategies will depend on landowner objectives and time since treatment.

Sustainable locations for dense forest with large trees

Locations with low to moderate current and future moisture deficits (Fig. 3) and low fire risk (Fig. 2) offer the most sustainable locations to maintain sufficient area and patch sizes of this habitat type. Sustainable locations are concentrated in the eastern and northern portions (Fig. 7). This sustainability map can be used in conjunction with treatment priority (Fig. 9) to select areas to shift to open forest vs. where to maintain this habitat type.





Left: Figure 6. Current and post-treatment proportions of forest types and structure classes. * mid-point of range in Table 1. Right: Figure 7. Sustainability of current and potential large tree, dense forest based on fire risk and drought vulnerability.

Landscape Treatment Prioritization

Prioritizing for forest health & to reduce fire exposure of homes

Landscape treatment priority integrates three metrics of forest health – forest fire risk (Fig. 2), drought vulnerability (Fig. 3), and presence of overabundant forest structure types (Fig. 4) – with wildfire transmission to homes (Fig. 8). We also recommend incorporating the large dense forest sustainability layer (Fig. 7) as an overlay when selecting treatment locations. Wildfire transmission is moderate to high in the western portion, indicating that wildfires starting in these locations are predicted to expose homes in and around the communities of Arden and Colville (Fig. 2).

Treatment priorities

Landscape treatment priority is highest along the western edge (Fig. 9), which is predominantly private land with homes, as well as some DNR land (Fig. 9). This area will require a mix of fuel reduction and defensible space treatments, as well as home hardening, to restore resilient forests and protect communities. High priority treatment areas are also present across the National Wildlife Refuge, on the north central block of DNR land, and on USFS land (Fig. 5, Fig. 9). Some low priority areas may need treatment to address species composition, insect and disease risk, or other issues.

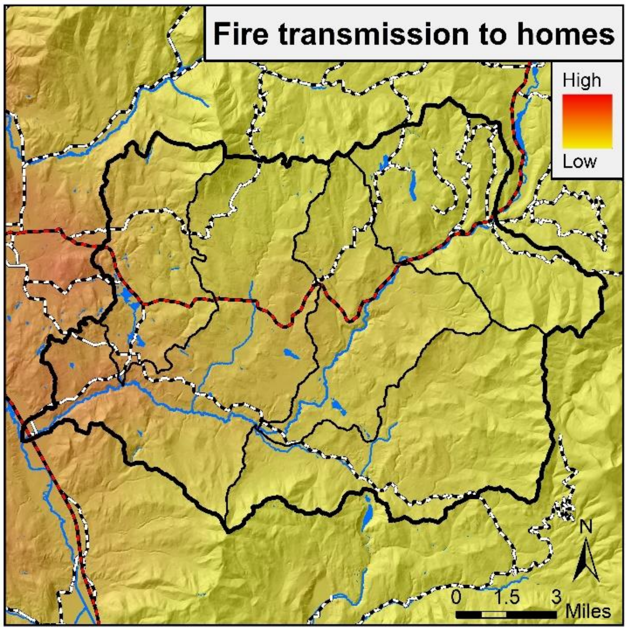


Figure 8. Fire transmission to homes shows where fires that expose structures are most likely to originate. It is based on simulated fire perimeters given contemporary patterns of fuels, topography, and wind.

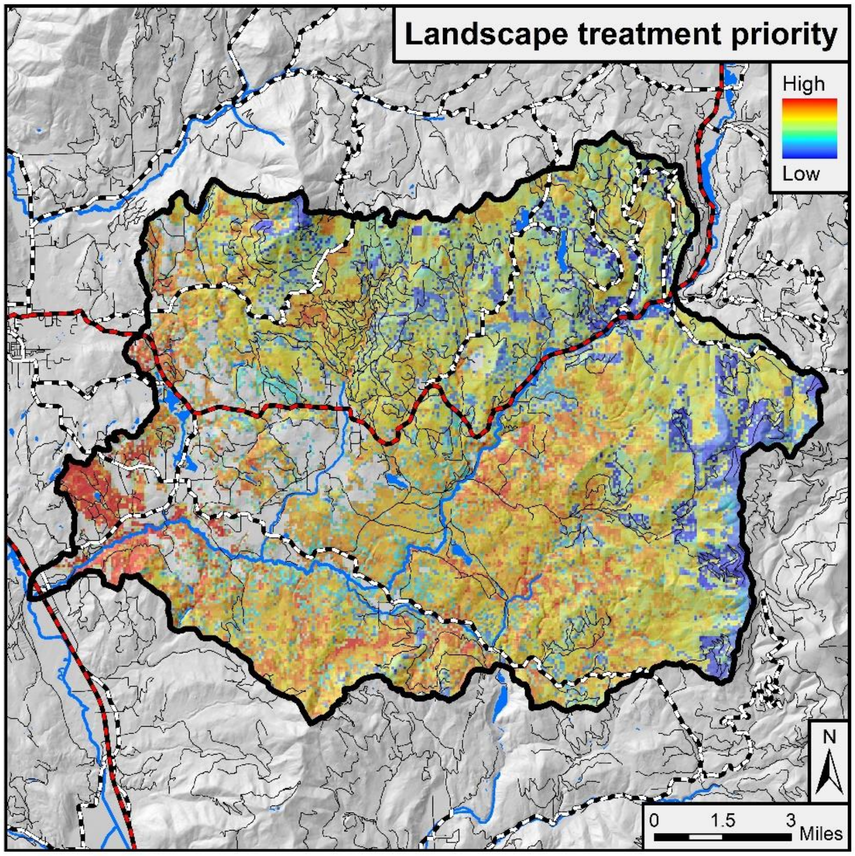


Figure 9. Landscape treatment priority is based on three metrics of forest health – forest fire risk (Fig. 1), drought vulnerability (Fig. 3), overabundant forest structure (Fig. 4) – as well as wildfire transmission to homes (Fig. 8).

Definitions

Vegetation Types

Cold forest: Upper elevation mixed-conifer forests with high-severity fires every 80-200+ years.

Dry forest: Ponderosa pine and Douglas-fir dominated forests that historically had surface fires every 5-25 years.

Moist forest: Forests that historically had mixed-severity fires every 30-100 years and were composed of fire-resistant (western larch, Douglas-fir) and fire-intolerant (grand fir) trees.

Woodland/Steppe: Grass and shrub lands that may have oak woodlands or ≤ 10% conifer cover.

Forest structure

Large tree: Overstory diameter > 20 inches.

Medium tree: Overstory diameter 10-20 inches.

Small tree: Overstory diameter < 10 inches.

Dense canopy: Greater than 40% tree canopy.

Open canopy: Less than 40% tree canopy.

Fuels: Shrubs, grasses, small trees, litter, duff, and dead wood.

Fuels treatments: some combination of mechanical density reduction (commercial or non-commercial) and surface and ladder fuel reduction (prescribed fire, piling & burning, etc.).

Managed wildfire: fire is allowed to burn under safe conditions to achieve management goals but can be suppressed if conditions change.

Wildfire Response Benefit Prioritization

Dual benefits for forest health and wildfire response

It is necessary to conduct treatments to both improve forest health and reduce fire risk to communities as well as provide conditions where firefighters can safely and efficiently conduct fire operations (e.g. suppression, prescribed burning, and managed wildfire). The wildfire response benefit metric (WRB; Fig. 10) identifies and prioritizes locations where values at risk that are more likely to be the focus of fire operations (homes, infrastructure, sources of drinking water, and commercially managed lands) coincide with areas likely to transmit wildfire to homes and generate severe fire behavior. Because there are positive feedbacks between healthy, resilient forests and safe, effective fire operations, the WRB metric also integrates the landscape treatment priority map (Fig. 9).

Where WRB is highest, actions may be needed to create and maintain conditions that provide a tactical advantage for fire operations. These actions will vary with the local context and can include landscape-level forest health and fuel treatments, treatments along fire control lines and escape routes, resident and community fire mitigation activities (e.g. defensible space, home hardening), and improving signage and road conditions. The WRB metric provides a high-level prioritization, and additional work at the local level is required to identify appropriate actions and assess their feasibility. WRB is useful for prioritizing Potential Control Lines (PCLs) for fire operations (Fig. 11). PCLs are a part of Potential Operational Delineations (PODs); see page 7.

In the Little Pend Oreille planning area, wildfire response benefit is highest in western portions (Fig. 2) due to the combination of high risk to homes and infrastructure with hotspots of relatively high landscape treatment priority (Fig. 9), wildfire transmission to structures (Fig. 8), and crown fire potential. Crown fire potential is high throughout the planning area in locations with dense, multi-layered forest structure.

Definitions (continued)

Wildfire response benefit: Any tactical advantage gained for wildfire response activities from actions on the landscape, including, but not restricted to, identifying and consolidating existing anchor points and control lines and reduction of potential fire behavior. Wildfire response benefit is not restricted to any specific wildfire management strategy and instead is centered on conditions that improve fire operations safety and effectiveness.

Potential Control Lines (PCLs): Boundaries of Potential Operational Delineations (PODs) relevant to fire control operations (e.g. roads, ridgetops, and water bodies).

Potential Operational Delineations (PODs) for wildland fire: Landscape containers whose boundaries are potential control lines (PCLs). PODs are useful for planning strategic response to unplanned ignitions, strategic fuel planning, and prioritizing fuel treatments within PODs.

Commercially managed lands: Commercially managed forestlands include: DNR Trustlands, Tribal forests, industrial forests, non-industrial private forests, and US Forest Service forests where timber is a primary management objective.

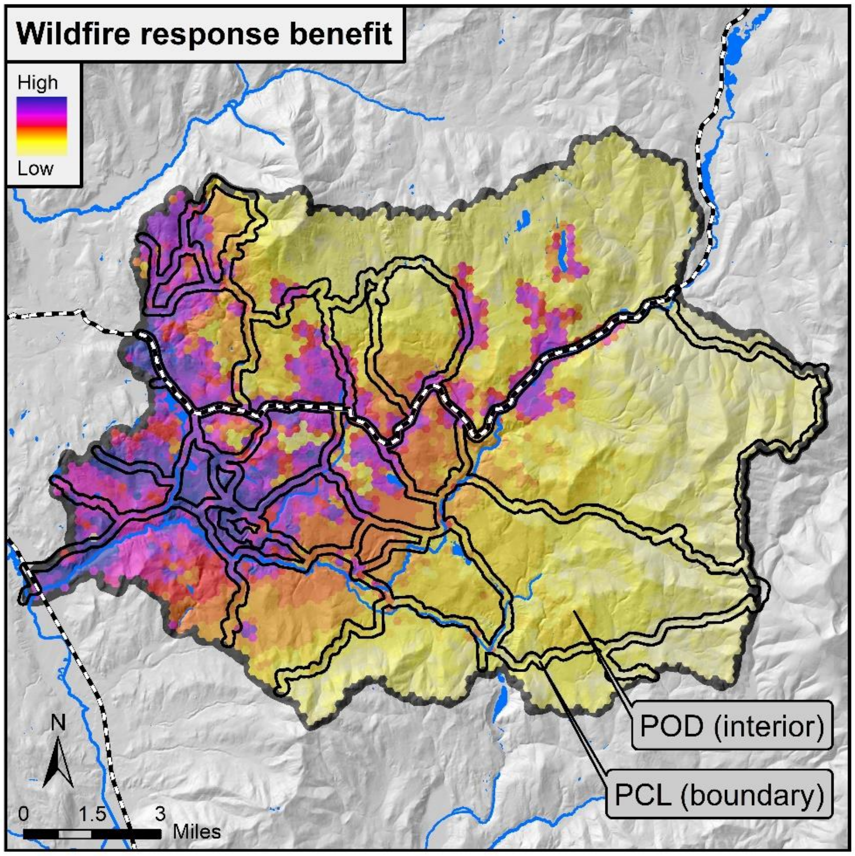


Figure 10. Wildfire response benefit (WRB) integrates multiple fire risk and forest health components. It includes four fire risk metrics representing highly valued resources – risk to homes, infrastructure, drinking water, commercially managed lands – as well as crown fire potential and wildfire transmission to homes (Fig. 8). Combined, these account for 75% of the wildfire response benefit. Landscape treatment priority (Fig. 9) accounts for the remaining 25%. Also shown are PODs: units bounded by PCLs (open black lines). One use of the WRB metric is to prioritize Potential Control Lines (PCLs) for fire operations (Fig. 11).

Prioritizing Landscape Treatments for Dual Benefits

Integration of forest health and wildfire response benefit using PODs

Potential Operational Delineations (PODs) provide a powerful spatial framework to communicate and identify locations that will deliver dual benefits for forest health and wildfire response at the landscape scale. PODs are large landscape areas delimited by Potential Control Lines (PCLs) for fire operations (suppression, prescribed fire, and managed wildfire), delineated by fire operations personnel. PCLs can be roads, ridgelines, or any artificial or natural fuelbreak that provides a strategic opportunity for fire operations. Summarizing landscape treatment priorities (Fig. 9) within PODs and wildfire response benefit priorities (Fig. 10) within PCLs enables planners and managers to identify, at a high level, locations where forest health or fuels treatments can be connected to a high-priority PCL that will support firefighter operations (e.g. ingress/egress route or opportunity for engagement).

Achieving forest health and wildfire response goals will require primarily large, landscape-level treatments across PODs (~100's-1,000's of acres) and, to a lesser extent, targeted treatments along PCLs.

There is important work to do in all Little Pend Oreille PODs to achieve the forest health treatment targets in Table 1. First priority PODs correspond to areas with moderate to high landscape treatment priority (Fig. 9) throughout the planning area (Fig. 11). Most areas across the southern portion of the planning area are first priority PODs. Many of the first priority PODs are associated with first and second priority PCLs, enhancing opportunities for dual benefit treatments. Additional first and second priority PCLs occur throughout the western half. Further work is needed to assess PCLs locally for their condition and detailed treatment needs, which will depend on management goals and values at risk. Ideally, landscape treatments will be implemented adjacent to priority PCLs where feasible to maximize both forest health and wildfire response goals.

Achieving forest health and wildfire response dual benefits will require primarily large, landscape-level treatments across PODs (~100's-1,000's of acres) and, to a lesser extent, targeted treatments along PCLs. These two approaches combined will contribute to restoring and maintaining large portions of the landscape in a resilient condition while providing safe and effective areas for firefighter engagement during suppression, prescribed fire, or managed wildfire operations.

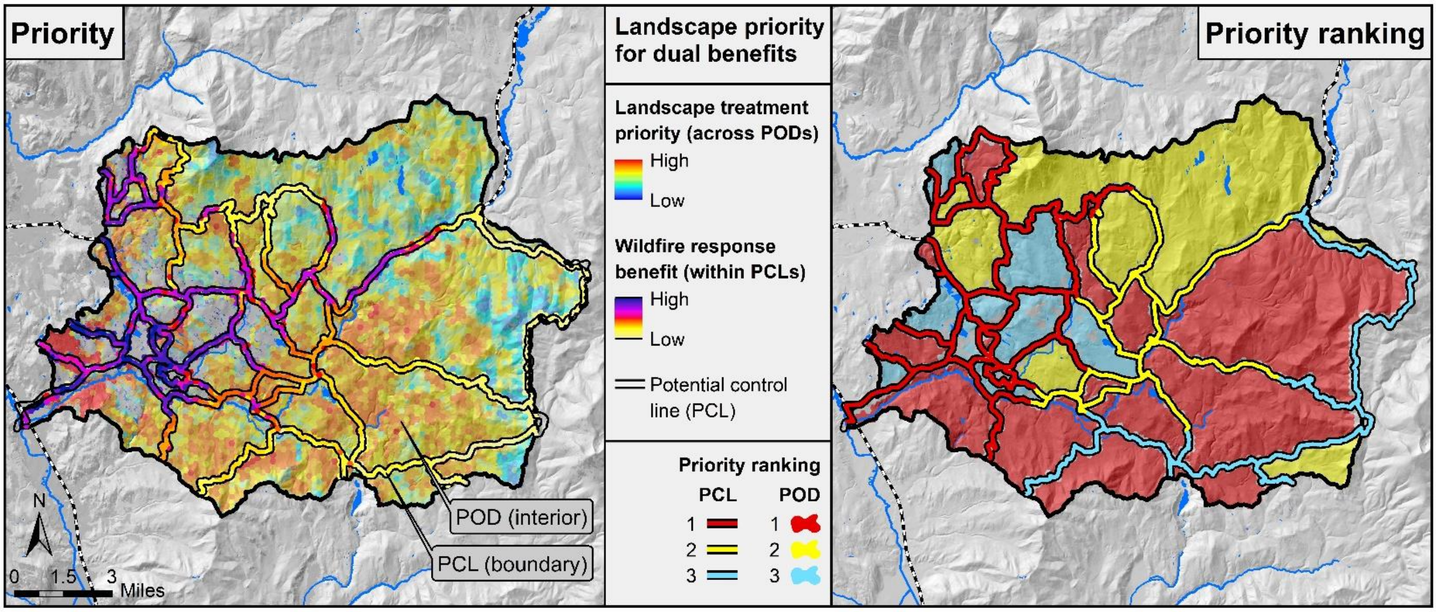


Figure 11. Landscape prioritization of dual benefits using PODs as a spatial framework to summarize treatment priorities. Both maps display landscape treatment priority within PODs and wildfire response benefit within PCLs. The map on the left shows the datasets at the raster level, while the map on the right shows the same information summarized and ranked within PODs and PCLs. PCL width is inflated to display spatial patterns. *PODs shown here are part of an ongoing process towards an all-lands delineation; POD boundaries are subject to change following on-the-ground vetting and continued dialogue among wildfire agencies and stakeholders.*

MT SPOKANE PLANNING AREA LANDSCAPE EVALUATION SUMMARY (2022 UPDATE)

Total Acres	Forested Acres	Treatment Goal (Acres)
121,767	95,814	29,000 - 42,000

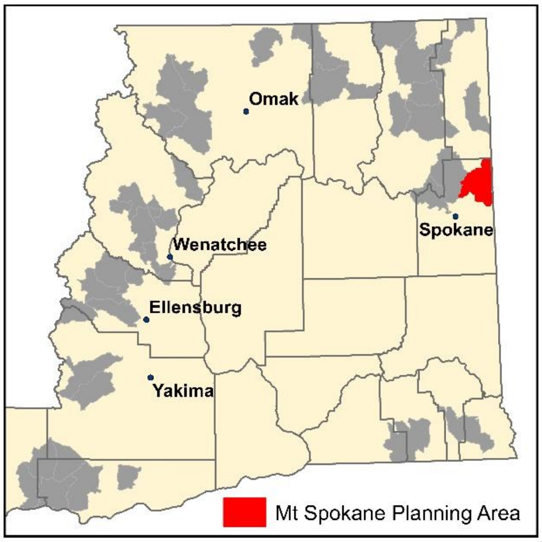


Figure 1. Planning area location in eastern WA.

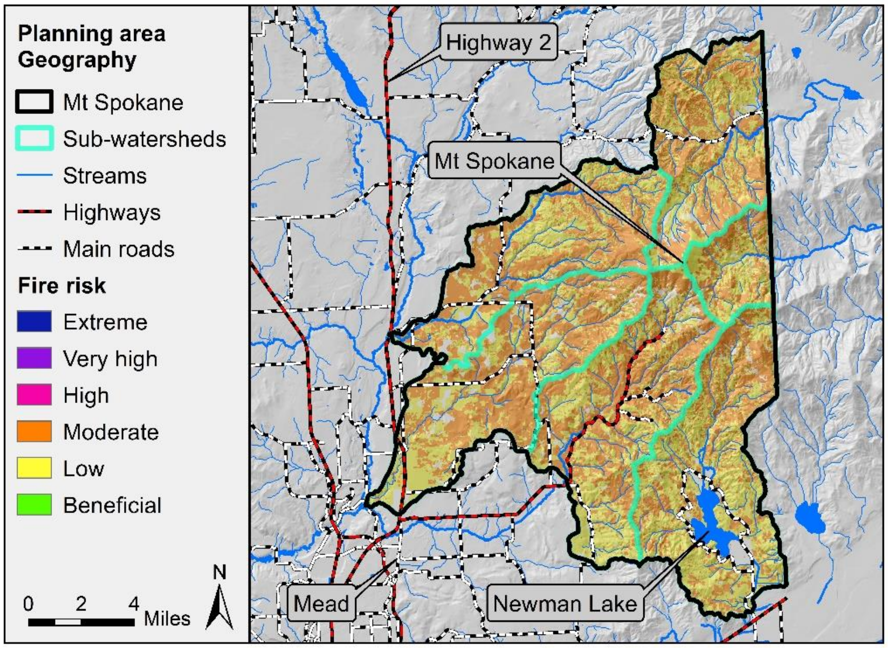


Figure 2. Planning area geography and fire risk, which integrates burn probability, fire intensity, and fire susceptibility of forests, infrastructure, and homes.

Planning Area Highlights

- This Landscape Evaluation is an update to the evaluation conducted in 2018. New LiDAR imagery covering the majority of the planning area was collected in 2019 and 2020, improving our estimates forest structure and treatment needs.
- Ownership is split among private lands (59%), industrial forestland (24%), Mt Spokane State Park (10%), DNR Trustlands (7%), and other ownerships (1%).
- Fire risk is moderate to low across the planning area. However, if multiple fires start during a period of hot, dry weather and overwhelm suppression resources, the risk of tree mortality and home loss is high in many areas.
- By mid-century, the majority of the moist forests in the planning area are projected to have a climate that currently supports dry forests. Spring snowpack on Mt Spokane is projected to decline significantly.
- Treating 30-44% of forested acres is recommended to increase resilience and reduce fire risk to communities using a combination of mechanical treatments, prescribed fire, and managed wildfire.
- High priority locations for potential treatments that maximize forest health and wildfire response benefit are located in central and northeastern portions. South-facing slopes within Mt Spokane State Park are also a high priority.

LEARN MORE

This landscape evaluation update was completed in 2022.
For more details about DNR's priority planning areas please see: **https://www.dnr.wa.gov/ForestHealthPlan**
For data products and methods see: **https://bit.ly/ForestHealthData**

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Overarching Goals

Reduce wildfire risk and protect communities

Fire risk is moderate across most of the planning area (Fig. 2) due to low burn probability. Fire starts have been common, but fire suppression has been highly effective in recent decades. If multiple fires start during a period of hot, dry weather and overwhelm suppression resources, risk is high for private property with homes. Predicted tree mortality in more densely forested areas is also high, especially around Mt Spokane. Without treatments, fire risk is predicted to rise as burn probability increases with projected climate change, which is underscored by recent dry spring and summer conditions in Northeast Washington. Landscape treatments will help reduce the risk of large, high-severity fire and restore conditions conducive to a more characteristic balance of low- and mixed-severity fire, with some high-severity patches, which will also give fire managers more options during wildfires. In addition, implementing fuel reduction treatments around homes and establishing potential control lines will increase firefighter safety and help protect communities.

Increase resilience and prepare for climate change

By mid-century, the majority of lower and mid-elevation forests in the planning area are projected to have moisture stress levels that are currently associated with dry forest (Fig. 3). Low and moderate moisture stress levels are projected to remain at higher elevations in the eastern portion, especially on north-facing slopes. Spring snowpack on Mt Spokane is projected to decline significantly. Treatments that reduce density and favor drought-tolerant species will help forests adapt to changing climate.

Sustain wildlife habitat (layers available in data products)

Habitat for dry forest, large tree, open canopy species (e.g. White Headed Woodpecker) is moderately abundant and well distributed along the northwestern boundary and southern area. Patch sizes are small to medium. Habitat is low in the middle and western portions. Habitat for species that depend on moist, closed canopy forest with large trees (e.g. Northern Goshawk) is abundant in the eastern region around Mt Spokane State Park, with mostly large and aggregated patch sizes. In higher fire risk locations, reducing tree density and canopy cover will reduce crown fire potential and drought vulnerability while helping to maintain habitat in the most sustainable locations (Fig. 7). This would extend the spatial distribution and increase patch sizes of open canopy habitat on dry sites at lower elevations in the south and west. Habitat for cold forest, large-tree, closed canopy species (e.g. American Marten) is also abundant in the moist and cold forest portions, with large patch sizes in Mt Spokane State Park.

Enhance rural economic development

Most of the planning area has road access, and most of the areas needing treatment will support commercial treatments. Meeting restoration treatment needs will produce a large amount of forest products and related economic activity. Although warming trends will necessitate managing for more drought-tolerant species and lower densities and fuel loads on current and future dry sites, long-term timber production should be possible. Reducing fire risk will help sustain recreation and tourism while reducing the potential of smoke affecting communities.

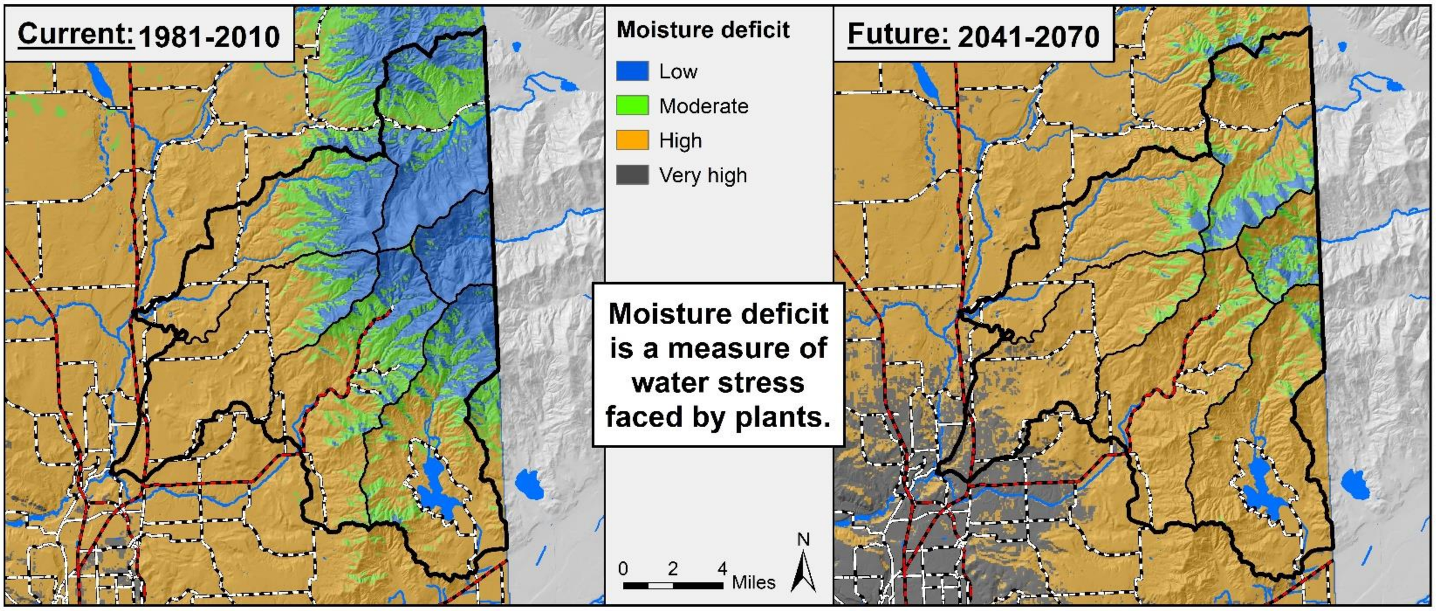


Figure 3. Current (left) and future (right) moisture stress levels based on water balance deficit. Low levels are associated with moist and cold forest types, high with dry forest types, and very high with woodland or shrub-steppe. Future climate is based on a relatively high greenhouse gas emissions scenario (RCP 8.5).

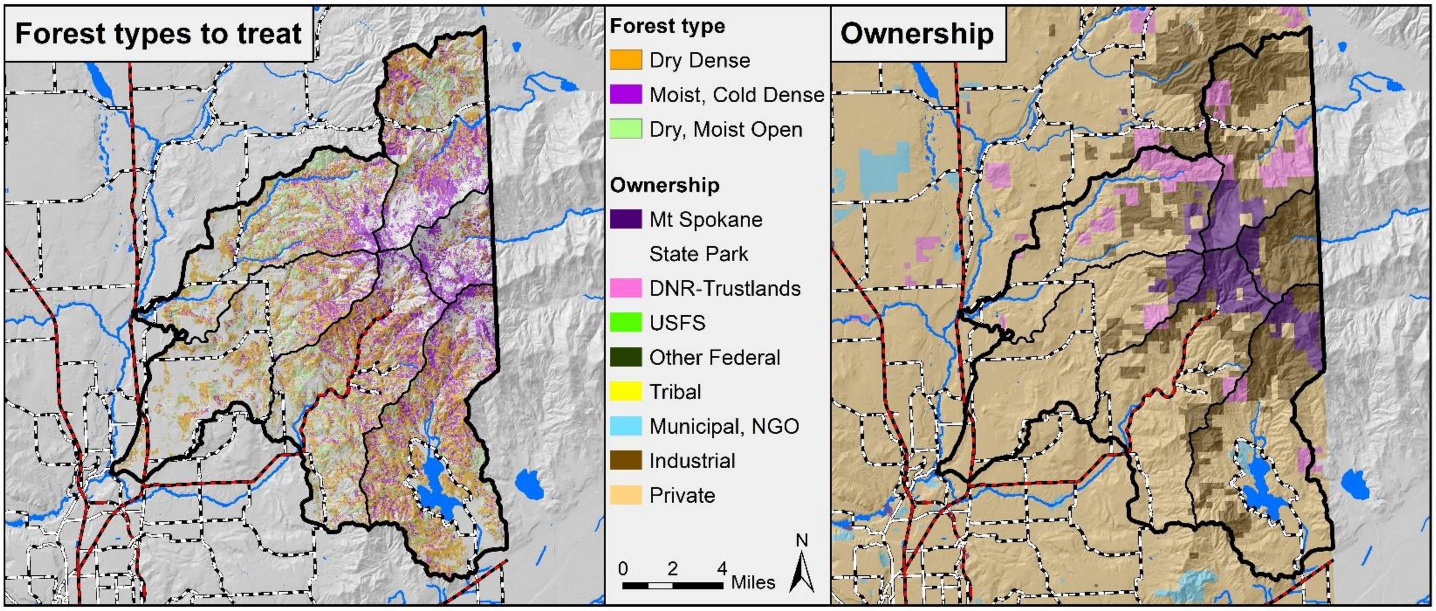
Forest Health Treatment Needs

Treating 29,000 to 42,000 acres is recommended to move the landscape into a resilient condition (30-44% of forested acres; Table 1). This total includes an estimated 24,500-35,000 acres to shift dense to open forest and 4,500-7,000 acres of maintenance treatments in existing open forest. Treatment need is 3,500 acres higher than in the 2018 Landscape Evaluation due to use of more accurate current condition data from 2019 and 2020 LiDAR. The majority of treatment need is located on private land, but substantial need exists on other ownerships as well.

Meeting this target range will require multiple treatment types (Table 1). Managed wildfire under safe conditions may be needed in less accessible locations. Most treatments are commercially viable based on tree size. Treatment type will depend on road access, logging systems, markets, and other considerations. Individual landowners will conduct their own planning and decision-making processes to determine acres and types of treatments to achieve the landscape goals while meeting their own objectives and regulatory requirements.

Table 1. Summary of forest health treatment needs. ***See methods for details on how the treatment need range is derived.***

Forest conditions to treat		Treatment need (acres)	Current acres by major landowner*				
Type	**Size class**		**Private**	**Industrial**	**State Park**	**DNR-Trustland**	**City-County**
Dry Dense	Small	1,000 - 1,500	770	1,653	26	118	0
	Medium-Large	17,000 - 24,000	20,641	7,042	1,428	2,062	254
Moist + Cold Dense	Medium-Large	6,500 - 9,500	7,864	6,961	3,839	1,698	56
Dry + Moist Open	Medium-Large	4,500 - 7,000	6,928	2,527	34	1,527	20
Total		**29,000 - 42,000**	**These are current acres, not targets*				
Anticipated treatment type	🟦	Noncommercial thin plus fuels treatment. May be fire only (prescribed or managed wildfire).					
	🟦	Commercial thin plus fuels treatment if access exists. May be noncommercial, fire only (prescribed or managed wildfire), or regeneration treatment.					
	🟩	Maintenance treatment: prescribed fire, managed wildfire, or mechanical fuels treatment. *Target range corresponds to 50-75% of dry open and 25-50% of moist open forests.*					



Left: Figure 4. Forest structure types that are overabundant relative to targets for a resilient landscape, as well as potential maintenance treatments. Only a portion of the areas shown need to be treated. Right: Figure 5. Current land ownership.

Forest Health Treatment Needs (continued)

Dry dense forest treatment need

Currently, dense forest structure of all size classes is overrepresented on dry sites. Much of the dry forest is dominated by Douglas-fir. These forests are vulnerable to uncharacteristic levels of high- and mixed-severity fire, as well as a combination of drought stress, root disease, and Douglas-fir beetle. Treating 18,000-25,500 acres of dry dense forest (Table 1) is recommended to create large patches (~100-1000 ac) of open forest and shift the majority of dry sites to open forest (Fig. 6). As the retained trees grow over time, much of the dry forest will shift to large tree, open forest, which is currently very low. Shifting composition toward ponderosa pine and western larch is also needed. In places where these species are poorly represented, planting may be needed after gap creation, variable retention harvests, or high-severity fire.

Moist and cold dense forest treatment need

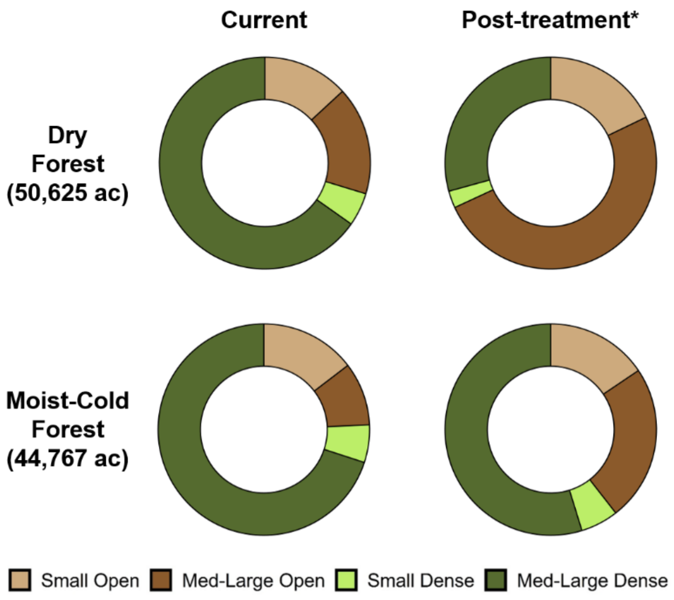
Dense, medium tree forest on moist sites exceeds desired ranges in the eastern region, while dense, large tree forest is at the upper end. Patch sizes are large and aggregated. Large tree, open structure is below desired ranges, as is small open forest. Treating 6,500-9,500 acres of this type (Table 1, Fig. 4) is recommended to create a mosaic of open, moderate, and dense patches that will reduce risks of large crown fire and insect outbreaks. A range of treatment types will be needed, including moderate to heavy thinning, regeneration treatments, and fire. Increasing the relative composition of western larch and ponderosa pine while decreasing grand fir and other fire-intolerant species is also needed, especially on sites projected to shift to dry forest (Fig. 3). If landscape treatment targets are achieved, over 60% of the total moist and cold forest area will remain dense (>40% canopy cover) (Fig. 6) to meet habitat, wood production, and other objectives.

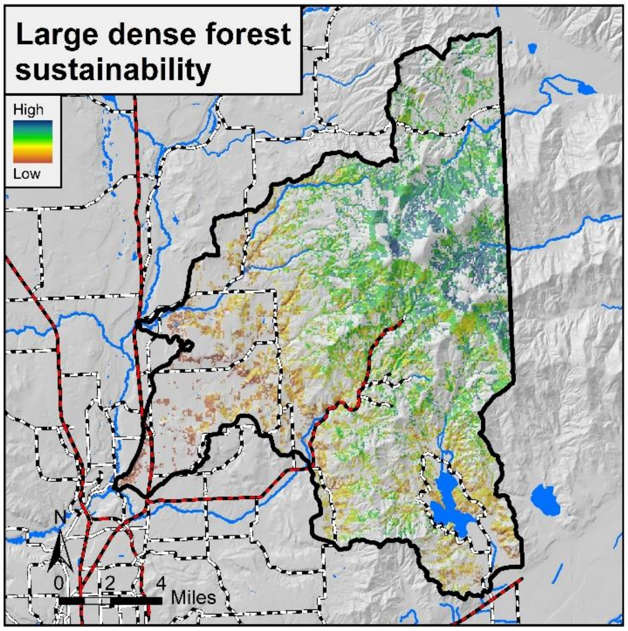
Open forest maintenance treatment need

Over the next 15 years, an estimated 4,500-7,000 acres of currently open forests on dry and moist sites will need prescribed fire, managed wildfire, or mechanical methods to maintain open conditions by reducing surface fuels and small trees. These sites include more open south-facing slopes and recently treated areas where fire is currently predicted to have beneficial effects (Fig. 2). Specific maintenance strategies will depend on landowner objectives and time since treatment.

Sustainable locations for dense forest with large trees

Locations with low to moderate current and future moisture deficits (Fig. 3) and low fire risk (Fig. 2) offer the most sustainable locations to maintain sufficient area and patch sizes of this habitat type and associated ecosystem functions. Sustainable locations include the northeastern portion, as well as north-facing slopes in the remainder of the eastern half (Fig. 7). This sustainability map can be used in conjunction with treatment priority (Fig. 9) to select areas to shift to open forest vs. where to maintain and increase large tree, closed canopy patches.





Left: Figure 6. Current and post-treatment proportions of forest types and structure classes. * mid-point of range in Table 1.
Right: Figure 7. Sustainability of current and potential large tree, dense forest based on fire risk and drought vulnerability.

Landscape Treatment Prioritization

Prioritizing for forest health & to reduce fire exposure of homes

Landscape treatment priority integrates three metrics of forest health – forest fire risk (Fig. 2), drought vulnerability (Fig. 3), and presence of overabundant forest structure types (Fig. 4) – with wildfire transmission to homes (Fig. 8). We also recommend incorporating the large dense forest sustainability layer (Fig. 7) as an overlay when selecting treatment locations. Wildfire transmission is generally low, indicating that wildfires starting in the planning area have a low probability of exposing homes (Fig. 2). However, transmission is moderate in the far western and southern areas.

Treatment priorities

Landscape treatment priority is highest in central and southern parts of the planning area (Fig. 9), mostly on small private and some industrial land (Fig. 5). A large block of medium to high priority exists around Newman Lake (Fig. 1). South-facing slopes within Mt Spokane State Park are also high priority, while north-facing slopes are generally low. Patches of forest in near the western edge are also high priority, even though they are surrounded by agricultural land. Some low priority areas may need treatment to address species composition or other issues. In addition, fuel reduction treatments, defensible space, and home hardening are needed on private parcels with homes throughout the area.

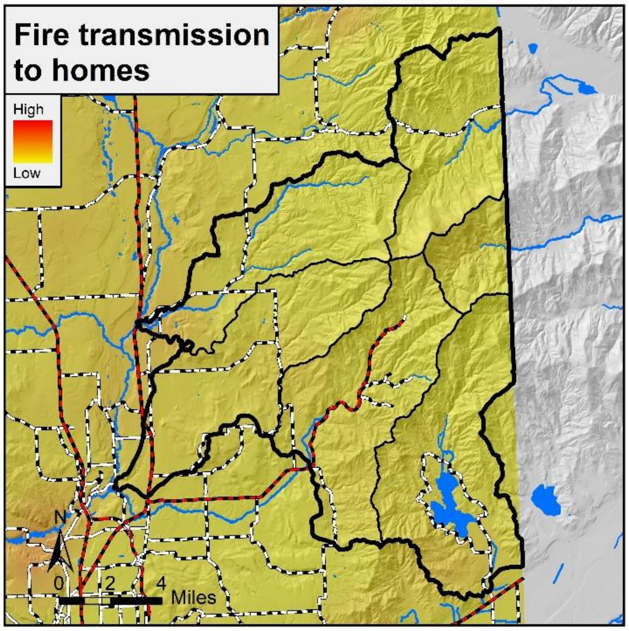


Figure 8. Fire transmission to homes shows where fires that expose structures are most likely to originate. It is based on simulated fire perimeters given contemporary patterns of fuels, topography, and wind.

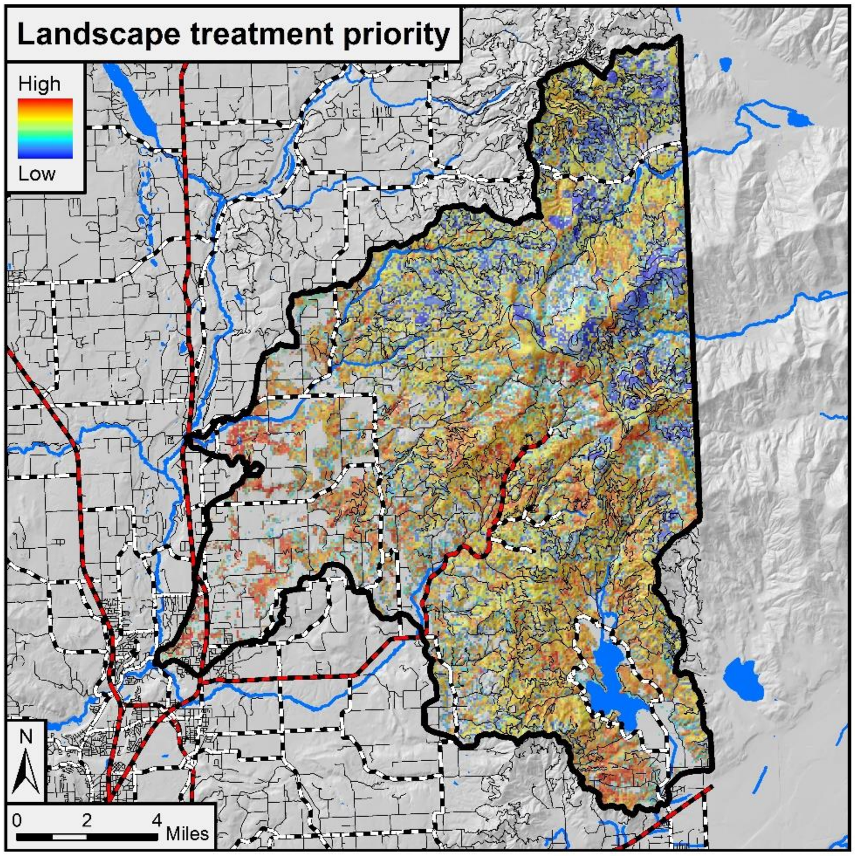


Figure 9. Landscape treatment priority is based on three metrics of forest health – forest fire risk (Fig. 1), drought vulnerability (Fig. 3), overabundant forest structure (Fig. 4) – as well as wildfire transmission to homes (Fig. 8).

Definitions

Vegetation Types

Cold forest: Upper elevation mixed-conifer forests with high-severity fires every 80-200+ years.

Dry forest: Ponderosa pine and Douglas-fir dominated forests that historically had surface fires every 5-25 years.

Moist forest: Forests that historically had mixed-severity fires every 30-100 years and were composed of fire-resistant (western larch, Douglas-fir) and fire-intolerant (grand fir) trees.

Woodland/Steppe: Grass and shrub lands that may have oak woodlands or ≤ 10% conifer cover.

Forest structure

Large tree: Overstory diameter > 20 inches.

Medium tree: Overstory diameter 10-20 inches.

Small tree: Overstory diameter < 10 inches.

Dense canopy: Greater than 40% tree canopy.

Open canopy: Less than 40% tree canopy.

Fuels: Shrubs, grasses, small trees, litter, duff, and dead wood.

Fuels treatments: some combination of mechanical density reduction (commercial or non-commercial) and surface and ladder fuel reduction (prescribed fire, piling & burning, etc.).

Managed wildfire: fire is allowed to burn under safe conditions to achieve management goals but can be suppressed if conditions change.

Wildfire Response Benefit Prioritization

Dual benefits for forest health and wildfire response

It is necessary to conduct treatments to both improve forest health and reduce fire risk to communities as well as provide conditions where firefighters can safely and efficiently conduct fire operations (e.g. suppression, prescribed burning, and managed wildfire). The wildfire response benefit metric (WRB; Fig. 10) identifies and prioritizes locations where values at risk that are more likely to be the focus of fire operations (homes, infrastructure, sources of drinking water, and commercially managed lands) coincide with areas likely to transmit wildfire to homes and generate severe fire behavior. Because there are positive feedbacks between healthy, resilient forests and safe, effective fire operations, the WRB metric also integrates the landscape treatment priority map (Fig. 9).

Where WRB is highest, actions may be needed to create and maintain conditions that provide a tactical advantage for fire operations. These actions will vary with the local context and can include landscape-level forest health and fuel treatments, treatments along fire control lines and escape routes, resident and community fire mitigation activities (e.g. defensible space, home hardening), and improving signage and road conditions. The WRB metric provides a high-level prioritization, and additional work at the local level is required to identify appropriate actions and assess their feasibility. WRB is useful for prioritizing Potential Control Lines (PCLs) for fire operations (Fig. 11). PCLs are a part of Potential Operational Delineations (PODs); see page 7.

In the Mt Spokane planning area, wildfire response benefit is highest across the central and southwestern portions due to interspersed homes on private property and infrastructure (Fig. 5). Wildfire response benefit is also high on the upper eastern slopes of Mt Spokane within the state park (Fig. 2). Crown fire potential is high throughout the planning area in locations with dense, multi-layered forest structure.

Definitions (continued)

Wildfire response benefit: Any tactical advantage gained for wildfire response activities from actions on the landscape, including, but not restricted to, identifying and consolidating existing anchor points and control lines and reduction of potential fire behavior. Wildfire response benefit is not restricted to any specific wildfire management strategy and instead is centered on conditions that improve fire operations safety and effectiveness.

Potential Control Lines (PCLs): Boundaries of Potential Operational Delineations (PODs) relevant to fire control operations (e.g. roads, ridgetops, and water bodies).

Potential Operational Delineations (PODs) for wildland fire: Landscape containers whose boundaries are potential control lines (PCLs). PODs are useful for planning strategic response to unplanned ignitions, strategic fuel planning, and prioritizing fuel treatments within PODs.

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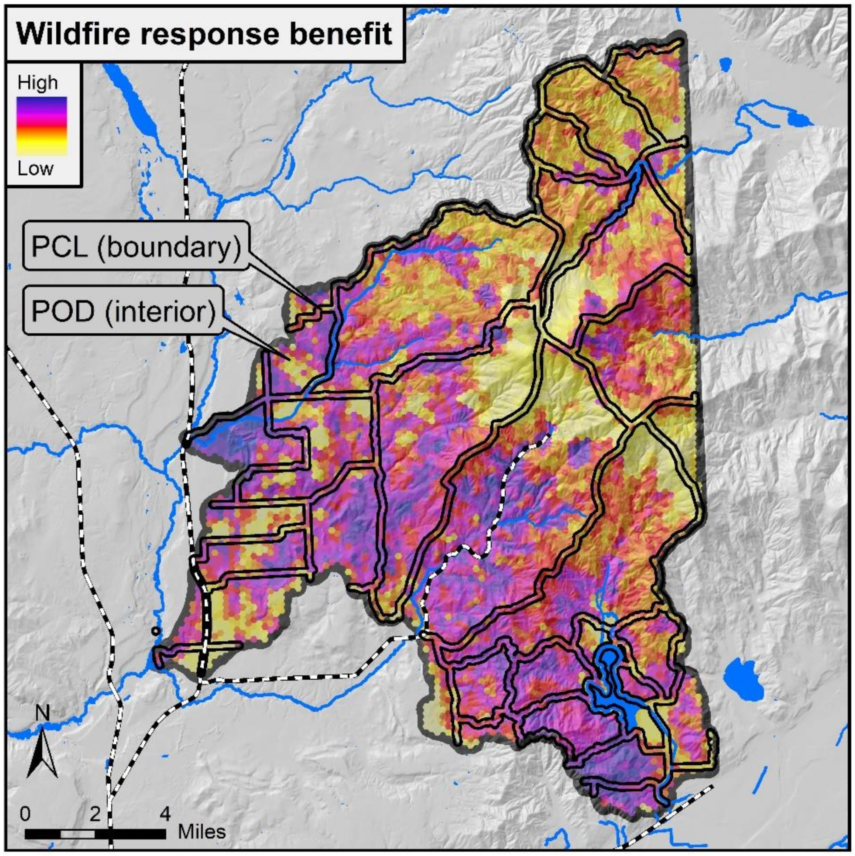

Figure 10. Wildfire response benefit (WRB) integrates multiple fire risk and forest health components. It includes four fire risk metrics representing highly valued resources – risk to homes, infrastructure, drinking water, commercially managed lands – as well as crown fire potential and wildfire transmission to homes (Fig. 8). Combined, these account for 75% of the wildfire response benefit. Landscape treatment priority (Fig. 9) accounts for the remaining 25%. Also shown are PODs: units bounded by PCLs (open black lines). One use of the WRB metric is to prioritize Potential Control Lines (PCLs) for fire operations (Fig. 11).

Prioritizing Landscape Treatments for Dual Benefits

Integration of forest health and wildfire response benefit using PODs

Potential Operational Delineations (PODs) provide a powerful spatial framework to communicate and identify locations that will deliver dual benefits for forest health and wildfire response at the landscape scale. PODs are large landscape areas delimited by Potential Control Lines (PCLs) for fire operations (suppression, prescribed fire, and managed wildfire), delineated by fire operations personnel. PCLs can be roads, ridgelines, or any artificial or natural fuelbreak that provides a strategic opportunity for fire operations. Summarizing landscape treatment priorities (Fig. 9) within PODs and wildfire response benefit priorities (Fig. 10) within PCLs enables planners and managers to identify, at a high level, locations where forest health or fuels treatments can be connected to a high-priority PCL that will support firefighter operations (e.g. ingress/egress route or opportunity for engagement).

Achieving forest health and wildfire response goals will require primarily large, landscape-level treatments across PODs (~100's-1,000's of acres) and, to a lesser extent, targeted treatments along PCLs.

There is important work to do in all Mt Spokane PODs to achieve the forest health treatment targets in Table 1. First priority PODs correspond to areas with moderate and high landscape treatment priority (Fig. 9) throughout the central portion of the planning area (Fig. 11). Other first priority PODs are located in the northern and southern ends. Most of the first priority PODs are associated with first priority PCLs, enhancing opportunities for dual benefit treatments. Additional first priority PCLs occur in western portions, primarily on private land (Fig. 5). Further work is needed to assess PCLs locally for their condition and detailed treatment needs, which will depend on management goals and values at risk. Ideally, landscape treatments will be implemented adjacent to priority PCLs where feasible to maximize both forest health and wildfire response goals.

Achieving forest health and wildfire response dual benefits will require primarily large, landscape-level treatments across PODs (~100's-1,000's of acres) and, to a lesser extent, targeted treatments along PCLs. These two approaches combined will contribute to restoring and maintaining large portions of the landscape in a resilient condition while providing safe and effective areas for firefighter engagement during suppression, prescribed fire, or managed wildfire operations.

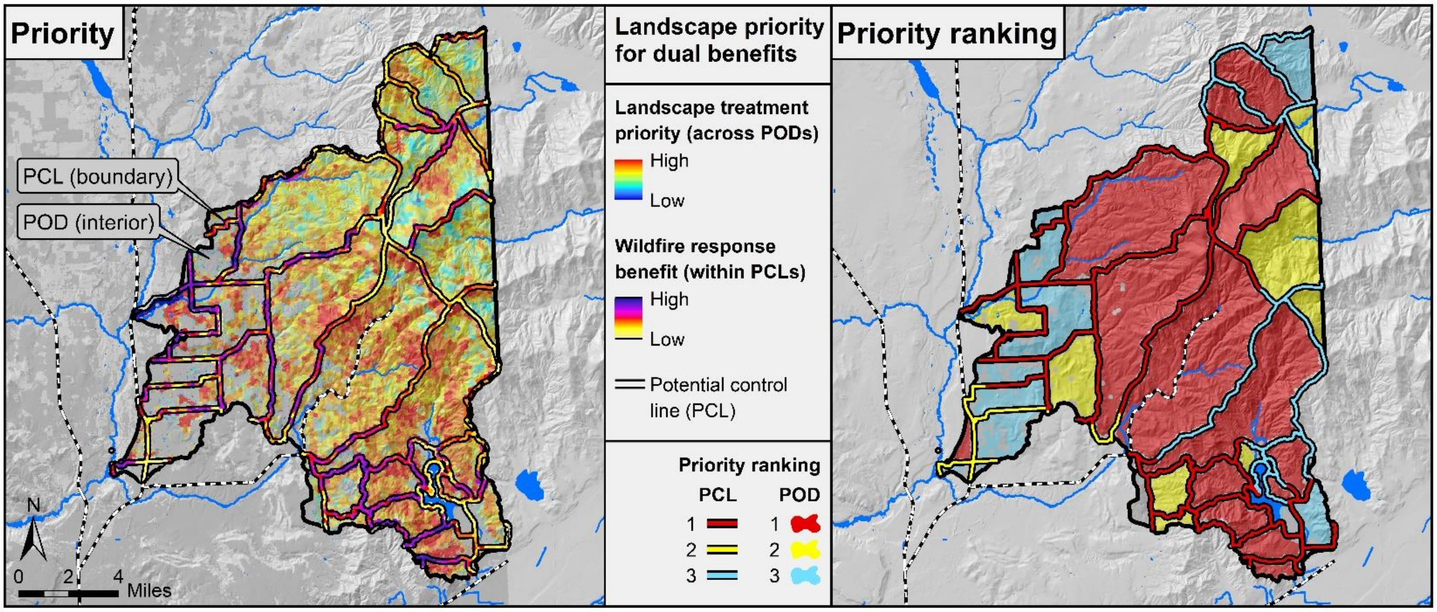

Figure 11. Landscape prioritization of dual benefits using PODs as a spatial framework to summarize treatment priorities. Both maps display landscape treatment priority within PODs and wildfire response benefit within PCLs. The map on the left shows the datasets at the raster level, while the map on the right shows the same information summarized and ranked within PODs and PCLs. PCL width is inflated to display spatial patterns. *PODs shown here are part of an ongoing process towards an all-lands delineation; POD boundaries are subject to change following on-the-ground vetting and continued dialogue among wildfire agencies and stakeholders.*

TOUCHET MILL PLANNING AREA LANDSCAPE EVALUATION SUMMARY (2022)

Total Acres	Forested Acres	Treatment Goal (Acres)
203,750	92,785	22,000 - 27,500

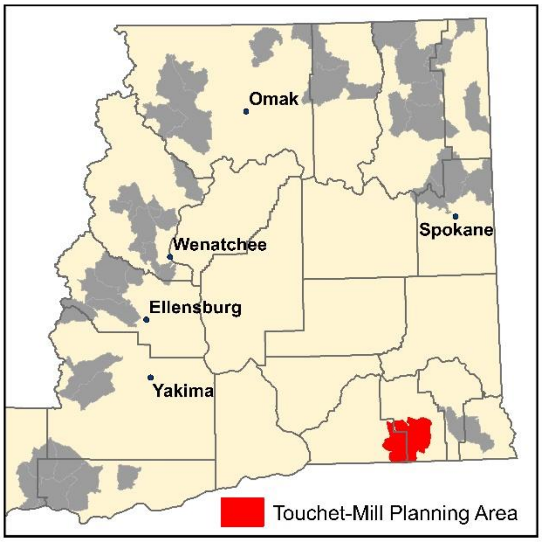

Figure 1. Planning area location in eastern WA.

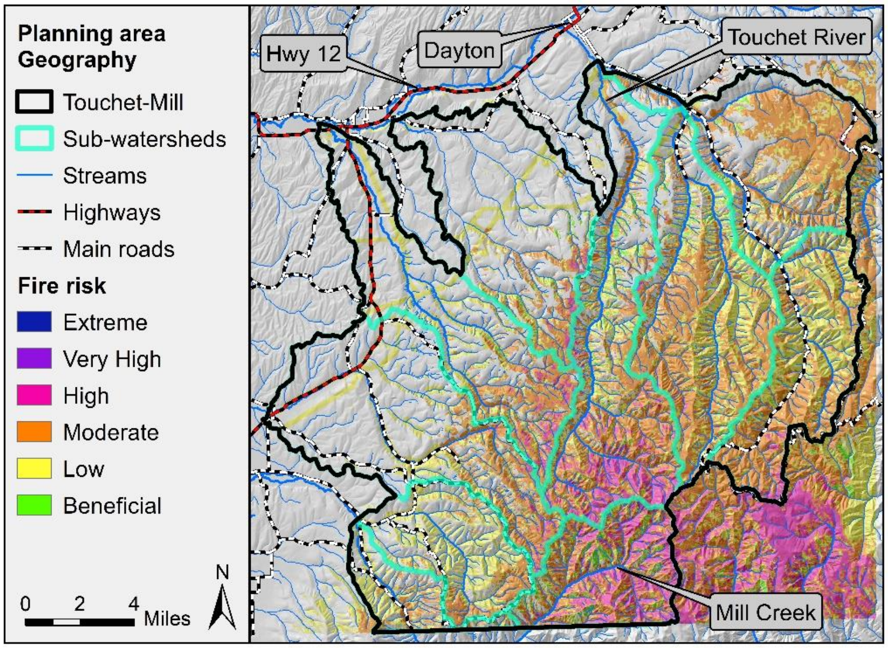

Figure 2. Planning area geography and fire risk, which integrates burn probability, fire intensity, and fire susceptibility of forests, infrastructure, and homes.

Planning Area Highlights

- This planning area encompasses the Touchet River and Mill Creek, which includes the water source for the City of Walla Walla. Touchet-Mill is the first DNR planning area analyzed in the Blue Mountains and is characterized by sharp transitions between vegetation types associated with precipitation, elevation, and aspect.
- The majority of the planning area is in private land ownership across forested and non-forested areas. Other important forest land owners include the Confederated Tribes of the Umatilla Indian Reservation and the Umatilla National Forest.
- Fire risk is highest in the central and southern portions of the planning area containing dense forests.
- Projected warming over the next 20-40 years will likely shift climate conditions suitable for moist forest towards conditions suitable for dry forest. Low elevation areas and south-facing slopes may no longer support forest.
- Treating 24-30% of forested acres is recommended to increase resilience and reduce fire risk to communities using a combination of mechanical, prescribed fire, and managed wildfire treatments. The Tiger-Mill project in the southern portion of the planning area is a high priority for the Umatilla National Forest and partners.
- High priority areas for potential treatments that maximize forest health and wildfire response benefit include locations throughout the southern and eastern portions of the planning area.

LEARN MORE

This landscape evaluation was completed in 2022.
For more details about DNR's priority planning areas please see: **https://www.dnr.wa.gov/ForestHealthPlan**
For data products and methods see: **https://bit.ly/ForestHealthData**

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Overarching Goals

Reduce wildfire risk and protect communities

Fire risk is moderate to high across the central and southern portions of the planning area due to high fuel loads associated with dense forest structure (Fig. 2). Areas in the northeastern portion have distinct fuel profiles due to large wildfires in recent decades, including the 2006 Columbia Complex. Landscape treatments will help reduce the risk of large, high-severity fire and restore conditions conducive to a more characteristic balance of low- and mixed-severity fire, with some high-severity patches. Over time, a restored landscape will provide managers more flexibility to utilize managed wildfire to maintain these fire-dependent ecosystems and thus harness the predicted increase in burn probability. In addition, implementing fuel reduction treatments around homes and establishing potential control lines will increase firefighter safety and help protect communities.

Increase resilience and prepare for climate change

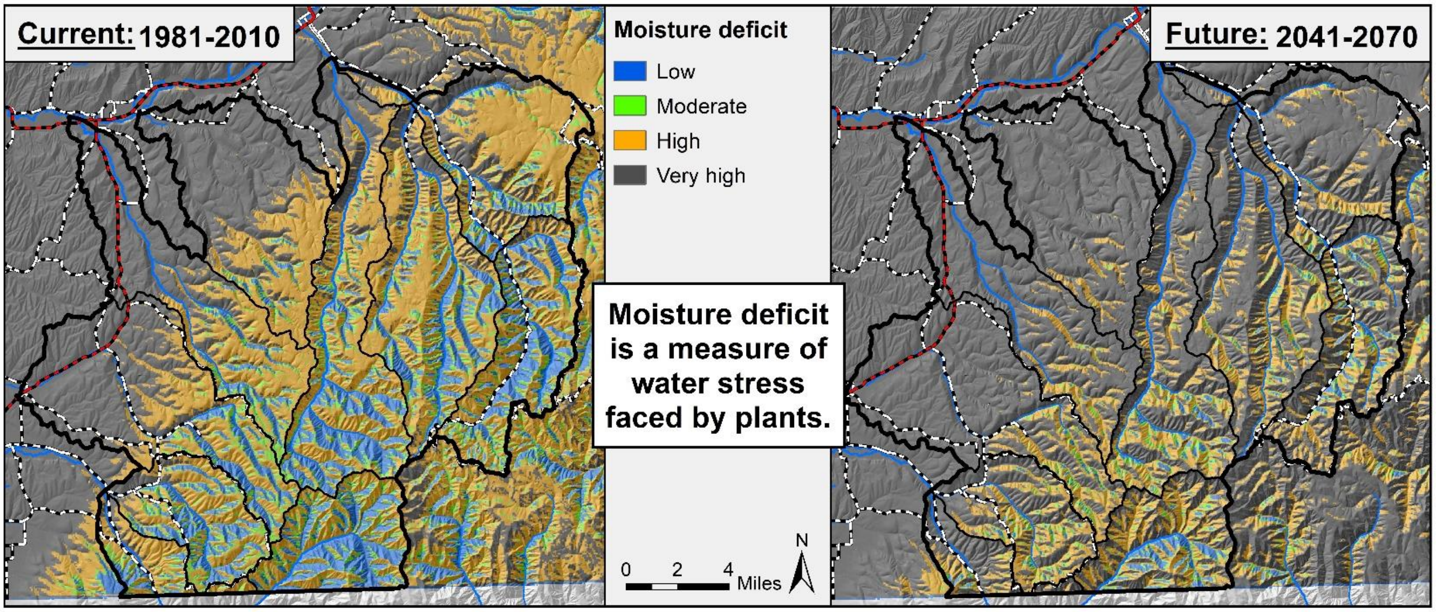
By mid-century, the majority of the planning area is projected to have moisture stress levels that are currently associated with dry forest or shrub-steppe (Fig. 3). Substantial acreage in the central portion with intermediate elevation is projected to shift to non-forest over time. Low to moderate moisture stress levels are projected to remain on north-facing slopes, primarily in southern portions. Treatments, as well as managed wildfires in roadless and other inaccessible areas, that reduce density and favor drought-tolerant species will support forest persistence into the future.

Sustain wildlife habitat

Habitat for dry forest, large tree, open canopy species (e.g. White Headed Woodpecker) occurs on lower elevation sites and locations with limited prior timber harvest and high-severity wildfire. Habitat for species that depend on moist, closed canopy forest with large trees (e.g. Northern Goshawk) is very abundant, with large and aggregated patch sizes. In high fire risk locations, reducing tree density and canopy cover will reduce crown fire potential and drought vulnerability while helping to maintain habitat in the most sustainable locations (Fig. 7). Treatments would also increase the extent and patch sizes of open canopy habitat on dry and moist sites. Habitat for cold forest, large-tree, closed canopy species (e.g. American Marten) is limited to higher elevations and north-facing slopes within the planning area. Habitat layers are available in the data products.

Enhance rural economic development

Many of the high treatment priority areas (Fig. 9) have road access and are capable of producing significant timber volume. Although warming trends and high burn probability will necessitate managing for lower densities and fuel loads, long-term timber production will likely be possible on multiple land ownerships. Reducing fire risk will help sustain recreation, tourism, and infrastructure, including the water supply of Walla Walla in Mill Creek. Treatments will also reduce the potential of smoke affecting communities within and near the planning area, including Walla Walla, Waitsburg, Dayton, and the Confederated Tribes of the Umatilla Indian Reservation.



Moisture deficit is a measure of water stress faced by plants.

Figure 3. Current (left) and future (right) moisture stress levels based on water balance deficit. Low levels are associated with moist and cold forest types, high with dry forest types, and very high with woodland or shrub-steppe. Future climate is based on a relatively high greenhouse gas emissions scenario (RCP 8.5).

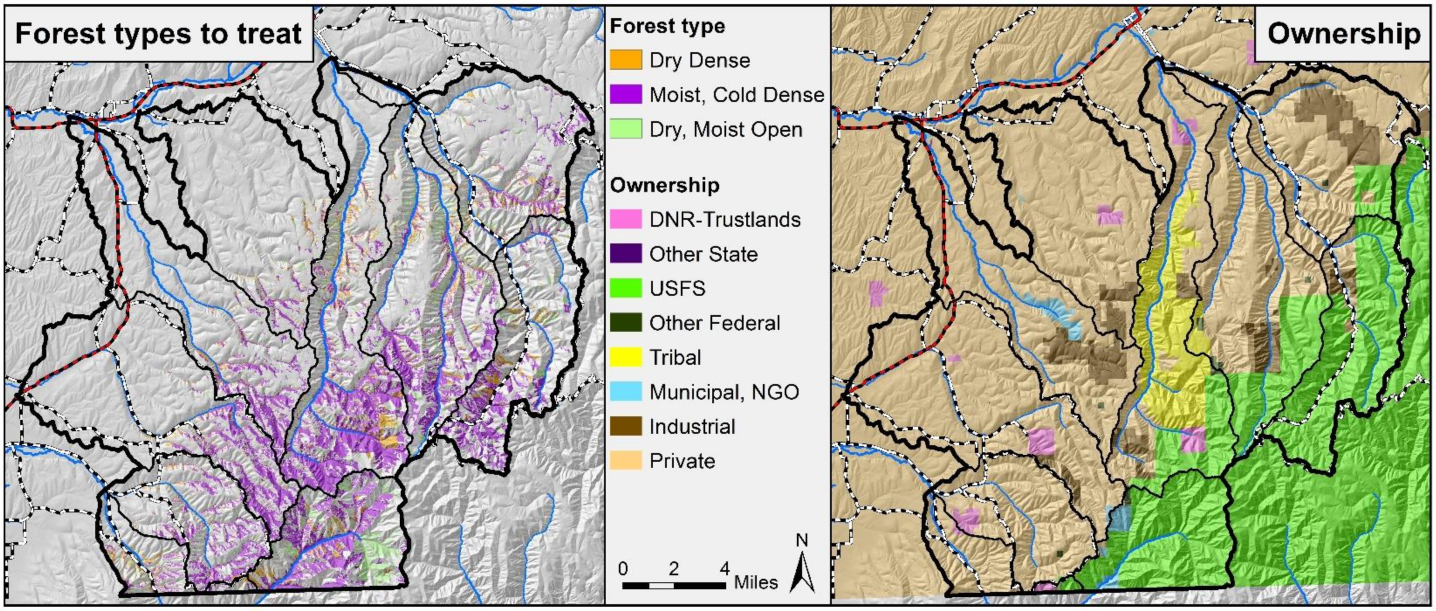
Forest Health Treatment Needs

Treating 22,000 to 27,500 acres is recommended to move the landscape into a resilient condition (24-30% of forested acres; Table 1). This total includes an estimated 20,500-24,000 acres to shift dense to open forest and 1,500-3,500 acres of maintenance treatments in existing open forest. These treatment targets are based on historical range of variation estimates from the Umatilla National Forest and current condition data from 2018 LiDAR imagery.

Meeting this target range will require multiple treatment types (Table 1). Managed wildfire under safe conditions will be needed, especially in less accessible locations. Most treatments are commercially viable based on tree size. Treatment type will depend on road access, logging systems, markets, and other considerations. Individual landowners will conduct their own planning and decision-making processes to determine acres and types of treatments to achieve the landscape goals while meeting their own objectives and regulatory requirements.

Table 1. Summary of forest health treatment needs. ***See methods for details on how the treatment need range is derived.***

Forest conditions to treat		Treatment need (acres)	Current acres by major landowner*				
Type	**Size class**		**Private**	**USFS**	**Industrial**	**Tribal**	**Other**
Dry Dense	Medium-Large	4,500 - 6,000	3,963	2,244	266	908	197
Moist Dense	Medium-Large	16,000 - 18,000	11,570	10,998	1,772	2,504	1,320
Dry + Moist Open	Medium-Large	1,500 - 3,500	2,591	2,513	219	385	138
Total		**22,000 - 27,500**	**These are current acres, not targets*				
Anticipated treatment type	🟦	Commercial thin plus fuels treatment if access exists. May be noncommercial, fire only (prescribed or managed wildfire), or regeneration treatment.					
	🟩	Maintenance treatment: prescribed fire, managed wildfire, or mechanical fuels treatment. *Target range corresponds to 50-75% of dry open and 25-50% of moist open forests.*					



Left: Figure 4. Forest structure types that are overabundant relative to targets for a resilient landscape, as well as potential maintenance treatments. Only a portion of the areas shown need to be treated. Right: Figure 5. Current land ownership.

Forest Health Treatment Needs (continued)

Dry dense forest treatment need

On dry sites, dense, multistory forest structure is currently over-represented. The large, contiguous patches of these forest conditions create high susceptibility to drought, insects, and stand-replacing wildfire especially in southern portions of the planning area. Treating 4,500-6,000 acres of dry dense forest (Table 1) is recommended to create large patches (~100-1000 ac) of open forest with a component of large trees (Fig. 4), flipping the majority of dry sites from closed to open forest (Fig. 6). Ponderosa pine and other drought-tolerant species will continue to be suitable as climate conditions get warmer and drier.

Moist and cold dense forest treatment need

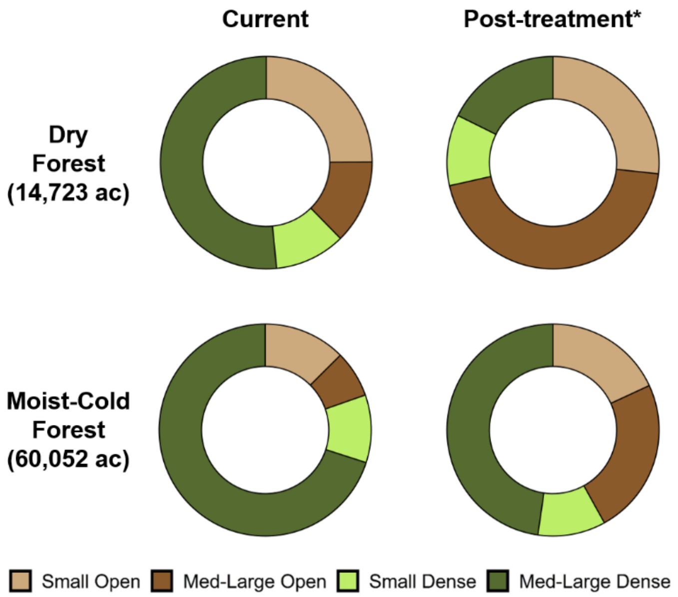
On moist sites, dense, multistory forest structure exceeds desired ranges. Patch sizes are large and aggregated. In contrast, open canopy forests with medium to large trees, as well as open forests with small trees, are below desired ranges. Treating 16,000-18,000 acres of these types (Table 1, Fig. 4) is recommended to create a mosaic of open, moderate, and dense patches that will reduce risks of large crown fire and insect outbreaks. A range of treatment types will be needed, including thinning, regeneration treatments, and managed wildfire in roadless areas. Increasing the relative composition of ponderosa pine and western larch is also needed to help these sites adapt to a warming climate. If landscape treatment targets are achieved, over 55% of the total moist and cold forest area will remain dense (>40% canopy cover) (Fig. 6) to meet habitat, wood production, and other objectives.

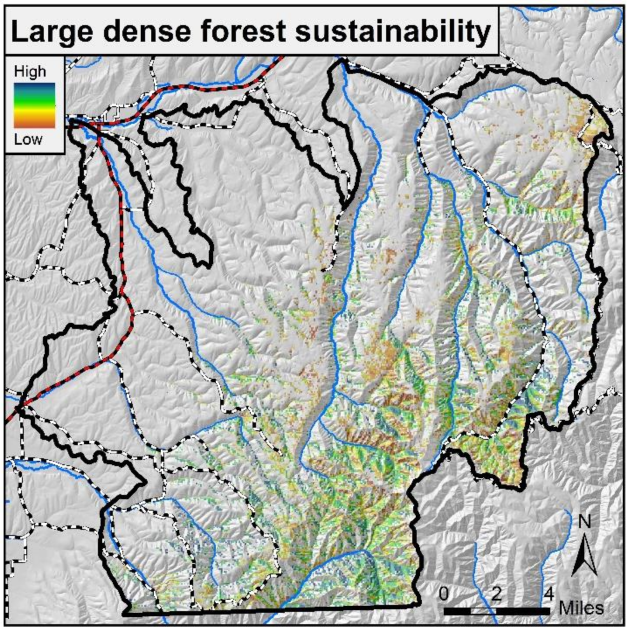
Open forest maintenance treatment need

Over the next 15 years, an estimated 1,500-3,500 acres of currently open forests on dry and moist sites will need prescribed fire, managed wildfire, or mechanical methods to maintain open conditions by reducing surface fuels and small trees. These sites include mechanically treated areas that may or may not have received fuel treatments, as well as parts of the 2006 Columbia Complex Fire, where additional fuel reduction is needed. Specific maintenance strategies depend on landowner objectives and time since last treatment.

Sustainable locations for dense forest with large trees

Locations with low to moderate current and future moisture deficits (Fig. 3) and low fire risk (Fig. 2) offer the most sustainable locations to maintain sufficient area and patch sizes of this habitat type and associated ecosystem functions. Sustainable locations include north-facing slopes and valley bottoms in eastern and southern portions of the planning area (Fig. 7). The large tree, dense forest sustainability map can be used in conjunction with treatment priority (Fig. 9) to select areas to promote open forest vs. where to maintain and build large tree closed canopy patches.





Left: Figure 6. Current and post-treatment proportions of forest types and structure classes. * mid-point of range in Table 1.
Right: Figure 7. Sustainability of current and potential large tree, dense forest based on fire risk and drought vulnerability.

Landscape Treatment Prioritization

Prioritizing for forest health & to reduce fire exposure of homes

Landscape treatment priority integrates three metrics of forest health – forest fire risk (Fig. 2), drought vulnerability (Fig. 3), and presence of overabundant forest structure types (Fig. 4) – with wildfire transmission to homes (Fig. 8). To ensure that habitat for closed canopy-dependent wildlife is incorporated into the prioritization, we recommend overlaying the large dense forest sustainability layer (Fig. 7) when selecting treatment locations. Wildfire transmission is relatively low across the planning area.

Treatment priorities

Landscape treatment priority is highest in central and southern portions (Fig. 9), primarily on USFS land (Fig. 5). The USFS Tiger-Mill project area includes high priority locations with high fire risk drought vulnerability, and departed forest structure. Medium and high priority areas are present in the northeast portion throughout the planning area and are spread across all major landowners. Some low priority areas may need treatment to address species composition, insect and disease risk, or other issues. In addition, fuel reduction treatments, defensible space, and home hardening are needed on private parcels with homes or other structures throughout the planning area.

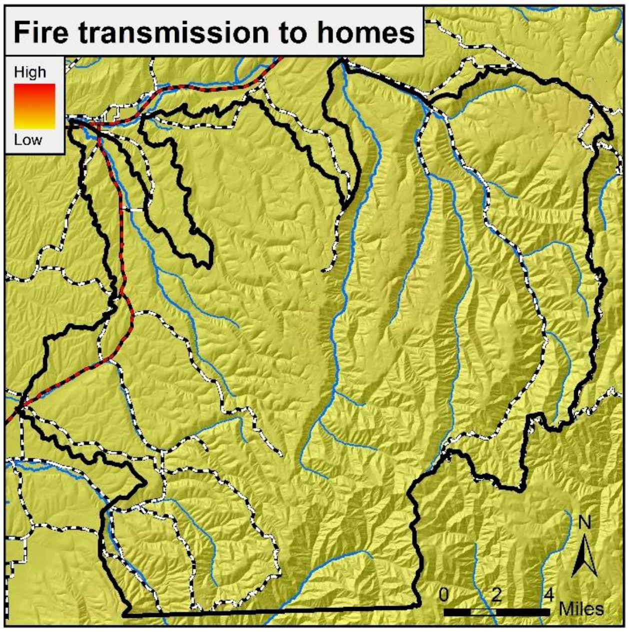


Figure 8. Fire transmission to homes shows where fires that expose structures are most likely to originate. It is based on simulated fire perimeters given contemporary patterns of fuels, topography, and wind.

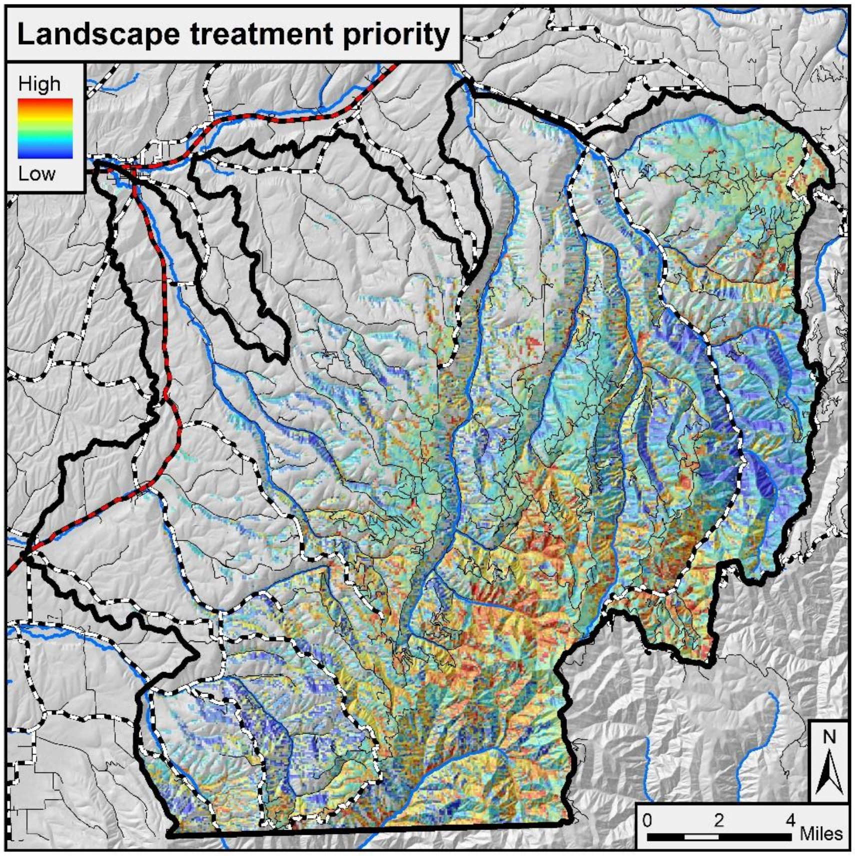


Figure 9. Landscape treatment priority is based on three metrics of forest health – forest fire risk (Fig. 1), drought vulnerability (Fig. 3), overabundant forest structure (Fig. 4) – as well as wildfire transmission to homes (Fig. 8).

Definitions

Vegetation Types

Cold forest: Upper elevation mixed-conifer forests with high-severity fires every 80-200+ years.

Dry forest: Ponderosa pine and Douglas-fir dominated forests that historically had surface fires every 5-25 years.

Moist forest: Forests that historically had mixed-severity fires every 30-100 years and were composed of fire-resistant (western larch, Douglas-fir) and fire-intolerant (grand fir) trees.

Woodland/Steppe: Grass and shrub lands that may have oak woodlands or ≤ 10% conifer cover.

Forest structure

Large tree: Overstory diameter > 20 inches.

Medium tree: Overstory diameter 10-20 inches.

Small tree: Overstory diameter < 10 inches.

Dense canopy: Greater than 40% tree canopy.

Open canopy: Less than 40% tree canopy.

Fuels: Shrubs, grasses, small trees, litter, duff, and dead wood.

Fuels treatments: some combination of mechanical density reduction (commercial or non-commercial) and surface and ladder fuel reduction (prescribed fire, piling & burning, etc.).

Managed wildfire: fire is allowed to burn under safe conditions to achieve management goals but can be suppressed if conditions change.

Wildfire Response Benefit Prioritization

Dual benefits for forest health and wildfire response

It is necessary to conduct treatments to both improve forest health and reduce fire risk to communities as well as provide conditions where firefighters can safely and efficiently conduct fire operations (e.g. suppression, prescribed burning, and managed wildfire). The wildfire response benefit metric (WRB; Fig. 10) identifies and prioritizes locations where values at risk that are more likely to be the focus of fire operations (homes, infrastructure, sources of drinking water, and commercially managed lands) coincide with areas likely to transmit wildfire to homes and generate severe fire behavior. Because there are positive feedbacks between healthy, resilient forests and safe, effective fire operations, the WRB metric also integrates the landscape treatment priority map (Fig. 9).

Where WRB is highest, actions may be needed to create and maintain conditions that provide a tactical advantage for fire operations. These actions will vary with the local context and can include landscape-level forest health and fuel treatments, treatments along fire control lines and escape routes, resident and community fire mitigation activities (e.g. defensible space, home hardening), and improving signage and road conditions. The WRB metric provides a high-level prioritization, and additional work at the local level is required to identify appropriate actions and assess their feasibility. WRB is useful for prioritizing Potential Control Lines (PCLs) for fire operations (Fig. 11). PCLs are a part of Potential Operational Delineations (PODs); see page 7.

In the Touchet-Mill planning area, wildfire response benefit is highest along both the north and south forks of the Touchet River (Fig. 2) due to risk to commercially managed lands (Fig. 5). The Mill Creek watershed in the southern portion also has very high wildfire response benefit because it is the source of drinking water for Walla Walla. Crown fire potential is high throughout the planning area in locations with dense, multi-layered forest structure.

Definitions (continued)

Wildfire response benefit: Any tactical advantage gained for wildfire response activities from actions on the landscape, including, but not restricted to, identifying and consolidating existing anchor points and control lines and reduction of potential fire behavior. Wildfire response benefit is not restricted to any specific wildfire management strategy and instead is centered on conditions that improve fire operations safety and effectiveness.

Potential Control Lines (PCLs): Boundaries of Potential Operational Delineations (PODs) relevant to fire control operations (e.g. roads, ridgetops, and water bodies).

Potential Operational Delineations (PODs) for wildland fire: Landscape containers whose boundaries are potential control lines (PCLs). PODs are useful for planning strategic response to unplanned ignitions, strategic fuel planning, and prioritizing fuel treatments within PODs.

Commercially managed lands: Commercially managed forestlands include: DNR Trustlands, Tribal forests, industrial forests, non-industrial private forests, and US Forest Service forests where timber is a primary management objective.

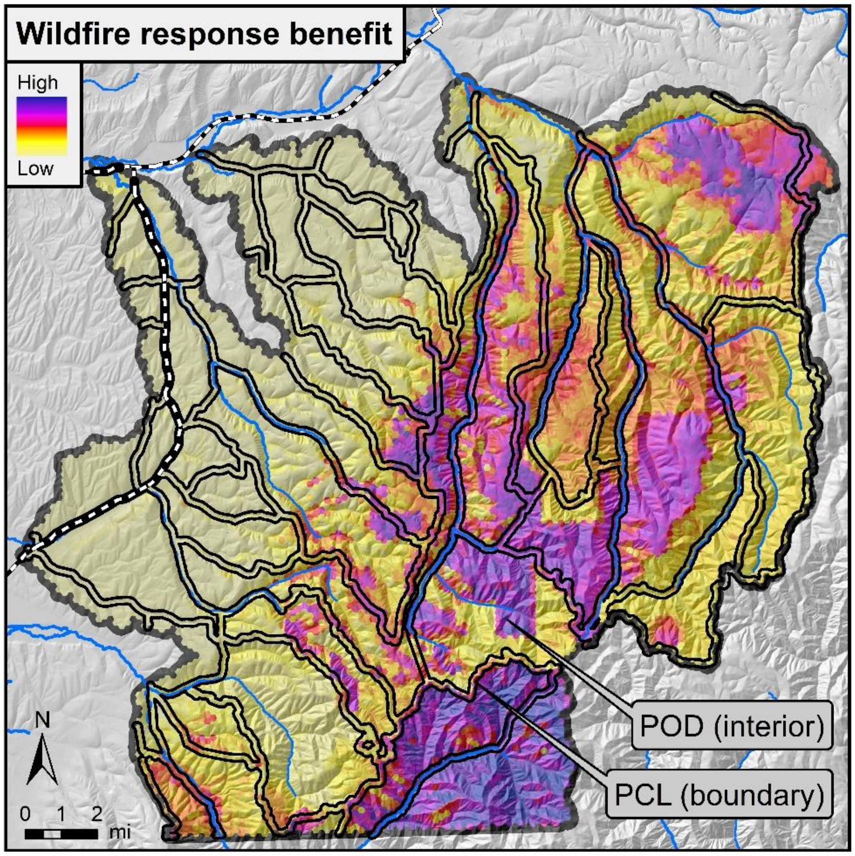


Figure 10. Wildfire response benefit (WRB) integrates multiple fire risk and forest health components. It includes four fire risk metrics representing highly valued resources – risk to homes, infrastructure, drinking water, commercially managed lands – as well as crown fire potential and wildfire transmission to homes (Fig. 8). Combined, these account for 75% of the wildfire response benefit. Landscape treatment priority (Fig. 9) accounts for the remaining 25%. Also shown are PODs: units bounded by PCLs (open black lines). One use of the WRB metric is to prioritize Potential Control Lines (PCLs) for fire operations (Fig. 11).

Prioritizing Landscape Treatments for Dual Benefits

Integration of forest health and wildfire response benefit using PODs

Potential Operational Delineations (PODs) provide a powerful spatial framework to communicate and identify locations that will deliver dual benefits for forest health and wildfire response at the landscape scale. PODs are large landscape areas delimited by Potential Control Lines (PCLs) for fire operations (suppression, prescribed fire, and managed wildfire), delineated by fire operations personnel. PCLs can be roads, ridgelines, or any artificial or natural fuelbreak that provides a strategic opportunity for fire operations. Summarizing landscape treatment priorities (Fig. 9) within PODs and wildfire response benefit priorities (Fig. 10) within PCLs enables planners and managers to identify, at a high level, locations where forest health or fuels treatments can be connected to a high-priority PCL that will support firefighter operations (e.g. ingress/egress route or opportunity for engagement).

Achieving forest health and wildfire response goals will require primarily large, landscape-level treatments across PODs (~100’s-1,000’s of acres) and, to a lesser extent, targeted treatments along PCLs.

There is important work to do in all Touchet-Mill PODs to achieve the forest health treatment targets in Table 1. First priority PODs correspond to areas with relatively high landscape treatment priority (Fig. 9) in eastern and southern portions of the planning area (Fig. 11). Other first priority PODs are located along the south fork of the Touchet River on the Confederated Tribes of the Umatilla Indian Reservation. Most of the first priority PODs are associated with first priority PCLs, enhancing opportunities for dual benefit treatments. Further work is needed to assess PCLs locally for their condition and detailed treatment needs, which will depend on management goals and values at risk. Ideally, landscape treatments will be implemented adjacent to priority PCLs where feasible to maximize both forest health and wildfire response goals.

Achieving forest health and wildfire response dual benefits will require primarily large, landscape-level treatments across PODs (~100’s-1,000’s of acres) and, to a lesser extent, targeted treatments along PCLs. These two approaches combined will contribute to restoring and maintaining large portions of the landscape in a resilient condition while providing safe and effective areas for firefighter engagement during suppression, prescribed fire, or managed wildfire operations.

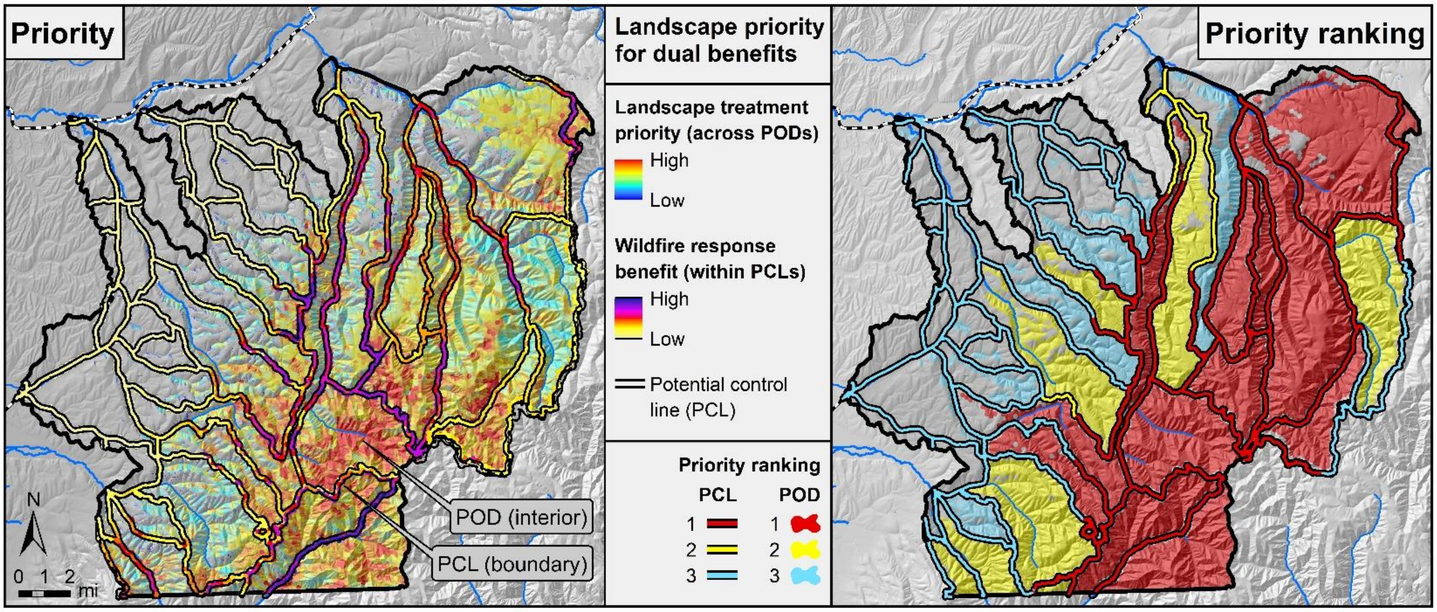
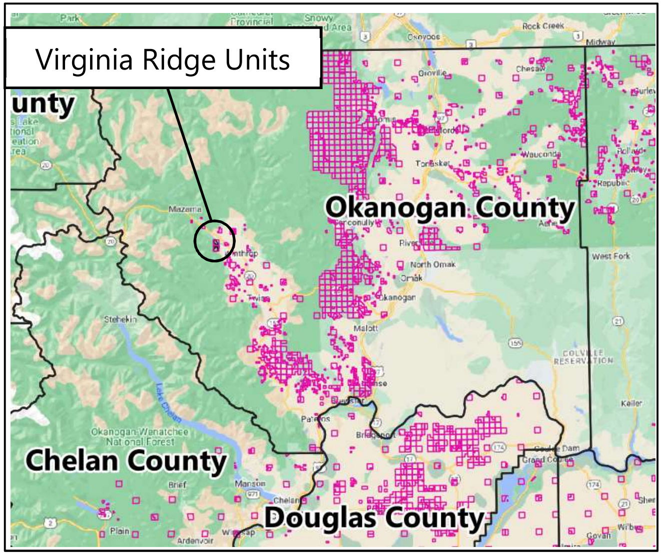


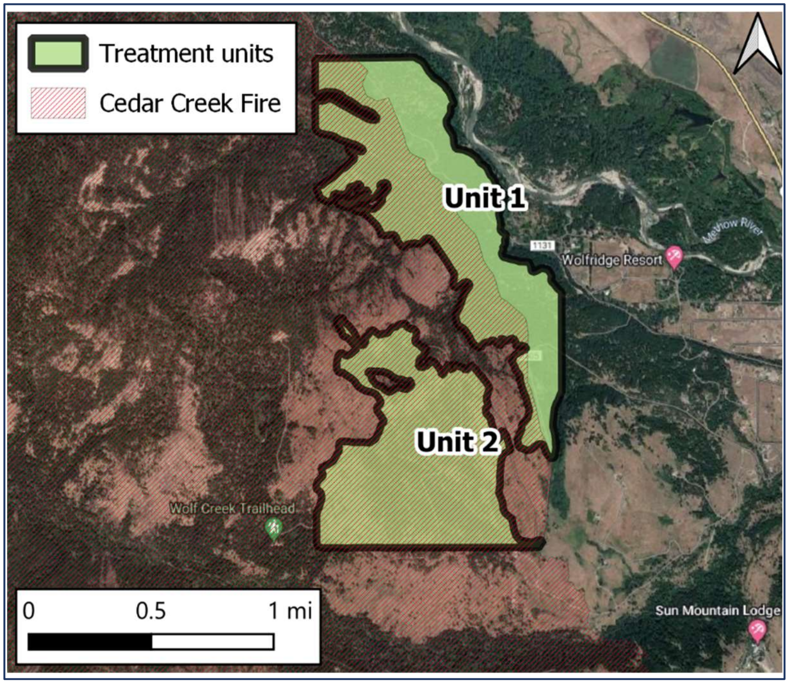
Figure 11. Landscape prioritization of dual benefits using PODs as a spatial framework to summarize treatment priorities. Both maps display landscape treatment priority within PODs and wildfire response benefit within PCLs. The map on the left shows the datasets at the raster level, while the map on the right shows the same information summarized and ranked within PODs and PCLs. PCL width is inflated to display spatial patterns. *PODs shown here are part of an ongoing process towards an all-lands delineation; POD boundaries are subject to change following on-the-ground vetting and continued dialogue among wildfire agencies and stakeholders.*

Appendix B: Virginia Ridge Stand-Level Monitoring Report

Virginia Ridge Project near Winthrop, WA Treatment Monitoring (2022)

Total acres	Landowner	Treatment date	Monitoring date	Fire date
720	DNR	Summer 2019	Post Tx: May 2021	July-Aug 2021





Above: Virginia Ridge location in WA state, DNR parcels are in magenta. **Right:** Local roads, unit boundaries, and Cedar Creek fire boundary.

Project goals

- Generate revenue for trust beneficiaries through sustainable harvest of DNR managed timber lands.
- Create a fire-adapted forest structure with lower density to resist severe wildfire, drought, and disease
- Increase the proportion of early-seral fire-adapted ponderosa pine compared to Douglas-fir
- Reduce fire risk for adjacent homes and private property.
- Maintain scenic, recreational values, and habitat values
- Note: All highlights below were limited by data availability to Unit 1 unless noted

Project highlights

- LiDAR and orthoimagery data showed trees per acre (TPA) reduced from 58 to 36 and basal area per acre (BA) from 83 to 58 ft^2
- Remote data was able to detect a quadratic mean diameter (QMD) increase of 1″ DBH
- A spatial mosaic of predominantly dispersed trees with 20′ open space between them, small clumps, and dispersed 0.1-to-2-acre gaps was created from a relatively homogenous canopy.
- Roughly 25% of the proportion of Douglas-fir shifted to ponderosa pine, however Douglas-fir was still 61% of the trees.
- The treatment reduced ladder and canopy fuels. Surface fuels after logging were generally low.
- Fire severity data indicates that treatments may have reduced fire severity relative to untreated areas in Unit 2.

Project area and background

The project area is a mountainous region located in the Methow River watershed near the town of Winthrop on land managed by the WA Department of Natural Resources. It is situated on the east slope of the Cascade Mountains and ranges from ~1,800' to 3,200’ elevation. The units are adjacent to private property with homes to the east and south and United States Forest Service land to the west and north.

The forest primarily consisted of Douglas-fir and ponderosa pine, with some quaking aspen, black cottonwood, and birch, depending on aspect. Most of the mature trees ranged from 60 -120 years old. The oldest trees in Unit 1 dated to 1930, while those in Unit 2 to 1910. Unit 2 contained natural openings with few to no merchantable trees.

Forests in this area were historically low density and park-like. Few smaller trees were isolated in clumps due to frequent fires that killed most of them and left surviving larger trees. Dense areas of forest were typically in relatively moist locations. Ingrowth of small shade-tolerant tree species has led to denser stands with vertically continuous fuels from the ground to the canopy (**Figure 1** & **2**), which increase the prevalence of severe wildfire.

Figure 1. Dense forest condition in Unit 2 before treatment

In recent years the Methow Valley has experienced several significant wildfires. As a result, there has been increased pressure on land managers to reduce the live tree density and the quantity of dead fuels to reduce the probability of stand-replacing fire.

Such crowded stands have also become more susceptible to disease and drought stress as trees compete for water. Disease spreads more easily between stressed, closely packed trees.

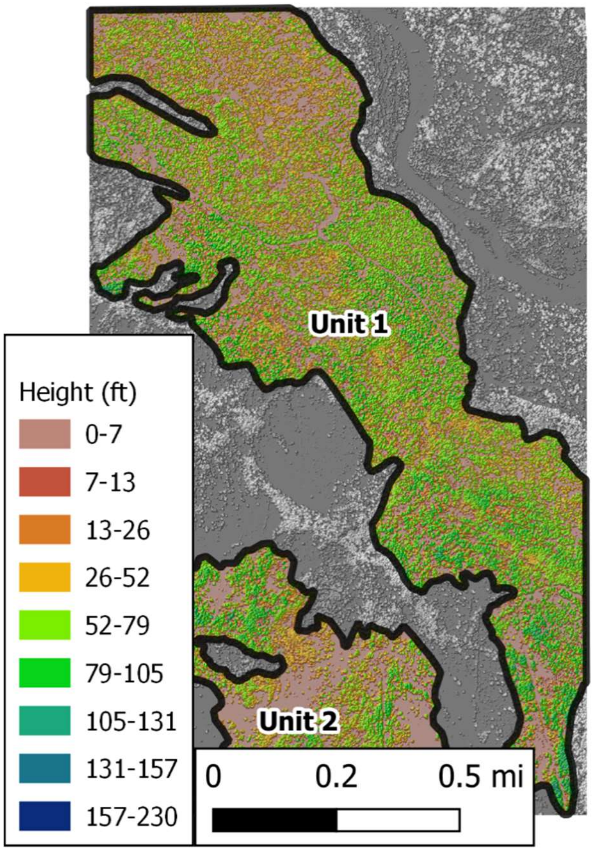


Figure 2. LiDAR imagery showing pre-treatment canopy height in Unit 1 and part of Unit 2. Mostly dense conditions and some open areas exist.

This project is a good case study because after it was treated, 57% of Unit 1 and all of Unit 2 burned in the Cedar Creek Fire (summer 2021). The objectives of this report were to examine if the treatment was able to create desirable conditions before the fire and to describe what proportions of the area burned at what severity relative to surrounding untreated US Forest Service land. Analyzing and fully understanding the effects of treatments on fire severity would require an in-depth modeling study that is beyond the scope of this report. The scope of this report will be limited to forest structure pre- and post-treatment, with only a descriptive analysis of fire effects in the treated areas.

Table 1. Prescription details paraphrased from State Environmental Policy Act documentation and the final prescription

Prescription	
Create a resilient stand that can meet the economic and social needs of future generations: Cut no legacy trees (those meeting vigor classes A and B from Van Pelt, (2008)) or trees >24" DBH, maintain intermediate diameter classes, and restore spatial patterns found in frequent-fire regimes consisting of individual trees, clumps, and openings. **Reduce overstocking to improve leave tree and understory growth**: Preferentially remove trees in the 8" to 18"-DBH range and leave trees in the 18"+DBH range **Reduce disease**: Remove mistletoe-infected trees unless needed to meet TPA targets	**Reduce susceptibility to insects and other disease**: Remove diseased trees unless they are >24" DBH or are needed to maintain 40 TPA **Reduce fuels from and after treatment**: Use whole-tree yarding and follow with non-commercial thinning, other fuel reduction (e.g. mastication), and prescribed fire **Maintain recreation**: Remove trees within 12' of trail to allow more snow for winter sports **Maintain habitat values**: Leave 2 TPA each of large wildlife trees, green trees for future snag creation, the largest trees, and leave snags where feasible **Maintain views**: Leave higher tree density in view of Sun Mountain Lodge (Unit 2)

Methods

Both plot-based data and remotely-sensed data were used to evaluate management outcomes. Pre-treatment plot data were from a variable radius (BAF 20) timber cruise summary from an unspecified number of plots. These included only >8"-DBH trees per acre (TPA) by species and 1" diameter classes. These data covered both Units 1 and 2. Post-treatment plot data were from 7 fixed-radius (10th acre) plots of diameter and species from Unit 1 only.

Because plot data were so limited, we only used them for analyses of species composition. Remote data were used to evaluate changes in density and tree size. The remote data (described below) had known issues, primarily that it does not "see" smaller trees, especially understory trees. These data are therefore useable for evaluating trends, but probably less useful for extracting exact values. This is truer of TPA than BA because large trees are normally detected and contribute more to BA.

Remotely sensed data were from aerial LiDAR pre-treatment and from drone-collected orthographic imagery post-treatment. Both data types were converted to a canopy surface model (CHM) showing relative heights of vegetation above the ground (**Figure 2**). The CHM was used to delineate approximate tree crowns—called tree approximate objects (TAOs) and extract the highest point in each (**Appendix B**).

TAO heights were used to estimate each TAO's DBH with a regression using plot diameter and height data (N = 136, R^2 = 0.68). TPA (TAO count) and BA were summarized across a continuous surface of 66 x 66 ft pixels covering the project area (**Appendix B**). TAO data were also used to estimate QMD, tree clumping based on a 20' limiting distance, and gaps.

Both plot-based and remote-based dataset were compared pre- and post-treatment via histograms and summaries of mean and 95% confidence intervals between time steps. Because post-treatment plot data and drone imagery only covered Unit 1, the analysis was limited to Unit 1 *throughout* this report *except* for evaluating fire severity across both units.

Monitoring Questions

This monitoring report is designed around specific questions. Some questions were based on targets from the treatment prescription (**Table 1**) while others were assessed based on a general description (**Table 2**).

Table 2. Specific targets to evaluate treatment implementation. All metrics except species composition and fire severity were assessed with remote data, so are approximate. Pre and post values are mean ±95% confidence interval. DF = Douglas-fir, PP = ponderosa pine.

Question	Metrics & Targets	Pre Tx	Post Tx	Conclusion
What was the forest density and mean diameter before and after treatment?	40 TPA[1]	58.2±0.68*	35.6±0.55*	Reduced the TPA to within the target range and reduced variability around the mean, but see **Appendix A***
	Describe BA[2] change	82.7±1.42	57.8±1.21	Reduced basal area
	Describe QMD[3] change	16.1±0.23	17.2±0.31	Large trees were retained
Was a mosaic spatial pattern with diverse patch types created?	Most of area in single trees, followed by half as much in 2-4 tree clumps, and limited numbers of 5-9-tree and 10-15-tree clumps.[4]	**1:** 14% **2-4:** 58% **5-9:** 21% **10-15:** 5% **15+:** 2.6%	**1:** 42% **2-4:** 49% **5-9:** 3.5% **10-15:** 0.2% **15+:** 0.1%	Area in single well-dispersed trees nearly tripled and larger contiguous canopy was broken into smaller clumps, but more small clumps could be in single trees and 10-15 tree clumps
	Approximately six 0.1-0.5-acre gap per 10 acres and one 0.5-2-acre gap per 15 acres.	**0.1-0.5:** 0.71% **0.5-2:** 0.08% **>2:** 0.05%	**0.1-0.5:** 7.7% **0.5-2:** 3.7% **>2:** 0.2%	Percent area in All gaps sizes were increased, sometimes dramatically. Total percent gap area increased from 0.8 to 11.6%
Did species composition shift toward more fire-resistant species?	Increased proportion of PP relative to DF	**PP:** 14.1% **DF:** 85.9%	**PP:** 38.8% **DF:** 61.2%	The proportion of Douglas-fir decreased relative to ponderosa pine, but had to remain high to meet TPA targets.
What was the fuel-loading after treatment and before the Cedar Creek fire?	Tons per acre of fuel moisture classes[5] and understory vegetation	—	**<10-hr:** 1.7±0.74 **100-hr:** 0.8±0.65 **1000-hr:** 5.0±6.86 **Vegetation:** 0.09±0.062	Fuels were generally low enough after treatment to limit severe fire except for in extreme fire weather conditions. High variability will lead to some areas with high fuel loading
What was the severity of the fire including secondary mortality?	Proportion of each unit in 1 of 7 BA mortality classes	—	See **Error! Reference source not found.**	Unit 1: BA mortality was concentrated in 25-50% range Unit 2: Mortality was mostly in the 50-90% range.
Is natural regeneration sufficient to re-establish forest post-fire?	Subjective judgement based on field observations and photos.	—	0 to 300 seedlings per acre	There is substantial variable natural regeneration, but we need to follow up in 2 to 3 years to assess its survival and abundance.

[1] Trees per acre

[2] Basal area (ft^2 per acre)

[3] Quadratic mean diameter in inches

[4] In percent of project area

[5] 1, 10, 100, 1000-hr fuels

*≤52% of trees can be missed by remote imagery if they are small

Q1: What was the pre- post-treatment forest density and mean tree diameter before the Cedar Creek fire?

Targets— Reduce density to 40 TPA and describe the BA change

Methods— Remote data were used to compare estimated TPA and BA before and after treatment. From TPA and BA, QMD was then calculated and the difference between pre- and post-treatment (i.e. shift in QMD) was compared to 0 to evaluate if QMD generally moved up or down. A comparison of plot and remote data are in **Appendix A**.

Results

Density

The TPA distribution shifted from a modal value of 60 TPA to 30 TPA (**Figure 3**). These numbers were likely lower than reality, especially pre-treatment, because remote data undercounted small trees targeted by the treatment more than large trees retained. The plot data verify this, showing 125 TPA pre- and 97 TPA post-treatment (**Appendix A**).

The distribution of BA values across the project area shifted from a modal value of 70 BA to 40 BA but with a few BA values areas ≥200 BA (**Figure 4**). These numbers are more realistic than TPA because the largest trees captured by remote sensing also contribute the most to BA. Plot data have BA of 83 and 56 for pre- and post-treatment, respectively.

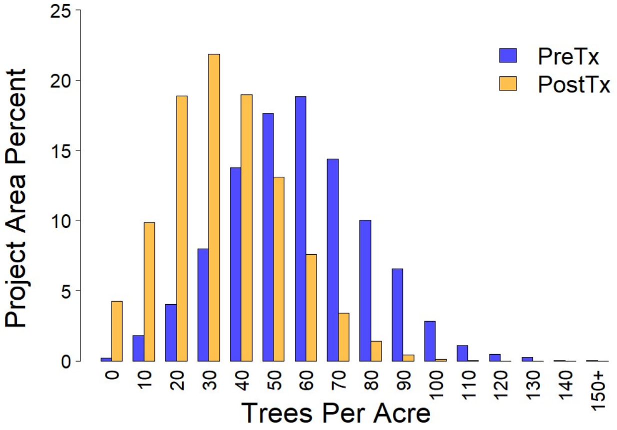


Figure 3. Proportion of project area in TPA bins as assessed by remote LiDAR and imagery.

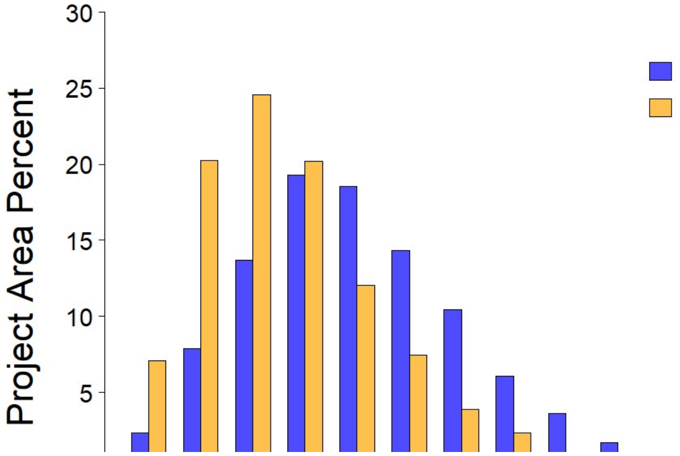


Figure 4. Proportion of project area in BA bins as assessed by remote LiDAR and imagery.

QMD

More area shifted to a higher QMD than to a lower QMD (**Figure 5**). The plot data were too variable to confirm or deny changes in the diameter distribution (**Appendix A**). Detecting even a moderate shift in these QMD from these data was surprising for the following reasons:

1) *Pre-treatment* LiDAR missed 52% (65 out of 125 TPA) of trees and these were mostly small. Thus, the measured QMD was *biased higher* than reality pre-treatment.
2) *Post-treatment* drone imagery produced a smoother CHM that lowered tree heights relative to pre-treatment LiDAR. Because DBH was predicted from height, the predicted basal area was lower. There were also fewer small trees to miss post-treatment, therefore, the measured QMD was *biased lower* than would have been predicted with LiDAR.
3) Subtracting the *high-biased* pre-treatment QMD from the *low-biased* post-treatment QMD resulted in less QMD gain than expected.

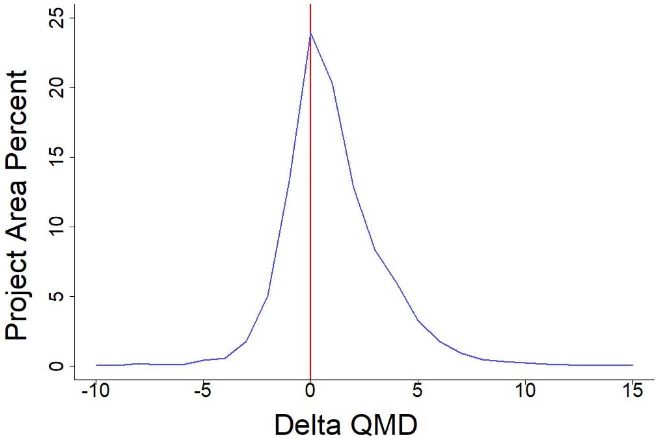


Figure 5. Change in predicted QMD post- and pre-treatment across project area (post – pre).

Management implications and recommendations:

The results are clear that the treatment reduced TPA and BA, but the absolute magnitude of the shift is unclear. Uncertainty in these magnitudes is a result of the types of data collected. For example, we know TPA was underestimated with remote data, but we do not know by how much because limitations of the plot data did not allow us to verify them. The pre-treatment cruise data with unknown plot locations or sample size (but likely high *N*) are probably more robust than the post-plot data (*N*=7).

Regardless of the absolute density, the resulting lower density of larger trees will likely accelerate development of fire resistance.

Q2: Was a mosaic spatial pattern with diverse patch types created?

Targets— The majority of area should be in dispersed single trees with half as much area in 2-4 tree clumps. Small amounts of remaining area should be in 5-9 and 10-15 tree clumps (**Table 3**).

Methods—Summaries of the proportion of area in each clump or gaps size were compared pre- and post-treatment. These data were not directly applicable to per-acre counts of clumps and gaps, although the summaries do allow us to assess the relative density of each clump or gap size.

Table 3. Prescription for clumping and gaps

Pattern metric	Size	Density
Clumping (trees per clump)	1	12 per acre
	2 to 4	6 per acre
	5 to 9	1 per 1.6 acres
	10 to 15	1 per 1.8 acres
Gaps (acres)	0.1 to 0.5	1 per 1.6 acres
	0.5 to 2	>1 total

Results

Clumping

The proportion of area in single trees (no neighbors within 20′) increased from 14% to 43%. In general, clumps were smaller, with only negligible amounts of clumps with >10 trees (**Figure 6**).

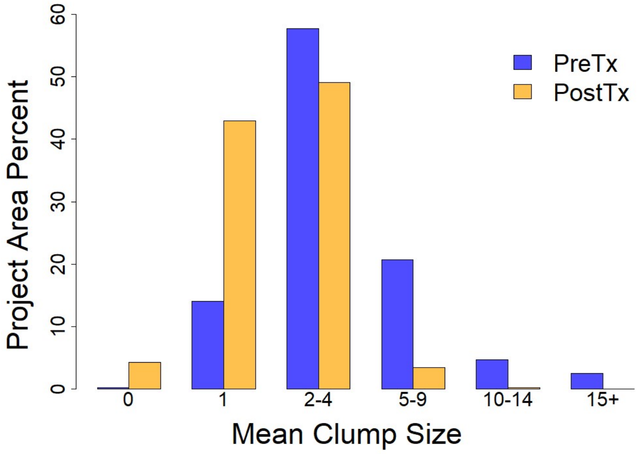


Figure 6. Percent area in bins of mean number of trees per clump summarized for each raster pixel Clump size 0 means those pixels had no trees., so represent open area

Gaps

Small gaps (less than 0.5 ac) rose 10-fold to 7.7% of project area, medium gaps (0.5 to 2 ac) rose 48-fold to 3.7% of area, and gaps larger than 2 acres rose 4-fold to 0.2% of area (**Figure 7**). In total, area in gap increased from 0.8% to 11.6%. There were virtually no 0.5-2 acres gaps prior to treatment, while after treatment there were some gaps larger than 2 acres.

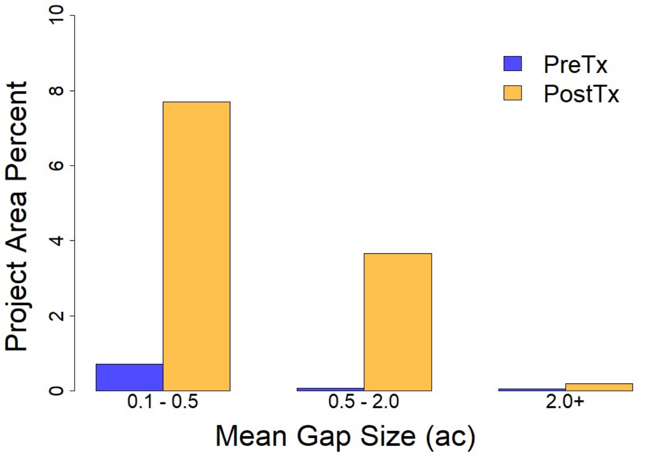


Figure 7. Percent area in bins for mean gap size summarized for each raster pixel. Pixels with tree and gaps are included, so total is larger than clump size of 0 in **Figure 5**.

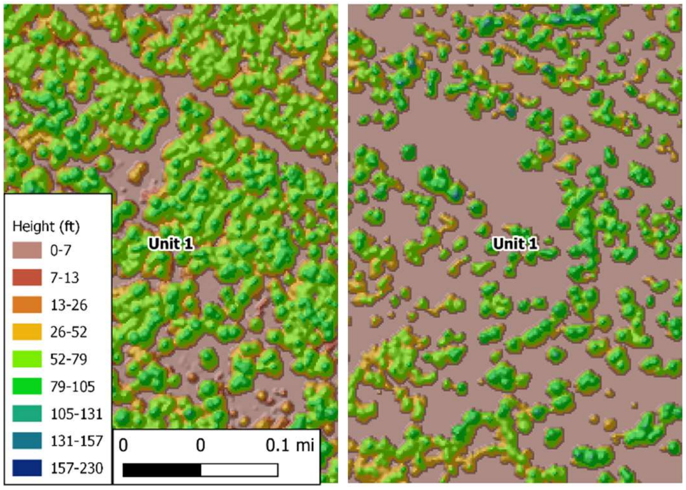


Figure 8. LiDAR-derived CHM (left) and Orthoimagery-derived CHM (right) showing tree spatial pattern and height before (left) and after (right) treatment in the same exact area.

Management implications and recommendations— The shift to smaller clumps sizes signifies more area between trees across broad areas of the treatment. There were still more small clumps than desired and too few 10-15-tree clumps. Large clump sizes of ≥15 trees represented dense closed-canopy regions, which were nearly eliminated by the treatment. The resulting structure had a lower canopy density and more light reaching understory vegetation (**Figure 8**), likely decreasing both crown fire potential and opening resources for understory biodiversity (**Figure 9**).

The treatment created a forest that was closer to a mosaic of single trees, small clumps, and gaps that was characteristic of a resilient dry frequent fire forest. While the TPA was still high and area in 2-4-tree clumps was nearly twice the target, this pattern should set the stage for future treatments. More space between trees should allow them to mature more quickly, develop fire resistance, and more diverse spatial patterns as future fires burn with different intensities across the treated area.

Figure 9. Spatial heterogeneity with linear gaps (above) and small clumps (below) in Unit 1 after treatment and the Cedar Creek Fire

Q3: Did species composition shift toward more fire-resistant species?

Targets— A meaningful shift in the proportion of ponderosa pine relative to Douglas-fir.

Methods— Plot-derived TPA and BA were summarized by species. Pre-treatment data only included trees ≥8″ DBH, so post-treatment data were filtered for trees ≥8″ DBH.

Results— The proportion of ponderosa pine rose and Douglas-fir declined by ~25% percent as defined by TPA and 19.5% as defined by BA (**Table 4**). Douglas-fir remained the majority of trees in the project area.

Table 4. Proportion of TPA and BA for trees >8″ DBH for each species pre- and post-treatment. PP = ponderosa pine, DF = Douglas-fir

Pre/post	Species	TPA %	BA %
Pre	DF	85.9	82.9
Pre	PP	14.1	17.1
Post	DF	61.2	63.4
Post	PP	38.8	36.6

Management implications and recommendations—

There were meaningful shifts in species to more fire and drought resistant ponderosa pine. However, the area was still predominantly Douglas-fir. If future TPA reduction is needed it should focus on Douglas-fir to reduce its dominance.

A high density of overstory Douglas-fir has two consequences. 1) It will likely suppress some of the less shade-tolerant ponderosa pine, and 2) will continue to provide most of the regeneration seed source. Therefore, without subsequent treatment, this forest may be on trajectory to become a predominantly Douglas-fir forest.

The forest appeared to be on this trajectory before the Cedar Creek Fire, when 94% of the regeneration was Douglas-fir, the remaining being ponderosa pine. How the fire altered these dynamics should be evaluated in a future study, but tree species mortality and post-fire regeneration data do not yet exist.

Q4: What was the fuel-loading after treatment and before the fire?

Targets— There are no targets, other than that fuel loading should be low

Methods— For each of 4 subplots in 14 larger plots, 1 to 100-hr wood and vegetation fuel loading (tons acre^{-1}) were estimated using photoload sampling (Keane, 2007). 1000-hr fuels were quantified along two 50′ transects with the plane intercept method (Brown, 1974).

Results— Wood loading was low and variable with all but 1000-hr fuels being below 1 ton acre^{-1} and standard errors ranging from 17 to 38% of the mean (**Table 5**). Using the equations of (Harrison et al., (2009) to estimate the mass of a 10″-DBH tree trunk and dividing 1000-hr fuel mass by this number, the 5 tons mass roughly equaled 16 10″-DBH logs per acre. Vegetation was low in loading and height, never exceeding 0.1 tons acre^{-1} or 6″ tall (**Figure 10**).

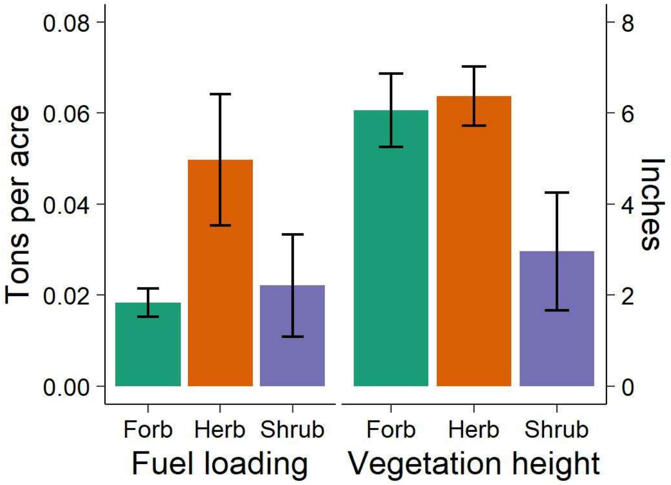


Figure 10. Fuel loading (left) and height (right) of understory vegetation

Table 5. Mean fuel loading across 4 subplots averaged across 14 fuels plots.

Fuel class	Loading (tons ac^{-1})	SD	SE	N
1-hr	0.84	0.73	0.20	14
10-hr	0.88	0.55	0.15	14
100-hr	0.79	1.12	0.30	14
1000-hr	5.01	7.42	2.80	7

Management implications and recommendations—

Much of the area appeared to have low fuel loading post-treatment (e.g. **Figure 11**). Nearly twice the fuel loading in eastern cascade forests as seen here did not have a strong influence on fire behavior (Agee and Lolley, 2006). In addition, dead wood and herbaceous loading were well below their potential maxima (1.4 to ~50% and 10% respectively, Dunn and Bailey, 2015).

Unless fire weather was severe, or fires consumed an especially dense patch of fuel, the surface fuel loads were not likely to create excessively long flame lengths that could torch whole trees *en masse*.

Figure 11. Example of low fuel conditions post-treatment in Unit 2.

Q5: What was the severity of the fire including secondary mortality?

Targets— Describe fire mortality in 4 and 7 classes

Methods— Data representing burn severity in 4 and 7 classes (Miller et al., 2009) were used to examine the proportion of area in each unit that burned at different severities. The datasets assess fire severity by estimating live BA loss at the following thresholds:

4-class: 0%, 25%, 75%, 100%
7-class: 0%, 10%, 25%, 50%, 75%, 90%, 100%

The percent area in each class was then summarized for each unit and in two areas in proximity that were not treated but had similar structural conditions according to the State Environmental Policy Act document, and aspect and topography pre-fire as assessed via a hill-shaded digital elevation model.

Results— Unit 1 was 43% unburned while Unit 2 burned entirely (**Error! Reference source not found.**). Of burned area, Unit 1 and the adjacent un-treated comparison unit had similar proportions in similar burn-severity classes. Unit 2 was similar in the lowest severity classes, but avoided the high percentages in >90% mortality in untreated comparison unit 2.

Table 6. Percent area in different burn classes based on predicted basal area mortality. Class values = higher severity and class 0 is out of the Cedar Creek Fire perimeter. See text for description of severity classes. U = treated unit, C = untreated comparison unit.

	Precent area				
Class	U1	C1	U2	C2	Notes
0	43	15	0.1	0.1	% project area
1	20	22	4	6	% burned area
2	66	62	27	34	% burned area
3	13	13	46	23	% burned area
4	0.4	3	23	38	% burned area

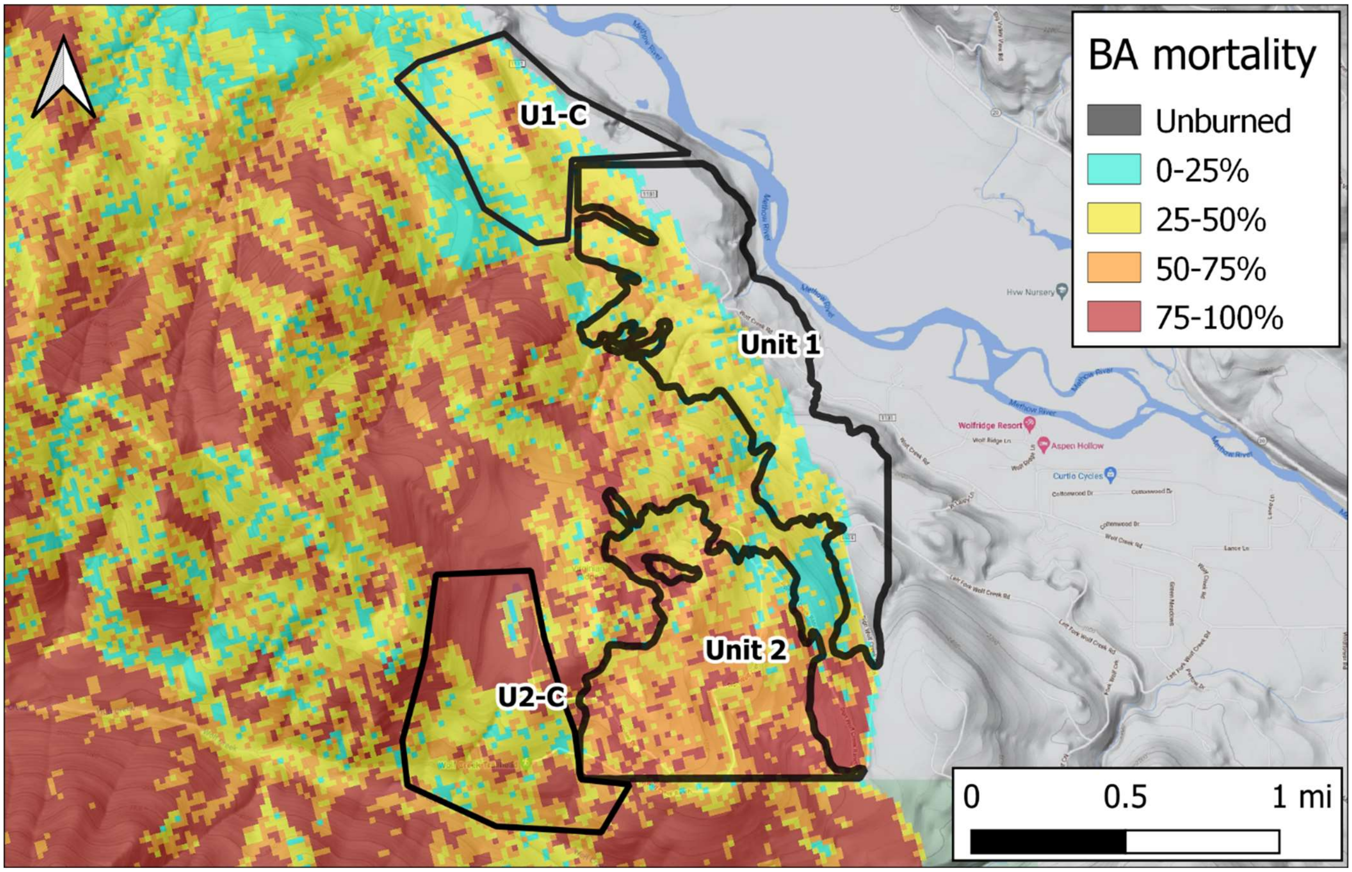


Figure 12. Map of the 7-class burn severity layer. Higher severity is in red and lower in blue. Comparison units were selected for similar pre-treatment forest structure, aspect, and topography.

Figure 13. Photos of Unit 2 in similar locations showing treated and untreated forest before the Cedar Creek fire (above) and after fire (below).

Management implications and recommendations—

The data suggest but do not definitively show that the treatment in Unit 2 reduced the highest severity burned area (e.g. **Error! Reference source not found.**), while the treatment in Unit 1 showed no difference compared with the control area.

Q6: Is natural regeneration sufficient to re-establish forest after the 2021 fire in unit 2?

Targets— Sufficient regeneration to meet DNR State Lands stocking guidelines of 100-200 TPA for this plant association.

Methods— DNR State Lands staff conducted an informal walk-through in the Spring of 2022 to visually assess natural regeneration abundance.

Results— DNR staff found natural regeneration throughout unit 2 that will likely meet targets. A systematic regen survey will be done in 1-3 years to assess the density and composition of regeneration, and determine planting needs.

Management implications and recommendations— Seedling survival is likely to be high due to the wet spring and summer in 2022. Surviving overstory trees will continue to provide seed source for additional regeneration. As unit 2 is a south facing, dry site, high density of regeneration is not desired. The need for replanting will be determine after the next regeneration survey in 1-3 years.

Management Implications

The species shift from Douglas-fir to ponderosa pine still left a majority trees as Douglas-fir. This was probably because Douglas-fir had to be retained to meet the TPA targets. Future treatments may consider reducing target TPA below 40 to allow for a greater shift in species composition. Additional monitoring could be done to quantify post-fire species composition and tree size distribution to assess whether conditions more closely mimic historical forest structure after treatment and fire.

Key Conclusions for Unit 1

- **TPA was reduced to within target ranges based on drone-based information.**
- **BA was reduced by ~25 ft^2 per acre based on drone-based information.**
- **Large trees were retained. QMD increased**
- **A spatial mosaic of individual trees, clumps, and gaps was created**
- **Species composition is still dominated by Douglas-fir although the proportion of ponderosa pine increased by ~25%**
- **Fuel loading was generally low but variable after treatment**
- **There is some evidence that the treatment reduced fire severity in unit 2**

Seedling survival and mortality should be re-assessed in 1 to 3 years. Douglas-fir may dominate regeneration, even though ponderosa pine is assumed to increase after fire. This assumption could be tested at this site, especially given the high proportion of overstory Douglas-fir retain post-treatment.

If higher accuracy results are required, future monitoring efforts should install more field plots. For a unit of this size, at least 30 plots with monumented locations that could be measured pre- and post-treatment would be ideal and provide more accurate information.

Limitations

Specific limitation of the datasets used in this study were evident in this case study. Aerial data tends to miss small trees, so TPA estimates are lower than actual, especially pre-treatment when thinning from below (**Appendix A**). These data are still useful for detecting relative change of the overstory.

Field data were used to assess species composition. The cruise summary pre-treatment data had no plots identified and the post-treatment data had $N = 7$, so these results are limited.

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LEARN MORE

This report was completed in September 2022.
More details about DNR's monitoring are available at: https://www.dnr.wa.gov/ForestHealthPlan
Data products are available at: https://bit.ly/ForestHealthData

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Appendix C: Treatment-Unit Monitoring Methods

Various datasets and methods were used to analyze the Bullfrog and Virginia Ridge treatment monitoring projects. This appendix provides detailed descriptions on the methods that were used. The strategy was to rely on plot data that was already collected by various land management agencies as part of their normal processes or by DNR from other projects and integrate these data with additional ground- and remote-based data collection. Additional ground-based data collection generally followed a new monitoring protocol, but was adapted in certain cases to make use of limited resources.

Site-treatment	Data type	Description	N	Acquisition year
Bullfrog-PreTx	Plot based	Variable radius BAF 20 timber cruise plots	Upland = 33, RMZ = 45	2019
Bullfrog-PostTx	Plot based	Fixed radius 10th acre monitoring plots	Upland = 33, RMZ = 46	2022
Bullfrog-PreTx	Remote	Areal LiDAR	NA	2019
Bullfrog-PostTx	Remote	Drone imagery	NA	2022
Virginia Ridge-PreTx	Plot based	Timber cruise summary	Unknown	2017
Virginia Ridge-PostTx	Plot based	Fixed radius 10th acre monitoring plots	Trees = 7, Fuels = 14	2022
Virginia Ridge-PreTx	Remote	Areal LiDAR	NA	2019
Virginia Ridge-PostTx	Remote	Drone imagery	NA	2022

Monitoring Plot Data

Two plot designs were implemented for the field data collection component of this project. These were the “macroplot” design, which included overstory, understory, and fine and coarse fuels components, and the “photoload cluster” design, which included only a fine fuels component. Macroplot locations were assigned in the field. Plot locations were selected to capture the range of overstory, understory, and coarse fuels at each site. Photoload cluster plot locations were similarly selected in the field to achieve a density of 7 plots per 50 acres. Photoload cluster plots were distributed between macroplots and were selected to capture the range of fine fuel conditions of each site. Targets were placed at plot centers for macroplots, photoload clusters, and photoload plots in order to facilitate location within the drone-based dataset.

Macroplot Design

For each macroplot, field crews inventoried tree data for Overstory trees, saplings, and seedlings. All overstory trees and snags (trees >= 5-in DBH) within a 10th-acre circle (37.2-ft radius) around the plot center. Individual trees were surveyed for species, DBH, status, decay class, percent scorch, and damage. Saplings (trees taller than 4.5 ft and <5-in DBH) within a 20th-acre (26.3-ft radius) plot were tallied by species in two diameter bins delineated at 2-in DBH. Seedlings counts by species within a 100th-acre (11.8-ft radius) plot were estimated and classified as <10, 10-20, or >20.

Fuels data were recorded for macroplots. General fire behavior indicators recorded for each plot included the distance to the nearest burn pile within 200-ft of plot center and average canopy fuel base height within the overstory plot radius. Litter and duff depth were recorded at four locations 5 and 15 feet north and south of the plot center. Fine fuel loadings were surveyed at 4 photoload plots located 20-ft from the plot center at cardinal directions following methods defined by the photoload sampling guide (Keane and Dickerson, 2007). Fine fuels loadings were surveyed separately for 1-hour, 10-hour, and 100-hour fuels within each photoload plot. Coarse fuels (1000-hour fuels) were surveyed along two 50-ft transects originating from locations 20 feet north and south of the plot center location. Coarse fuels were inventoried using the plane intercept method (Brown, 1974).

Vegetation data were collected for macroplots within a 20th-acre (25.3-ft radius) circle around the plot center. Percent cover was estimated for the classes of shrubs, grasses, and forbs. The two most dominant species within two height strata delineated at 3-ft, were recorded, as well as any invasive species with >5% cover.

Photoload Design

Photoload cluster plots were inventoried for fine fuel loading at 4 photoload plots located between 10 and 40-ft from plot center. The azimuths and distances of photoload plots from the plot center were unique and selected in the field in order to capture a range of conditions adjacent to the plot center. Fine fuel loadings were surveyed following methods defined by the photoload sampling guide (Keane and Dickerson, 2007). Fine fuels loadings were surveyed separately for 1-hour, 10-hour, and 100-hour fuels within each photoload plot.

Different components of these plot designs were used for the Bullfrog and Virginia Ridge project areas. The Bullfrog project area used only the macroplot design, and only for overstory, seedling, sapling, and 1000 hour fuels data. The Virginia Ridge project area used the full macroplot and photoload designs.

Other data

Other datasets were acquired opportunistically from pre-treatment timber and implementation compliance surveys. These had various protocols, but were primarily variable radius plots in which a prism with a basal area factor was used to determine if trees were in or out of a plot. If a tree was in, its species, live or dead status, and diameter were recorded. BA per plot was calculated as the basal area factor times number of trees. Trees per acre (TPA) represented by each tree in the plot was calculated as the basal area factor divided by the basal area of each tree then summed across all trees in the plot to attain the TPA for that plot. Quadratic mean diameter in these plots was calculated as:

$$QMD = \sqrt{\frac{\sum(DBH^2 * TPA)}{\sum TPA}}$$

where DBH and TPA are the diameters and TPA of individual trees in a plot.

Remote forest structure data

Data were either obtained via an aircraft using LiDAR or by Drone using imagery. Both methods are able to reconstruct the canopy surface by constructing a 3d point cloud. The most important difference between these point clouds is that the imagery-derived data tends to smooth tree crowns, making the heights shorter than expected in the field and when compared to LiDAR. At Bullfrog we were able to visit and measure heights of known trees in the remote imagery-based dataset to create a height correction of 0.9214 * height (ft) + 28.526. LiDAR was assumed to have produced accurate heights.

For both LiDAR and orthoimagery data, tree-approximate objects (TAOs) were segmented from pre- and post-treatment canopy height models using a watershed transform, implemented within the lidR software package (Roussel et al., 2020). Each TAO was associated with an *xyz*-value corresponding to the 3D location of the TAO's high point relative to the ground. TAOs were attributed with estimated diameter at breast height (DBH) values based on linear models predicting DBH from height, fitted from the plot data (Table 1, R^2 = 0.68, N = 136).

Table 1. Coefficients and statistical summaries for linier model predicting diameter as a function of height for field measured trees within the project area post-treatment.

Coefficients	Value	Standard Error	T value	Pr(>|t|)
Intercept	2.68455	0.99268	2.704	0.00773
Height	0.19216	0.01127	17.045	< 2e-16

TAO spatial patterns were characterized in terms of clumps and gaps. TAOs less than 20 ft from one another were grouped into clumps based on their high point locations (Jeronimo et al., 2019). Each TAO was assigned a clump size value corresponding to the total number of TAOs that it shared a clump with. Canopy gaps were detected using methods from Jeronimo et al. (2019), where a gap was required to have at least 100 ft^2 of area farther than 30 ft from the nearest canopy edge. Canopy edge was defined by a 6-ft-height threshold on the canopy height model.

Patterns of TAO metrics were summarized across the treatment units on a 66 foot grid (0.1 ac cell size). A 66-ft resolution matches DNR's remote sensing inventory, and is 0.1 ac which is convenient for understanding the summary scale. TAOs per acre (TPA) was calculated as the count of TAOs within each cell divided by the size of the cell. Estimated basal area per acre (BA) was calculated as the sum of $DBH^2 * 0.005454$ for TAOs within the cell divided by the size of the cell. Mean clump size was calculated as the TAO-by-TAO average of clump size values within each cell. Gap metrics were calculated from a 1-ft resolution binary gap raster, where percent gap was the percent of each 66-ft pixel in a gap, and mean gap size was the area-weighted average size of gaps within the pixel.

Mean clump size was summarized by binning mean clump size values across the treatment areas into ranges of 0, 1, 2-4, 5-9, 10-14, and >=15 tree clumps. Proportions of project area occupied by each clump size bin were reported. Mean gap size was summarized by binning mean gap size values across the treatment areas into ranges of <0.1, 0.1-0.5, 0.5-2.0, and >=2.0 acre gaps. Proportion of project area occupied by each gap size bin were reported.

QMD was estimated across the treatment units on a 66-ft grid. BA and TPA values were used to calculate QMD values for each pixel with the following equation:

$$QMD = \sqrt{\frac{BA}{0.005454 * TPA}}$$

For each pixel, pre-treatment QMD was subtracted from post-treatment QMD to estimate delta QMD (the change in QMD) as a result of treatment. Delta QMD was summarized by plotting the distribution curve of delta QMD value within the treatment area.

Fire data

To assess the burn severity of the Cedar Creek fire across the Virginia Ridge treatments, the RAVG dataset for that area was downloaded (https://burnseverity.cr.usgs.gov/ravg/). This is a derivative product of satellite data using topography and the relative difference normalized burn ratio to estimate percent BA mortality (Miller et al., 2009). These values are then summarized into a raster where each cell represents a different burn severity in 1 of 4 classes. We summarized the percent of area in each class across both units in Virginia Ridge.

Plot vs Remote data for monitoring

This appendix compares results from plot vs remote imaging data for evaluating treatment effects in monitoring projects. This is the second of the major objectives of this monitoring effort, the first being to assess implementation of prescriptions. One challenge of meeting both objectives was that monitoring was done *post hoc,* thus, pre-treatment (and sometimes post-treatment) plot data were used from a variety of sources not designed for answering monitoring questions. Additionally, the pre- and post-treatment remote data were similar yet imperfectly compatible.

Plot and remote data had many sources summarized below.

Project	Condition	Plot data	Remote data
Bullfrog	Pre-Tx	Upland: 33 variable-radius timber cruise plots Riparian: 45-fixed radius monitoring plots$^+$	Aerial LiDAR* of all units
	Post-Tx	Upland: 33 fixed-radius monitoring plots Riparian: 46 fixed-radius plots	Drone-based orthoimagery** of all units
Virginia ridge	Pre-Tx	Timber cruise summaries for Units 1 & 2 with unknown *N*	Aerial LiDAR of all units
	Post-Tx	7 fixed-radius plots in Unit 1 designed for fuel estimation	Drone-based orthoimagery of Unit 1
$^+$Monitoring plots were designed specifically for monitoring * Point cloud acquired via aircraft using lasers ** Point cloud acquired via drone using video frames to reconstruct 3D image			

First, we present a summary of items that become clear when reporting results from these respective datasets, followed by a few examples and recommendations:

Plot data	Remote data
1. If plot data were not collected in the same location and via the same methods before and after treatment, it was hard to compare metrics for change (e.g. less common species appear to be present or not depending on where plots were) 2. Plots were good at estimating understory components and species composition 3. Rare structures like snags or rare species needed larger plots to get an adequate sample. 4. Plots cannot define horizontal structural diversity unless they are large and tree locations are mapped	1. High spatial fidelity allows direct comparisons of the same area through time 2. Tree detection is biased to tall trees, misses short trees, and can only readily directly measure tree height. 3. “Plot-style” metrics such as basal area and TPA of trees larger than a cutoff diameter must be derived from remote data via predictions because tree diameter cannot be measured. These are approximations, not actual values, leading to confusion. 4. Large extent allows description of tree and gap spatial patterns

Plot data examples

Plot data were from variable-radius-plot cruise data before harvest and from fixed radius (10th acre) plots post-harvest, which produced some inconsistent results (Table 1). For example, for tree species in upland plots, it appeared that quaking aspen was eliminated and black cottonwood appeared, even though both were supposed to be untouched by the treatment. We do not actually know what happened with these less common species because they may not have been adequately captured in both pre- and post-treatment plots with different locations.

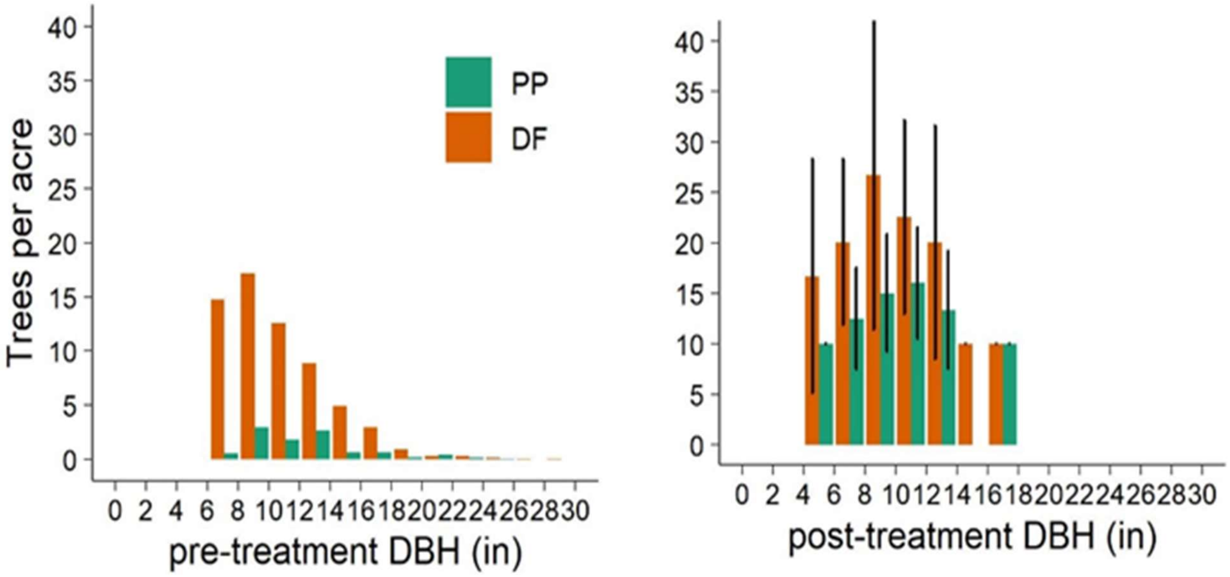
With large trees and snags, the sample size was low and thus uncertainty high, therefore, we could not predict the direction of change (**Table 1**). It appeared that ≥24"-DBH trees slightly increased in number, but this is impossible in such short timeframes. Snags were so few that the uncertainty in the estimate eclipsed the estimate itself.

Table 2. Examples showing a few limitations of plots.

Attribute	Pre	Post
Species TPA composition	DF: 36% PP: 62% GF: 1.5% QA:<1%	DF: 10% PP: 86% GF: 1% BC: 3% QA: 0%
>24"-DBH trees	6±2.0	9±3.6
Snag count	1.3±1.86	0.9±1.04

Some questions were unanswerable using plot data because of their inconsistencies. For example, summaries of timber cruises could not be used to compare the 7-fixed-radius plots installed at Virginia Ridge (**Figure 1**). There were no plot-level data pre-treatment so uncertainty could not be estimated, while both the magnitude and variability were high post-treatment due to a small sample. It is impossible for the tree counts to increase after treatment and unlikely for variability to increase when most of the treatment was thinned from below. We had to rely on remote data for density metrics which gave some strange numbers (see below).

Figure 1. Pre- (left) and post-treatment (right) comparisons of the diameter distribution based on plots at Virginia Ridge for ponderosa pine (PP) and Douglas-fir (DF).

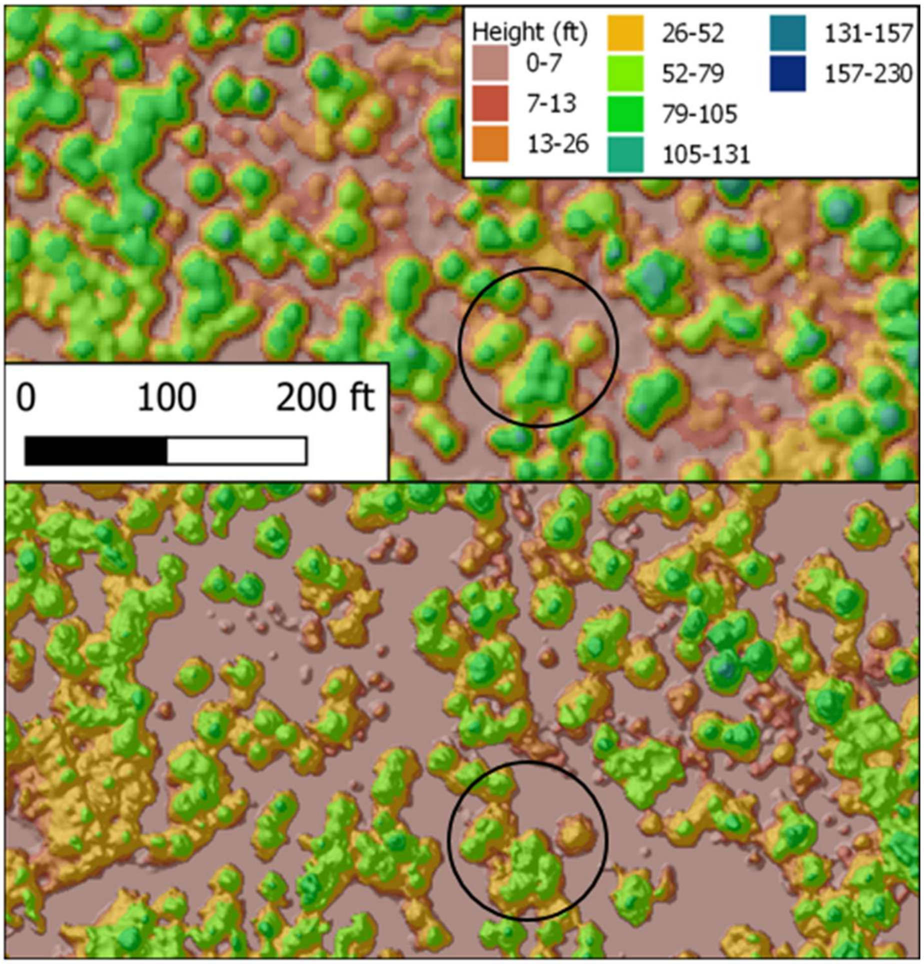


Remote data examples

Using a drone to collect remote data offered some exciting options because it was portable, could be deployed rapidly, and was cost effective. There were some tradeoffs between using LiDAR and orthoimagery we encountered that could be investigated more specifically for use in future monitoring efforts.

Even though both remote data sets (LiDAR vs orthoimagery) were similar and spatially explicit, they were not equivalent. The ortho-imagery data appeared to miss more smaller trees and estimate lower heights than LiDAR data (**Figure 2**). The consequence was that orthimagery biases metrics of diameter and tree count *low* compared to the same metrics derived from LiDAR.

Figure 2. Untreated area as seen by LiDAR above and orthoimagery below. Circle shows highlights the same trees within the area.



It was also evident from **Figure 2** that remote data were useful for showing the spatial patterns in a forest. Clumps, gaps, and heights of trees were easily visible and could be isolated using simple limiting distance measurements. For example, for the analyses in the monitoring reports, we used a limiting distance of 20′ from treetop to treetop do determine if a tree was an individual or part of a clump and a distance of 30′ from a canopy edge and an area with no trees

≥100ft^2 to define gaps. This allowed us to quantify the gap-size and clump-size distributions that would have been impossible with plot-level data.

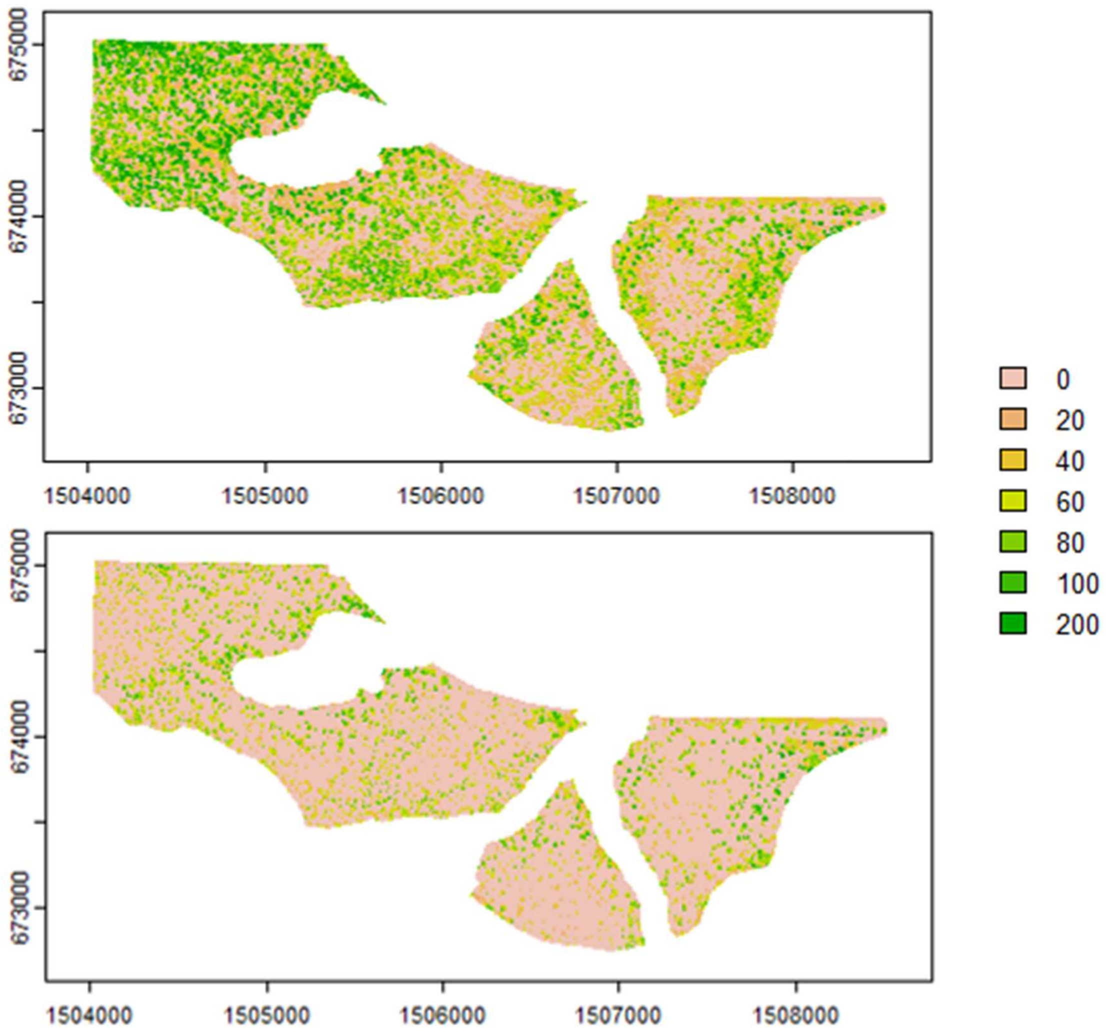
Remote data were able to easily assess peaks in the canopy height model representing treetops and canopy coverage at various heights, although the differences between the LiDAR and orthoimagery datasets reduced our confidence in the results. For example, in the Bullfrog project, the LiDAR data were collected several years prior to treatment, while orthoimagery data were collected immediately after treatment. To standardize them, we estimated height growth after the LiDAR flight and before treatment as 8-ft based on field observations and added this to the LiDAR-derived tree heights. The Orthoimagery models tend to smooth the treetops, lowering their heights. Based on field comparisons of trees measured with orthogimagery to actual tree heights we applied a regression (new ht = old ht * 0.9214 + 28.526) to these data to correct them.

Although these data were not perfect, they could help answer questions such as how much of the canopy was left in a particular tree size class by using height as a surrogate for diameter (**Table 2**). If we were confident the two remote datasets were measuring the same aspects of canopy structure, then these analyses would show that a little less then half of trees >100-ft tall were removed and may be of concern in a treatment where large trees were to be retained. However, by carefully examining individual tree crowns in **Figure 3**, we can see that post-treatment heights appeared slightly shorter than pre-treatment height, despite the height correction. This exemplifies why remote dataset collection should be standardized pre- and post- treatment, or carefully calibrated to each other.

Table 3. Summary of trees located pre- and post-treatment above various height cutoffs using remote data.

Height cutoff (ft)	Condition	Tree count	Mean height (ft)	TPA
20	Pre-Tx	4523	80.5	51
	Post-Tx	3076	84.5	35
80	Pre-Tx	2459	100.0	28
	Post-Tx	1189	97.2	21
100	Pre-Tx	1132	111.5	13
	Post-Tx	667	110.2	8
110	Pre-Tx	552	118.7	6
	Post-Tx	268	118.6	3

Figure 3. Canopy height model binned into intervals. Bins are all canopy height ≤ to the height (ft) cutoffs in the key.



One of the promises of remote datasets is the ability to monitor the same exact location through time with repeated measurements of a given geographically defined area. One goal of the projects was to determine if quadratic mean diameter (QMD) increased, which it appeared to on average (**Table 3**). But we can also theoretically answer if this was true in most areas with remote data.

To test this theory, trees were segmented (identified) from the two remote datasets described above and diameter predicted from height based on plot data (*N* = 136, R^2 = 0.68) QMD was calculated for each 66 x 66 ft area (pixel) across the entire treatment area separately for upland and RMZ treatments. Because we expected areas containing small trees only to be removed and such cells to decrease in QMD, the lowest 33% of QMD raster cells in the pre-treatment data were removed from the analysis of both pre- and post-treatment datasets.

Each remaining pre-treatment pixel was subtracted from the same post-treatment pixel to produce a population of locations with the QMD change (Delta QMD). Positive values indicated that QMD increased following treatment, while negative values indicated that QMD decreased. Delta QMD was compared to zero under the assumption that if no large trees were cut, the QMD must increase.

Delta QMD for both upland and RMZ treatments showed that most were nearly unchanged and about the same number showed a decrease as those that showed an increase in QMD across the project area (**Figure 4** & **Figure 5**).

Figure 4. QMD post-treatment subtracted from QMD pre-treatment in **upland areas**.

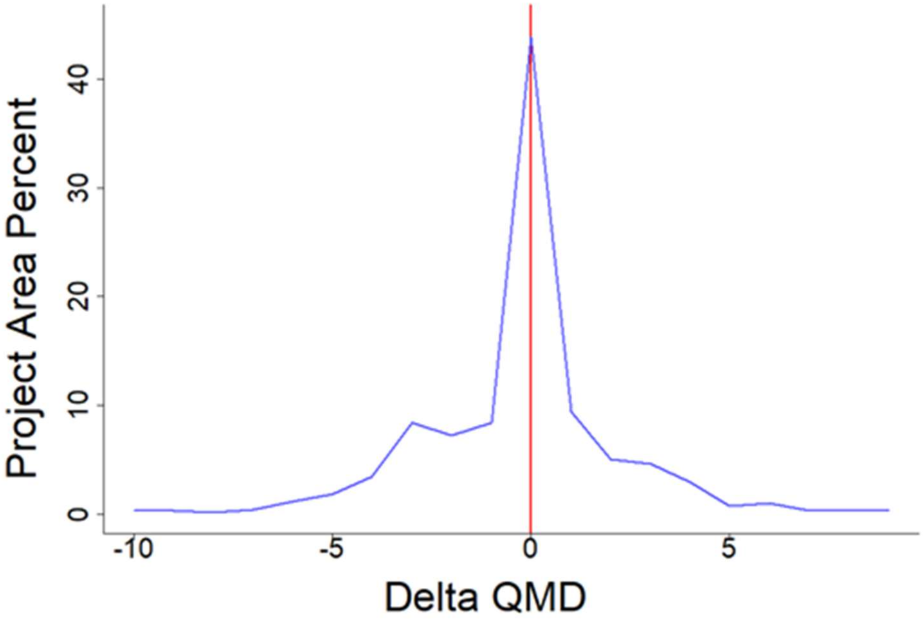
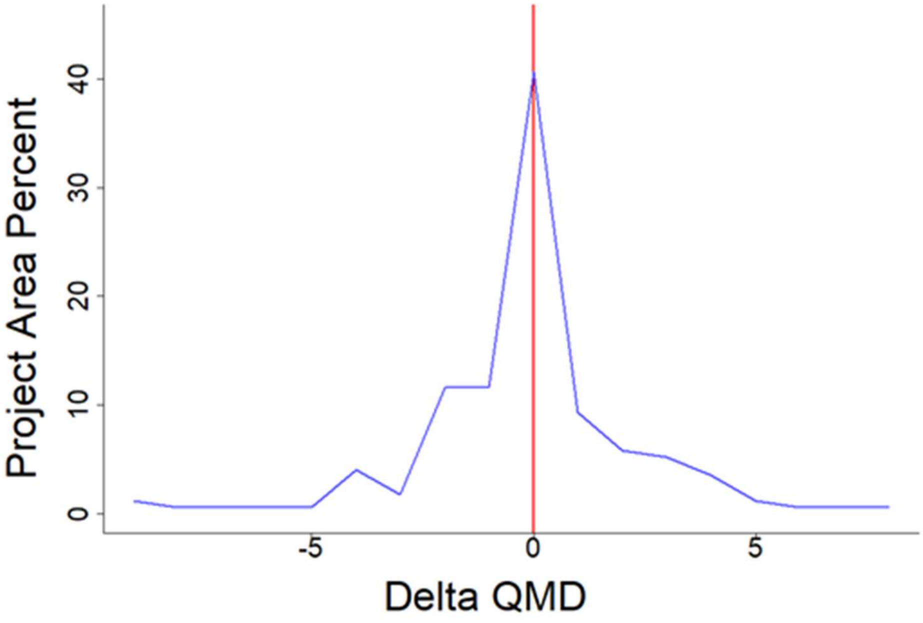


Figure 5. QMD post-treatment subtracted from QMD pre-treatment in **RMZ areas**.



Detecting positive shifts in QMD from these remotely sensed data was challenging for the following reasons:

1. Pre-treatment aerial LiDAR missed many small trees that were later removed by the treatment. Thus, measured QMD was *higher* than reality pre-treatment because those small trees would have brought it down.
2. Post-treatment drone imagery produced a smoother CHM that lowered tree heights relative to the pre-treatment LiDAR. Although we attempted to correct for this, there still appeared to be a bias. Because DBH was predicted from height, the predicted basal area was lower. There were also fewer small trees to miss post-treatment, therefore, the measured QMD was *lower* than would have been predicted with LiDAR.
3. Subtracting the *higher* pre-treatment from the *lower* post-treatment QMD may have resulted in an unexpected QMD shift.

For remote data to hold more promise for area-by-area-based tree change detection it will need to be cross validated with georeferenced plots and be collected in the same format and during the same growing season pre and post-treatment.

Comparing across datasets

One of the hardest differences to reconcile between plot and remote data are in plot-style metrics derived from remote data. Foresters are so accustomed to using ground-based metrics that it is useful to convert remote metrics into approximations of them. These approximations do not produce the same values (**Table 3**), but there are consistent directional differences among them.

Pre-treatment trees per acre (TPA) was underestimated by remote data more than post-treatment TPA (**Table 3**). This makes sense because many of the same small trees removed during thinning were those missed by remote data. Likewise, basal area per acre (BA) was underestimated by remote data, likely for the same reasons. Sometimes the estimates were close (e.g. Virginia Ridge post-treatment) and may have had to do with how the treatment created matrix of well-spaced and shorter trees than in Bullfrog. For example, in a taller forest like Bullfrog, more tall trees that contribute substantially to BA will be missed by remote data because they are overtopped by even taller trees, whereas in a shorter forest, the missed trees will may be relatively minor contributions to BA.

Table 4. Comparison of remote and plot-based variables pre- and post-treatment with 95% confidence interval. are shown for plot variables. LiDAR is from a 2014 flight.

Area	Attribute	Plot value pre	LiDAR value pre	Plot value post	Imagery value post
Bullfrog upland	TPA	70 ±18.9	51	37±6.9	34
	BA	109.4±18.77	97.2	80.4±17.34	67.5
	QMD	19.2± 1.75	18.7	19.8 ±1.75	19.2
Bullfrog riparian	TPA	86±12.5	52	49±5.6	50
	BA	123.8±20.12	101.6	105.9 ±18.00	102.9
	QMD	17.0±1.60	18.9	19.9 ±1.58	19.4

Conclusions

Remote and plot data are not directly comparable without further work to refine the methods used to analyze them. Although the differences are obvious and sometimes large, there are consistent biases that can be corrected to some degree. Pre-treatment estimates based on remote data are *lower* than post-treatment estimates so will need to be calibrated independently.

For these calibrations, we will need plot data collected with the same protocols in the same locations pre-and post-treatment. Plots should also be in the center of a given pixel of summarized remote data and the diameter of the plot should a multiple of the pixel size so that summaries of plots and remote data are of a similar areas.

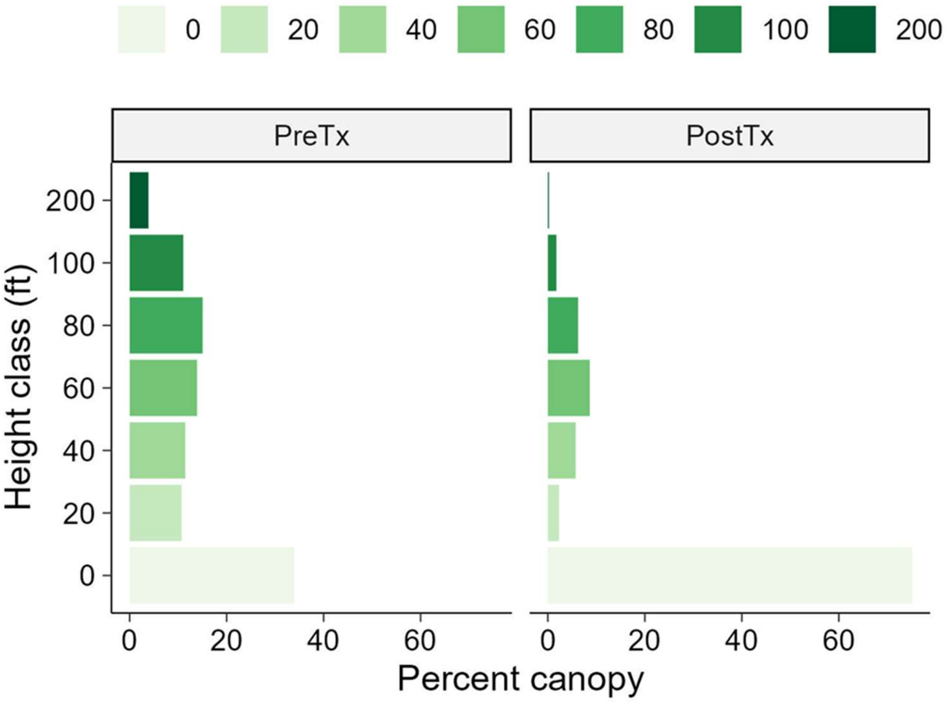
We recommend three sets of comparisons to calibrate these different types of data.

1. Compare plots with LiDAR pre- and post-treatment— Use these to calibrate LiDAR metrics to plot metrics.
2. Compare plots with orthoimagery pre- and post-treatment— Use these to calibrate orthoimagery and to discover systematic differences between LiDAR and orthoimagery
3. Compare LiDAR with orethoimagery on untreated areas—Use these to discover how these datasets differ in their ability to assess what cannot be assessed by plot data such as spatial pattern. Examine how delineation of trees, clumps, and gaps differ.

In addition to calibrating plot-style metrics from remote datasets with plot data, it is worth considering other metrics that plots cannot quantify to estimate forest density. There are metrics in remote datasets that have no analogy to plot-based measurements such as a point cloud density profile that could be very useful for monitoring. Such metrics are measurements of vegetation density, but are focused more on the whole canopy rather than individual trees in the same way fire ecologists use the metric of canopy bulk density. If we can change our perspective and use metrics more directly quantified with remote data, we can have high spatial and temporal fidelity in our measurements because the datasets are spatially explicit and repeatable.

As an example, we calculated percent of the canopy height model in each of 20-ft-height bands pre and post treatment in the Bullfrog project. For this analysis, points below 6 ft were considered non-tree and the rest were considered canopy cover. The total canopy cover above 6-ft height was 66.1% pre-treatment ad 24.9% post treatment. Cover vs. no cover may be the best resolution for these data given they are from different sources (LiDAR vs Drone imagery), however, if data were directly comparable, a useful analysis would be to compare the proportion of canopy cover occupied in each height band (**Figure 6**). If the data in **Figure 3** were collected identically per- and post-treatment it would be immediately apparent that too many of the tallest trees were removed, while overall canopy cover was reduced as desired.

Figure 6. Percent canopy cover in binned height bands. Each label represents the percent of raster cells where the height of that cell is ≤ the label. This would quickly show where most of the trees were removed if the data pre- and post-treatment were collected identically.



Appendix D: Change Detection Monitoring Methods

The change detection analysis involves two distinct steps, (1) satellite-based detection and attribution of change locations, and (2) evaluation of changes in forest structure in areas of change. The first component of the analysis involves using a USFS product, the Landscape Change Monitoring System (LCMS; USDA Forest Service, 2022) to locate disturbances, and then a Random Forest model created by DNR scientists to attributes changes to disturbance types. The second part of the analysis uses Digital Aerial Photogrammetry (DAP) data to assess how forest structure classes, determined using canopy cover and tree height metrics, has changed. Both components are detailed below, including areas for future improvements.

Disturbance Detection

The first step in determining changes to forest conditions across eastern Washington is to locate potential disturbances. After evaluating several options, including the Continuous Change Detection and Classification (CCDC) and LandTrendr approaches, we chose to use the LCMS data from the USFS. LCMS products include annual maps of forest losses and gains, with losses split into areas of fast or slow loss. The method is an ensemble modeling approach created using CCDC and LandTrendr, which are both temporal segmentation algorithms that analyze time series for breaks in natural temporal patterns (i.e., changes in canopy greenness over time). See the LCMS methods documentation (Housman et al., 2022) for more details about the product.

LCMS forest loss and gain data for 2015 – 2021 were downloaded for the 2022 change detection analysis on July 18, 2022 from Google Earth Engine (Gorelick et al., 2017). Products were downloaded for all of eastern Washington and downloaded tiles mosaicked together with GDAL by first combining tiles into a virtual raster using *gdalbuildvrt* and then translating the virtual raster to a GeoTIFF using *gdal_translate*. The end result is a multi-band raster for fast forest loss, slow forest loss, and forest gain, where each band represents detected changes for an individual year.

Disturbance Attribution

LCMS areas of forest loss and gain are not attributed to causal agents. As such, attribution models were developed by DNR scientists. Several Random Forest (Breiman 2001) models were tested, with the final model chosen to minimizing classification errors while maximizing the number of classes predicted. Random Forest models are a set of decision trees that are each trained using a different subset of the input data. The final model represents suite of trees where the end classification is the majority agreement among trees. This machine learning approach allows for rapid and accurate classification of data points into disturbance classes.

Training Data

The DNR Large Fires dataset, USFS Aerial Detection Surveys (ADS), DNR State Lands completed harvest information, DNR Forest Practices harvest data, and DNR Forest Resilience Forest Health Tracker data were all used to label areas of known disturbance for training the model. All datasets were limited to 2017 – 2020. The ADS data were used to label insect activity, while all of the DNR datasets were combined to label regeneration harvest, thinning, broadcast burning, and pile burning.

All of the training data sources contain polygon boundaries rather than pixels. Polygon datasets are challenging to use for prediction because not all pixels within the polygons are equally affected by the labeled disturbance, or even affected at all. For instance, ADS polygons are drawn around large areas of insect activity, but there may be a considerable amount of undisturbed forest within those boundaries. To get around this issue, the ADS and DNR datasets were filtered and refined to make it more likely that pixels labeled as those disturbances were actually disturbed. For ADS polygons, only areas where bark beetles or defoliators with greater than or equal to 10 trees per acre affected were included. The full list of insects included is found in Table 1. DNR harvest and treatment data were limited to completed treatments and were relabeled into simple categories (Table 2). Once harvest and treatment data were reclassified, the datasets were merged, with more severe disturbance types taking priority in areas of overlap (e.g., regeneration harvest if both regeneration harvest and pile burning occurred in the same pixel). Finally, because predictions were made at the pixel scale, all filtered and merged datasets were converted to raster format for the analysis using the *velox* package in R (R Core Team, 2022).

Table 1. ADS codes and descriptions included as insect activity in training the Random Forest attribution model.

Code	Description
1	Douglas-fir Beetle
2	Douglas-fir Engraver
3	Engelmann Spruce Beetle
4	Fir Engraver
5	Western Balsam Bark Beetle, Sub-Alpine Fir
6B	Mountain Pine Beetle, Whitebark Pine
6L	Mountain Pine Beetle, Lodgepole Pine
6P	Mountain Pine Beetle, Ponderosa Pine
6W	Mountain Pine Beetle, Western White Pine
7	Pine Engraver Ips
8	Western Pine Beetle
88	Western Pine Beetle, Pole-sized Ponderosa
9	Silver Fir Beetle
AB	Balsam Wooly Adelgid
BS	Western Spruce Budworm
LS	Black Pine Needle Scale
SM	Satin Moth
SF	Sawfly, True Fir
SP	Sawfly, Ponderosa Pine
CH	Larch Casebearer
AS	Spruce Aphid
TM	Douglas-fir Tussock Moth

Table 2. DNR harvest and treatment data classes. Simple classes were used to train the Random Forest attribution model.

Original Label	Simple Class
Forest Practices Data	
EVEN-AGE	Regeneration Harvest
EVEN-AGE	Regeneration Harvest
EVEN R/W	NA
EVEN/SALVAGE	Regeneration Harvest
R/W SALVAGE	Regeneration Harvest
RIGHT-OF-WAY	NA
SALVAGE	Regeneration Harvest
UN/SALVAGE	Thinning
UNEVEN-AGE	Thinning

UNEVEN R/W	NA
State Lands Data	
COMMRCL_THIN	Thinning
VARIABL_THIN	Thinning
SELECT_PROD	Thinning
VRH	Regeneration Harvest
UNEVNAGE_MGT	Thinning
CLEAR_CUT	Regeneration Harvest
SHELTER_INT	Regeneration Harvest
SEEDTREE_INT	Regeneration Harvest
SHELTER_REM	Regeneration Harvest
SEEDTREE_REM	Regeneration Harvest
TEMP_RET_REM	Regeneration Harvest
TEMP_RET_1ST	Regeneration Harvest
PILE	Thinning
LAND_USE_CONV	NA
PATCH_REGEN	Regeneration Harvest
Forest Health Tracker Data	
Precommercial Thin	Thinning
Thinning for Hazardous Fuels Reduction	Thinning
Jackpot Burning - Scattered concentrations	NA
Burning of Piled Material	NA
Slashing - Pre-Site Preparation	Thinning
Piling of Fuels, Hand or Machine	Thinning
Site Preparation for Planting - Burning	Thinning
Single-tree Selection Cut (UA/RH/FH)	Thinning
Chipping of Fuels	Thinning
Shelterwood Establishment Cut (with or without leave trees) (EA/RH/NFH)	Thinning
Commercial Thin	Thinning
Shelterwood Removal Cut (w/ leave trees) (EA/NRH/FH)	Regeneration Harvest
Road Maintenance - Vegetation Reduction	Thinning
Underburn - Low Intensity (Majority of Unit)	Broadcast Burning
Seed-tree Seed Cut (with and without leave trees) (EA/RH/NFH)	Regeneration Harvest
Rearrangement of Fuels	Thinning
Invasives - Pesticide Application	Thinning
Salvage Cut (intermediate treatment, not regeneration)	Thinning

Pruning to Raise Canopy Height and Discourage Crown Fire	Thinning
Yarding - Removal of Fuels by Carrying or Dragging	Thinning
Two-aged Seed-tree Seed and Removal Cut (w/res) (2A/RH/FH)	Regeneration Harvest
Site Preparation for Planting - Mechanical	Thinning
Site Preparation for Natural Regeneration - Manual	Thinning
Prune	Thinning
Broadcast Burning - Covers a majority of the unit	Broadcast Burning
Liberation Cut	NA
Group Selection Cut (UA/RH/FH)	Regeneration Harvest
Sanitation Cut	Thinning
Stand Clearcut (w/ leave trees) (EA/RH/FH)	Regeneration Harvest
Planting	NA
Lop and Scatter	Thinning
VRH	Regeneration Harvest
UNEVNAGE_MGT	Thinning
SEEDTREE_REM	Regeneration Harvest
SHELTER_REM	Regeneration Harvest
VARIABL_THIN	Thinning
SEEDTREE_INT	Regeneration Harvest
COMMRCL_THIN	Thinning
PATCH_REGEN	Regeneration Harvest
HAND_CUT	Thinning
FOLIAR_BROAD	Thinning
PILE_BURN	NA
HAND_PLANT	NA
MASTICATION	NA
FOLIAR_DIRECT	Thinning
GROUND_HERB	Thinning
GROUND_MECH	Thinning
Non-Commercial	Thinning
Hand Crew	Thinning
Hand Crew/Chipper/Masticator	Thinning
Hand Crew/Masticator	Thinning
Handcrew	Thinning
Masticator	NA

Mechanized Logging	NA
Helicopter	NA
Hand Crew - Chipper	Thinning
Mastication	NA
Commercial	Thinning
Fire	Broadcast Burning
Commercial _thinning	Thinning
Broadcast Burn	Broadcast Burning
Biomass Removal	NA
Thinning	Thinning
Machine Pile Burn	Broadcast Burning
Hand Pile Burn	NA
Mowing	Thinning
Hand Pile	Thinning
Shaded Fuel Break	Thinning
PCT	Thinning
Stand Improv - Non-comm	Thinning
Stand Improv - Commercial	Thinning
PreCommercialThin	Thinning
PileAndBurn	NA
Hand Crew/Chipper	Thinning
Handcrew & Chipper	Thinning
LAND_USE_CONV	NA

Predictor Variables

Landsat-derived metrics of forest greenness were used as predictors in the attribution model. A suite of vegetation indices, including Normalized Difference Vegetation Index (NDVI), Normalized Difference Water Index (NDWI), Shortwave Infrared (SWIR), Normalized Burn Ratio (NBR), and Tasseled Cap Wetness, Greenness, and Brightness (TCW, TCG, TCB), were compiled in Google Earth Engine (GEE; Gorelick et al., 2017). The indices were calculated on each Landsat image over the study period, and then the mean values were calculated for each year. Rasters of mean values were downloaded from GEE and tiles mosaicked using GDAL. Four sets of predictors were calculated from the downloaded annual indices: magnitude change, the standard deviation of magnitude, magnitude change within a 90x90m neighborhood, and the standard deviation of change in magnitude within a 90x90m neighborhood. Magnitude change was calculated as the change in index value the year of the disturbance relative to the mean of three prior years. Landsat metrics were extracted at change locations, matching years between Landsat and change detection layers.

In addition to Landsat-derived predictors, the probability of fast or slow loss, as well as gain, from LCMS was extracted for each location where change was labeled. Additionally, the mean and standard deviation of fast or slow loss probability was calculated for 90x90m neighborhood around each pixel and those values were also considered as predictors.

The final dataset used to create the models used data from 2017 – 2020, to match the harvest data available. Change locations were limited to forested locations (see the forest mask product in the DNR data dictionary) in eastern Washington. Each change location was limited to one year of change over the study period and one known disturbance agent. If any years were labeled with fast loss, that was the year of change for that pixel. Otherwise, the last year where change was detected was used as the year of change. If more than one disturbance existed in a change pixel, they were prioritized as follows: fire, regeneration harvest, thinning, broadcast burning, and insect activity. The final model dataset had Landsat and LCMS predictor variables for the year change was detected, along with one known disturbance type (if present at the pixel).

Random Forest Model

The Random Forest model was created using the *randomForest* package (Liaw and Wiener, 2002) in R. To ensure an even sample from each disturbance class, the training sample was a random subset of each class with 60% of the number of pixels in the smallest class. The resulting model sample had 2,390 pixels for each class. All predictors were evaluated for their ability to distinguish between disturbance classes by looking at density diagrams. If the values for the predictor didn't show any differences in their distribution based on the disturbance class, they were removed from the dataset. The final predictors used are shown in Table 3. The Random Forest model was trained with 500 trees. Variable importance is displayed in Figure 1. The 40% of the data not used for training the model was used to test it, and the resulting confusion matrix showing classification errors by change agent is shown in Table 4. The resulting attribution model was used to predict disturbance types at all locations where LCMS detected forest loss between 2015 and 2021, with results reported annually as raster layers (Table 5).

Table 3. Predictor variables used in the final Random Forest model. Neighborhood predictors were calculated over a 90x90m moving window around each pixel.

Predictor Variable Code	**Predictor Variable Name**	**Description**
	Pixel Variables	
PROB_FL	Probability of Fast Loss	Probability of fast forest loss from the LCMS model.
PROB_SL	Probability of Slow Loss	Probability of slow forest loss from the LCMS model.
PROB_G	Probability of Gain	Probability of forest gain from the LCMS model.
CHANGE_TYPE	Change Type	LCMS predicted type of change (fast loss, slow loss, or gain),

		based on the probabilities of fast low, slow loss, and gain.
NDVI	NDVI Magnitude Change	Change in NDVI the year change was detected relative to the three years prior.
NDWI	NDWI Magnitude Change	Change in NDWI the year change was detected relative to the three years prior.
NBR	NBR Magnitude Change	Change in NBR the year change was detected relative to the three years prior.
SWIR	SWIR Magnitude Change	Change in SWIR the year change was detected relative to the three years prior.
TCG	TCG Magnitude Change	Change in TCG the year change was detected relative to the three years prior.
TCB	TCB Magnitude Change	Change in TCB the year change was detected relative to the three years prior.
TCW	TCW Magnitude Change	Change in TCW the year change was detected relative to the three years prior.
	Neighborhood Variables (90x90m area around each pixel)	
PMEAN_FL	Mean Prob. of Fast Loss	Mean probability of fast forest loss.
PMEAN_SL	Mean Prob. of Slow Loss	Mean probability of slow forest loss.
PMEAN_G	Mean. Prob. of Gain	Mean probability of forest gain.
PSD_FL	Std. Dev. Prob. of Fast Loss	Standard deviation probability of fast forest loss.
PSD_SL	Std. Dev. Prob. of Slow Loss	Standard deviation probability of slow forest loss.
PSD_G	Std. Dev. Prob. of Gain	Standard deviation probability of forest gain.
NDVI_SD	Std. Dev. NDVI Magnitude Change	Standard deviation of the magnitude change in NDVI.
NDWI_SD	Std. Dev. NDWI Magnitude Change	Standard deviation of the magnitude change in NDWI.
NBR_SD	Std. Dev. NBR Magnitude Change	Standard deviation of the magnitude change in NBR.

SWIR_SD	Std. Dev. SWIR Magnitude Change	Standard deviation of the magnitude change in SWIR.
TCG_SD	Std. Dev. TCG Magnitude Change	Standard deviation of the magnitude change in TCG.
TCB_SD	Std. Dev. TCB Magnitude Change	Standard deviation of the magnitude change in TCB.
TCW_SD	Std. Dev. TCW Magnitude Change	Standard deviation of the magnitude change in TCW.

Figure 1. Variable importance for the final Random Forest change attribution model. Variable descriptions are found in Table 3. The higher the mean decrease in Gini score, the higher the variable importance in the model.

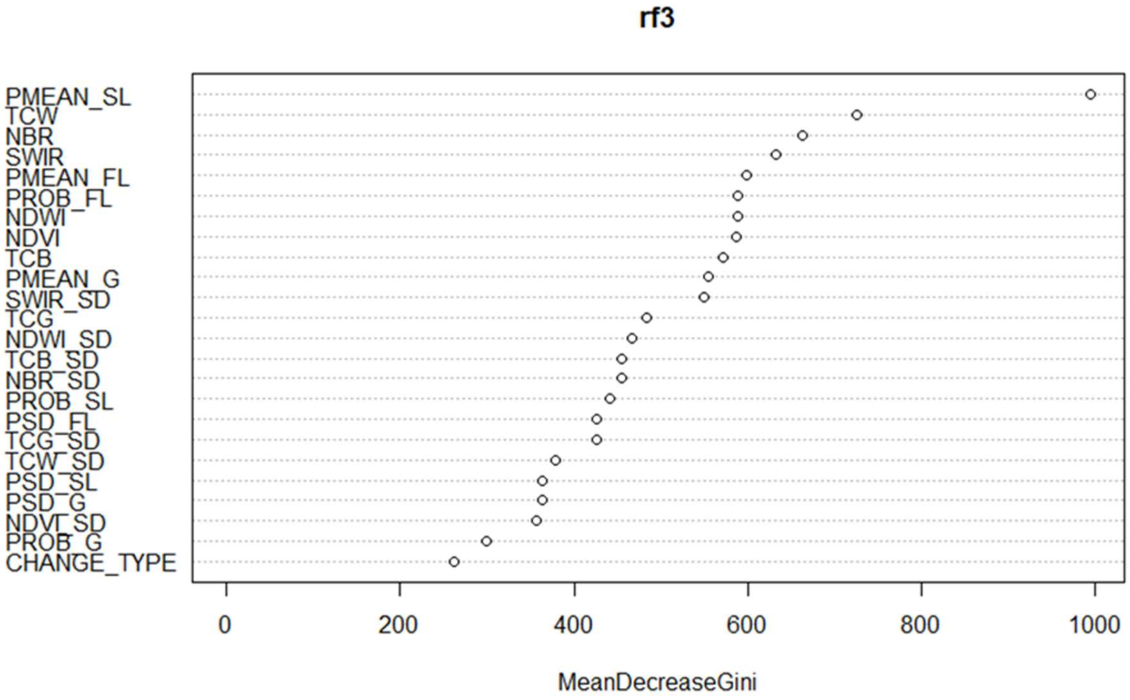


Table 4. Confusion matrix of Random Forest model results using the 40% sample of data for testing. Values are number of pixels, and the "Class Errors" are the percentage of each class that were incorrectly classified. The row names are the actual class of each pixel, and the column names are the predicted class.

	Fire	Regen. Harvest	Thinning	Insect Activity	Broadcast Burning	Class Errors
Fire	1326	17	130	77	41	16.7%
Regen. Harvest	122	763	667	22	19	52.1%
Thinning	77	227	4354	61	42	8.5%
Insect Activity	80	33	338	1098	38	30.8%
Broadcast Burning	58	43	424	17	1039	34.3%

Table 5. Raster value key for change detection output. Initial Random Forest output is that predicted from the final attribution model directly. The full and simple post-processed output rasters are identical, except that one includes different severities of fire, whereas the other labels all fire as the same class. Pile burning locations are found in separate raster layers.

Raster Value	**Disturbance Type (Initial Random Forest Output)**	**Disturbance Type (Full Post-Processed Output)**	**Disturbance Type (Simple Post-Processed Output)**
1	Wildfire	Low Sev. Wildfire	Wildfire
2	Regeneration Harvest	Mod. Sev. Wildfire	-
3	Thinning	High Sev. Wildfire	-
4	Insect Activity	V. High Sev. Wildfire	-
5	Broadcast Burning	Regeneration Harvest	Regeneration Harvest
6	-	Thinning	Thinning
7	-	Insect Activity	Insect Activity
8	-	Broadcast Burning	Broadcast Burning

Post-Processing

The resulting attributed annual rasters were then processed further for several reasons. First, the pixel-level predictions often meant that multiple disturbance types (e.g., wildfire, thinning, and insect activity) would occur within a single landscape patch in the same year. This is not a realistic scenario, so post-processing was used to limit patches to one type of disturbance. Second, some areas labeled as broadcast burning were within thinning or regeneration harvest areas, likely indicating pile burning locations. These could occur within the same year as thinning or harvest, so we wanted to separate the locations out into separate layers. Third, while LCMS detected the majority of fire activity across eastern Washington, many areas of low severity fire were excluded. DNR fire severity layers are more accurate for this purpose, so we decided to add in separate fire data to LCMS results. Finally, there were a number of locations where isolated pixels or very small patches of pixels were labeled as having changed. While this is possible for some disturbances (i.e., insect activity), it is extremely unlikely for most, including wildfires and any forest health treatments.

To address these issues, several post-processing steps were included in the analysis. All steps were conducted in R. To include all wildfire locations, DNR fire severity data was merged in with the annual attributed model results, replacing the LCMS locations labeled as wildfire. Next, for each annual raster, we located patches of disturbance using the "get_patches" function from *landscapemetrics* (Hesselbarth et al. 2019), considering all 8 surrounding pixels as neighbors. Any patches below a specified size threshold for each disturbance class were removed, thus removing single pixel and very small change locations. For all disturbance types other than insect activity, a threshold patch size of 5 acres was used. Insect activity can occur over much smaller areas, so a threshold patch size of 1 acre was used for that disturbance type. Next, each identified patch was limited to a single disturbance type. The patch disturbance type was determined as the disturbance with the most pixels in the patch (e.g., if 70% of the patch pixels were wildfire, then all pixels within the patch were changed to wildfire). The final post-processing step was to find and extract potential pile burning locations. Here, we found all areas of broadcast burning in the raw model output rasters that also overlapped thinning or regeneration harvest patches in the simplified rasters (with wildfire added, limited to larger patches, and a single disturbance per patch). All broadcast burning locations other than these overlap areas were removed and then the resulting annual rasters were exported. The pile burning locations could occur within the same year as thinning or regeneration harvest, so they were not added to the simplified change detection results (hereafter, CD output) and instead were kept separately. Finally, the accuracy of the CD output (Table 6) was determined through comparison of 2017 – 2020 results with the testing dataset used to test the Random Forest model. If there were multiple disturbances within the same location over the time period, the disturbance priority was determined in the same way as the initial training dataset. The accuracy of pile burning locations could not be assessed with the given data, so these areas are designated potential pile burning locations and should be used with caution. Further field work should be used to determine their accuracy.

Table 6. Confusion matrix for the simplified version of change detection results, after all post-processing (CD output). Pile burning accuracy was not assessed. Values are number of pixels, and the "Class Errors" are the percentage of each class that were incorrectly classified. The row names are the actual class of each pixel, and the column names are the predicted class. Errors were assessed relative to the 40% testing dataset from the Random Forest model.

	Fire	Regen. Harvest	Thinning	Insect Activity	Broadcast Burning	Class Errors
Fire	1518	2	10	3	0	1.0%
Regen. Harvest	1	662	643	12	0	49.8%
Thinning	2	85	2657	92	1	6.3%
Insect Activity	6	19	117	690	1	17.2%
Broadcast Burning	115	0	312	16	588	43.0%

Evaluation of Forest Structural Changes

Digital Aerial Photogrammetry (DAP) Data

Digital Aerial Photogrammetry (DAP) data are point clouds that can be used in the same way as lidar data. While DAP data tend to be less accurate than LiDAR data, it is substantially cheaper than LiDAR to collect, and the stereo imagery used to produce the data is available every two years. This makes DAP a critical tool for monitoring across large landscapes where wall-to-wall structure information is needed on a regular basis. Here, we describe our use of the data to assess changes to forest structure in areas where change was detected in the satellite-based detection approach described in previous sections.

Currently, DNR photogrammetry staff produce DAP data from NAIP stereo imagery approximately every two years, as imagery are available. The last two cycles (2019 and 2021) of NAIP imagery have been incomplete, necessitating two years of data collection to get wall-to-wall coverage across Washington. Therefore, 2019 data actually include 2019 and 2020 imagery, and 2021 data will include both 2021 and 2022 imagery. The derivation of structure metrics from DAP is somewhat complicated by multiple sources of errors in the DAP data. Tree shadows can reduce the accuracy of the derived point clouds, and this error changes based on the time of year and time of day of each flight. As such, DAP precision (Figure 2) is lower than LiDAR because flights take place on different dates and at different times across flight years. Additionally, processing decisions can also change the point cloud results and occasional re-processing is required to test other options to improve the data. DAP also tends to reduce tree heights in open canopies and canopy cover saturates at ~80% canopy cover (Figure 3). The DNR Forest Resilience division has an ongoing contract to determine the exact accuracy and precision of DAP relative to LiDAR data (see Figure 4), the results of which will be included in future reports.

Figure 2. Histogram of differences in cover between different years of DAP, in locations where LiDAR canopy cover is less than 80% and shows no changes (<3% between years). DAP canopy cover saturates to 100% when LiDAR canopy cover is >80%. Values are the absolute difference between DAP canopy cover across years in areas with overlapping LiDAR flights, with 0 indicating that measurements were the same. Produced by Jonathan Kane (University of Washington).

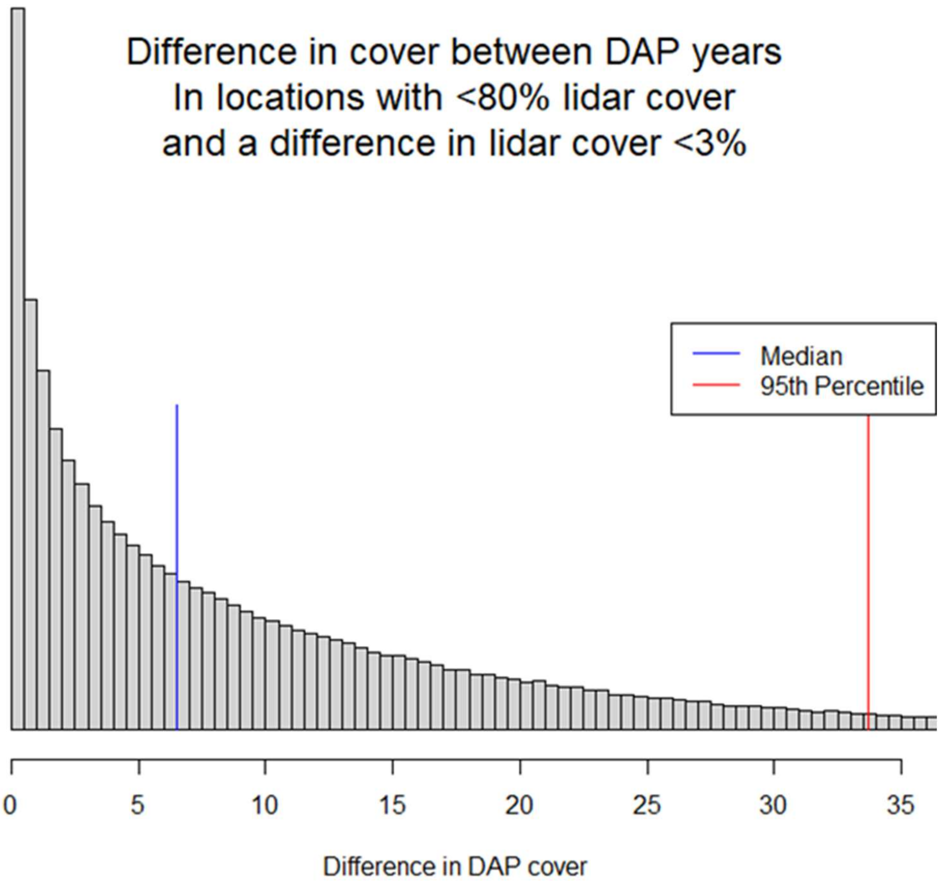


Figure 3. LiDAR versus DAP canopy cover, for all areas in eastern Washington where the LiDAR year was within 2 years of a DAP year. There was a 3x3 smooth applied to both datasets, and LiDAR cover was multiplied by 1.25 because DAP tends to saturate at ~80% of LiDAR canopy cover (i.e., LiDAR canopy cover of 80% is roughly equivalent to DAP canopy cover of 100%). Produced by Jonathan Kane (University of Washington).

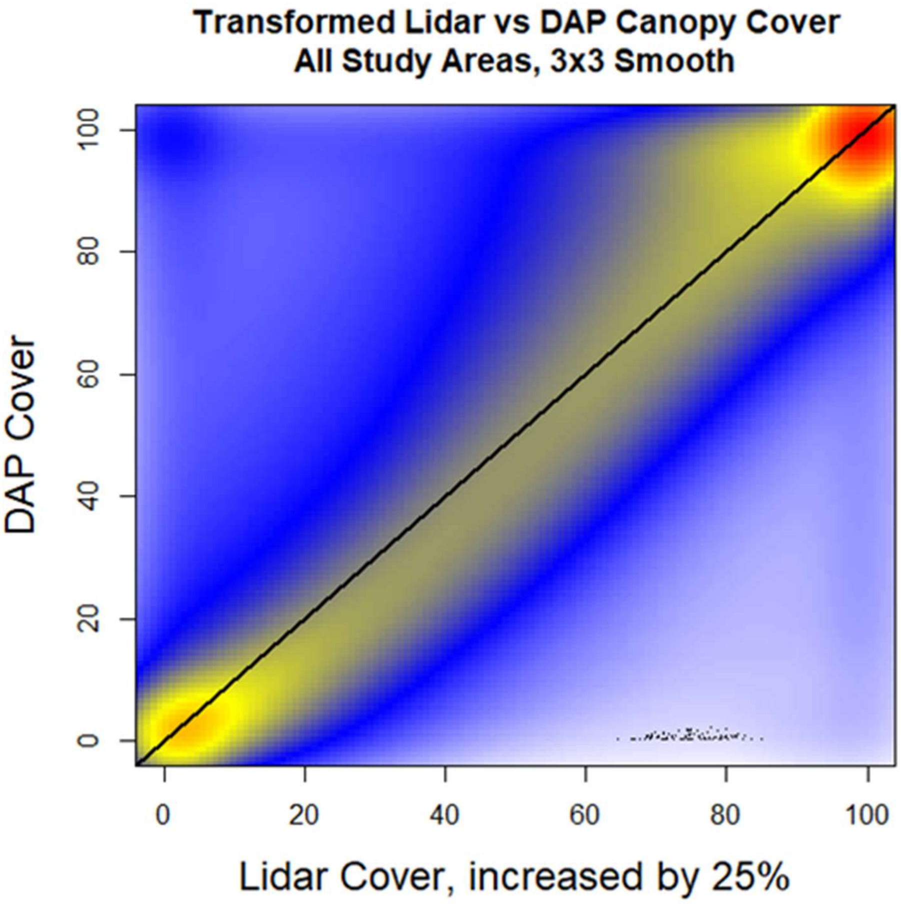
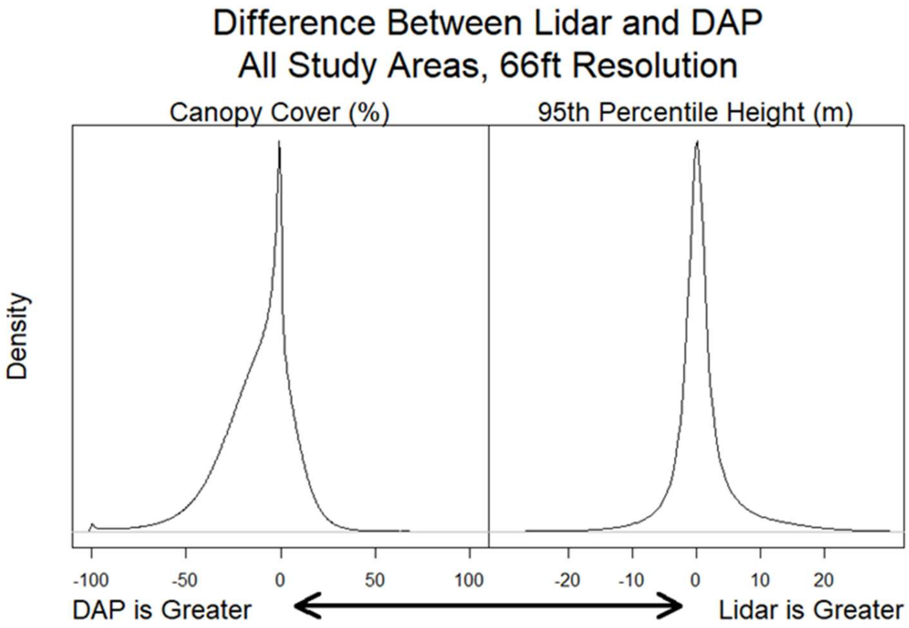


Figure 4. The difference between LiDAR and DAP canopy cover and height, for all areas where LiDAR data were within 2 years of a DAP year. The data are summarized at 66 foot resolution. Produced by Jonathan Kane (University of Washington).



To minimize any DAP errors in the data used for structure change analysis, DNR staff and contractors manually investigated DAP-derived canopy height and top surface data for obvious anomalies. Areas where potential errors were found were re-processed by DNR photogrammetry staff to attempt to remove the errors. In most cases, this was successful, however, there were some errors remaining in the data. DNR staff currently have a contract at UW to produce a tool that will detect and label remaining errors so that the areas are flagged as unreliable. An error layer will be included in change detection results in the future to better represent the uncertainties in the results.

Once point clouds were as clean as possible given the manual error inspections and re-processing, forest structure metrics were estimated using the program FUSION. A variety of canopy cover and tree height metrics were created, using a minimum height cutoff of 6 feet and a maximum height of 350 feet. Grid metrics were created at 66 foot resolution for all years where DAP data were available. 2019 and 2020 data were processed separately.

Structure Class Modeling

DAP-based structure classes (Table 7) were created using models of 75th percentile quadratic mean diameter (QMD) size class and canopy cover class. Both size class and cover class were modeled using Random Forest classification with DAP gridmetrics and a collection of satellite-based climate metrics as predictors (Table 9). The training data for the both models came from field plots in eastern Washington. Several models were tested, with the final models chosen for accuracy and simplicity. Variables used in the size and cover models and their relative importance are shown in Figure 5. In general, the DAP-based size and cover classes (used to create structure classes) matched those from LiDAR well, with the exception of the medium size class and moderate cover class, which are over-represented (Table 8). This is expected, given the issues with locating canopy gaps with DAP. That being said, the model does fairly well at predicting structure classes, and certainty about structure changes should improve over time when we get more DAP years. With more post-change DAP measurements, we can take averages over several years rather than relying solely on a single measurement, thus reducing the impact of bad image angles or other causes of shadowing. DAP structure classes were developed by Kevin Ceder as part of a DNR contract.

Table 7. Structure classes used in the DAP structure change analysis are shown in the "LiDAR/DAP 8 Classes" column. Columns 2, 3, and 5 crosswalk the structure classes used for this analysis to others used in eastern Washington and as part of landscape evaluations.

LiDAR/DAP 8 Classes	**6 Classes**	**Colville NF 5 Classes**	**Definition**	**Corresponding Structure Classes from Photo-Interpretation System**
Small Open	Small Open	Early	canopy cover[1] < 10% OR dbh[2] < 10”, canopy cover ≥ 10% dbh and < 40%	Stand Initiation
Small Closed	Small Dense	Early	dbh < 10", canopy cover ≥ 40%	Stand Initiation; Stem exclusion closed canopy
Medium Open	Medium Open	Mid Open	dbh ≥ 10” and < 20”, canopy cover ≥ 10% and < 40%	Stem exclusion open canopy
Medium Moderate	Medium Dense	Mid Closed	dbh ≥ 10” and < 20”, canopy cover ≥ 40% and < 60%	Young forest multistory; understory re-initiation; Stem exclusion closed canopy
Medium Closed	Medium Dense	Mid Closed	dbh ≥ 10" and < 20", canopy cover ≥ 60%	
Large Open	Large Open	Late Open	dbh ≥ 20", canopy cover ≥ 10% and < 40%	Old forest single story; Stem exclusion open canopy
Large Moderate	Large Dense	Late Closed	dbh ≥ 20", canopy cover ≥ 40% and < 60%	Old forest multistory; young forest multistory
Large Closed	Large Dense	Late Closed	dbh ≥ 20", canopy cover ≥ 60%	

[1] Canopy cover is derived from LiDAR or DAP using the percent of returns above 6.6 feet.

[2] Tree diameter at breast height (DBH) was derived from modeling relationships between LiDAR or DAP tree height layers and tree diameter from field plots. Tree diameter used to define structure class is based on the mean diameter of the dominant and co-dominant trees in a field plot. It is calculated by deriving the quadratic mean diameter of trees whose diameters are in the top 25% of trees that are greater than 5" in diameter.

Figure 5a. Variable importance for predictors used as part of the Random Forest models for DAP size (a) and cover (b) classes. A larger Mean Gini Importance decrease means that the variable was more important in the model. Variable descriptions are found in Table 6.

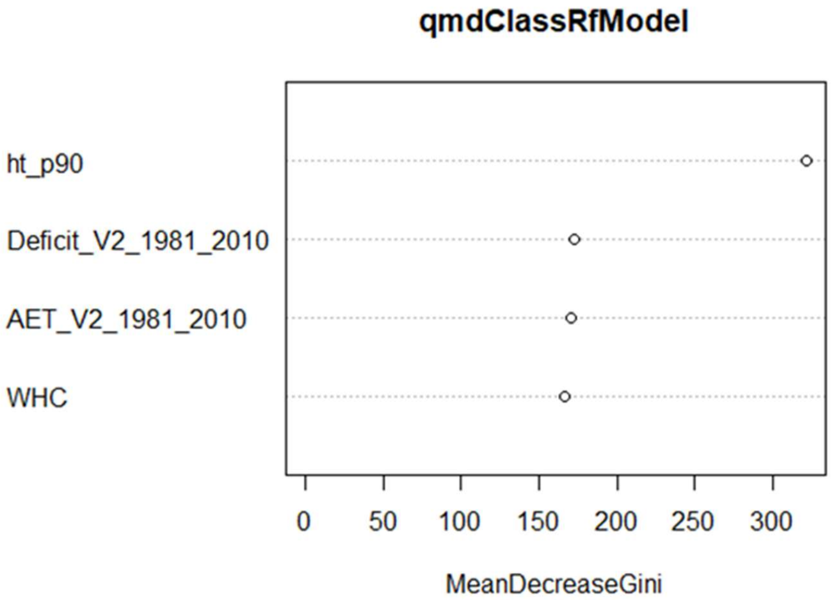


Figure 5b. Variable importance for predictors used as part of the Random Forest models for DAP size (a) and cover (b) classes.

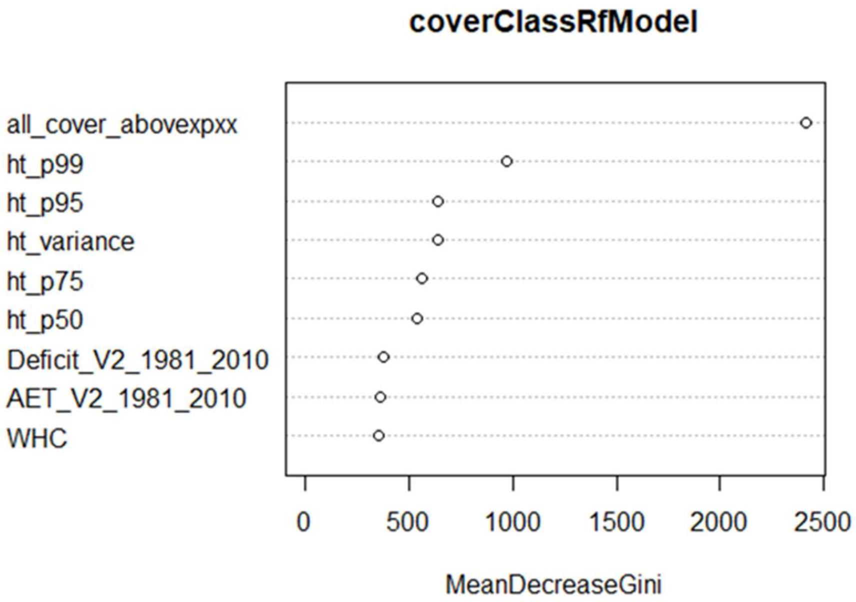


Table 8. Confusion matrices for modeled size class (a) and canopy cover class (b). The true classes are from field plots. Values represent numbers of sampled pixels.

(a)	**Small**	**Medium**	**Large**	**Error**
Small	86	57	3	41.1%
Medium	28	671	71	12.9%
Large	5	145	385	28.0%
(b)	**Open**	**Moderate**	**Closed**	**Error**
Open	4151	257	163	9.2%
Moderate	265	448	516	63.5%
Closed	75	208	3918	6.7%

Table 9. Predictor variables used in the size class and cover class Random Forest classification models. See the DNR Forest Resilience Data Dictionary for more detailed information on how the climate metrics were calculated. All DAP metrics were calculated using FUSION, with a cell size of 66 feet.

Variable Name	**Description**
DAP Metrics	
ht_p99	99th percentile height within the grid cell.
ht_p95	95th percentile height within the grid cell.
ht_p90	90th percentile height within the grid cell.
ht_p75	75th percentile height within the grid cell.
ht_p50	50th percentile height within the grid cell.
ht_variance	Variance of height within the grid cell.
all_cover_abovexpxx	Canopy cover above 6 feet.
Climate Metrics	
Deficit_V2_1981_2010	Climatic water deficit for the 1981-2010 climate normal period.
AET_V2_1981_2010	Actual evapotranspiration for the 1981-2010 climate normal period.
WHC	Water holding capacity.

Change Evaluation

Changes in structure were evaluated across several planning areas, chosen for their large amounts of change between 2015 and 2021, as well as to ensure a good geographic coverage of eastern Washington. Seven planning areas (Methow Valley, Twisp River, Teanaway, Republic, Upper Swauk, Mill Creek, and White Salmon) were chosen to look at the typical structure transitions for each type of disturbance, and three of those (Republic, Mill Creek, and White Salmon) were then chosen as case studies to look at the impact of change on restoration needs.

For both the evaluation of structure class transitions as well as HRV departure and changes to restoration needs, DAP structure classes were estimated for each year where data were available using the model describe in Section 3b. Data were incomplete for 2019, 2020, and 2021. The 2019 and 2020 years together formed a complete dataset however, so they were combined for these analyses. Where there was overlap, 2019 data were used.

Transition diagrams were created by comparing pre-disturbance DAP structure class to post-disturbance DAP structure class. The percentage pixels within the study planning areas that fell into individual transition types (e.g., medium moderate to small open) were calculated for use in the transition diagrams (Figure 3 in the main report). The pre- and post-disturbance DAP years to use were determined in one of two ways, depending on the type of disturbance. For changes labeled as thinning, the pre-disturbance year was the DAP year closest, but prior to, the year of change for each pixel. The post-disturbance year was the DAP year closest, but later than, the year of change for each pixel. For other disturbances, 2015 was used as the pre-disturbance year and a merged dataset of 2021, 2019, or 2020 DAP data (in order of priority) was used as the post-disturbance year. This difference in calculation was used to better pick up shifts due to thinning treatments, where other treatments often follow rapidly. Additionally, the 2015 vs. 2019/2020/2021 method was used for disturbances where mortality could be delayed (i.e., insects) or where there is less likely to be another disturbance immediately afterwards (i.e., wildfire or regeneration harvest).

For the HRV diagrams (see Figures 5, 7, & 9 in the main report), structure change was determined as the change from 2015 to a merged dataset of 2021, 2019, or 2020 (in order of priority) DAP data. This was done to more fully capture the change to restoration needs over the entire time period, regardless of disturbance type. A combination of post-disturbance years was required because 2019, 2020, and 2021 were incomplete flight years. Historical ranges of variation (HRVs) were calculated for each vegetation type and structure class combination, with the overall range for each structure class estimated as a weighted average of HRVs for vegetation types within the planning area. The ranges are derived from state and transition models (STMs; see Appendix B of the 2020 Legislative Report), and are used throughout the landscape evaluation process. While either LiDAR or Photo-interpreted structure classes are used for departure assessments for landscape evaluations, here we used pre- and post-disturbance DAP structure classes. These are similar to those from LiDAR, but may differ slightly, especially for the medium and moderate size and canopy cover classes. For this initial analysis, DAP structure classes were simply plotted against HRVs. Movement towards or away from these goals will continue to be tracked in future years as more data become available.

Future Work

This analysis is a preliminary introduction of the change detection approach, and a number of improvements to the methods are planned for future years. For the attribution modeling, we will continue to fine-tune the Random Forest model with improved training data. More years of Forest Health Tracker data will be especially beneficial for training the model to better identify broadcast and pile burning. Additionally, work is currently underway through a contract with the Kennedy lab at Oregon State University to improve our ability to both detect and attribute insect activity. Improvements should allow us to pick up more insect and disease types, and to differentiate among types. DAP data will also be improved in the future, both in terms of data accuracy and precision, as well as in our understanding of the data's strengths and limitations. An ongoing contract with researchers at UW will result in tools to locate and label potential DAP errors, which can then be reprocessed if possible. The contract also includes the preparation of a scientific manuscript detailing the accuracy and precision of DAP data relative LiDAR data across eastern Washington, which will allow us to better understand the certainty with which we can say structure has changed under different scenarios. Finally, additional work to fine-tune the size and cover class models will be conducted to make sure that we have models that are robust to changes in location and DAP flight characteristics.

Appendix E: Wildfire Emissions Methods

Wildfire emission estimates are a function of: 1) area burned, 2) the vegetation type and structure burned, and 3) fire severity (i.e., how it burned). We estimated total wildfire emissions by developing specific emission factors for each combination of vegetation type, structure, and severity, and multiplying those emission factors by area burned.

Calculating emissions from wildfires begins with spatially identifying fire perimeters for a given year using data produced by DNR's Wildfire Division. These boundaries are used to map wildfire severity within each fire, using satellite imagery. In essence, satellites take a snapshot of any given place on earth that enables detection of fire-induced changes in ground and tree cover. Summertime imagery is used to assess change from the previous year, and is typically available by mid- to late-September. As such, while DNR fire perimeters are available relatively quickly, the earliest date that emissions estimates can be obtained is early fall the following year (e.g. Fall 2022 for 2021 fires).

Wildfire severity is calculated annually in Google Earth Engine based on pre- and post-fire Landsat satellite imagery averaged over the fire season (June 15 – September 15), following the protocol in Parks et al. (2018, corrected in 2021). Pre-fire imagery is obtained the year prior to the fire year, and post-fire imagery is from the year following the fire. Severity is calculated at the 30m pixel scale as the Relative differenced Normalized Burn Ratio (RdNBR), a measure of vegetation change, with an offset to minimize variations in severity among individual fires. We create locally calibrated fire severity maps of low, moderate, and high severity fire based on RdNBR values. Classification is done based on thresholds provided by Saba Saberi and Brian Harvey at the University of Washington (UW; Saberi and Harvey, 2022). Thresholds were determined by collecting data on basal area mortality from plots across Washington and Oregon, and determining the RdNBR values that correspond with various mortality levels. Low, mixed, and high severity areas indicate <25%, 25-75%, and >75% basal area mortality, respectively. Thresholds were created separately for the eastern and western sides of the state.

We identified pre-fire vegetation structure using GNN (Gradient Nearest Neighbor) forest type data (https://lemma.forestry.oregonstate.edu/data). The GNN mapping approach uses a combination of satellite imagery and field plots to develop a consistent, wall-to-wall map of vegetation structure across all forest-capable lands. Developed by the Pacific Northwest Research Station, GNN maps are currently the only maps that cover all forested lands irrespective of landowner/manager and are commonly used in the peer-reviewed literature in the region. We used GNN vegetation type and age class attributes to create a table with all possible combinations of vegetation type (species codes) and age class that burned in a given year and severity class. These attributes were then translated to specific fuelbeds, based on expert knowledge (S. Prichard

(UW) and R. Ottmar (USFS)). We use fuelbeds to estimate fire emissions using the model Consume (Prichard et al. 2006), developed by the Pacific Northwest Research Station (https://www.fs.fed.us/pnw/fera/research/smoke/consume/index.shtml). Emission factors in Consume are specific for each fuelbed and fire severity. Emission factors are then multiplied by area burned in each fuelbed/severity combination and summarized for each fire season.

The crux in creating these estimates is 1) the quantification of fire severity, 2) fuelbed assignments, and 3) the vintage of pre-fire conditions. We used the best available data and relied on experts to inform our decisions, but there are additional steps that could be taken to improve these results. For example, when describing pre-fire conditions, we only utilized 2012 and 2017 GNN data because these two years are readily available. However, a slightly more robust approach would be to use annual GNN data for each fire year (e.g., 2015 GNN data for 2015 fires). Assuming GNN data are continuously produced, this more robust approach would greatly increase the amount of expert time needed to relate GNN data to fuelbeds, and is something we may implement as time and funding permits.