

Cliff Knox Project

Fire, Fuels, and Air Quality Report

Prepared by:
Kenneth C. Boucher Jr.
Fire Management Specialist

for:
Prairie City Ranger District
Malheur National Forest

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(Updated by Joe Behrens and Tracie Buhl, Fire Management Specialists)



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Introduction

The Cliff Knox Project on the Malheur National Forest is proposing to improve forest resiliency, reduce risk of uncharacteristic disturbances, and improve wildlife habitat. The purpose and need for the project include:

- Increase forest resilience to drought, insect and disease outbreaks, and uncharacteristic wildfires; by moving the landscape toward a more historical range of variability for structure, density, and species composition.
- Increase public and firefighter safety throughout the planning area by restoring fuel profiles to types primarily conducive to surface fire, with special attention to lands adjacent to strategic roads and areas identified as wildland-urban interface.

Strategic Roads Treatments

Strategic roads treatments are planned to better set up landscapes for restoration by unplanned ignitions in a cost-effective manner and to improve access and egress for firefighter and public when wildfires occur. Large wildfires are inevitable and are more likely, for a variety of reasons (including climate, fuel buildup, and land management objectives). Our current large fire strategies often rely on dropping back to roads, ridges, past treatments to contain fires, or any combination, but in many cases our landscapes are not well prepared. A specific, mapped fuels treatment strategy that anticipates wildfire will allow us to use part of the fuels program to create locations to contain large fires, in effect creating a “habitat” for wildfire, allowing us to use wildfires to improve land condition when the risk is within acceptable limits. A mapped strategy that can be handed off to an incident management or interdisciplinary NEPA planning team. (USDA Forest Service 2019).

The planning area covers approximately 40,000 acres on National Forest System lands. Fire is the most widespread and dynamic disturbance regime affecting the planning area (Johnson 1994). The area is characterized by terrain that influences the structure, composition, and productivity of vegetation. These vegetation patterns in turn influence fire behavior and patterns of fire severity. A combination of treatments would be used across the planning area, resulting in some acres being treated with multiple prescriptions to achieve objectives.

Regulatory Framework for Fire and Fuels

The action alternatives for the Cliff Knox Project were developed to comply with applicable management direction as well as all Federal, State, and local laws, regulations, and policies. Direction for the proposed action is derived from the following:

Malheur National Forest Land and Resource Management Plan (1990)

Desired Future Condition

“Prescribed fire will have played a role in converting 75,000 acres of mixed conifer stands back to ponderosa pine stands. Most all the subclimax ponderosa pine timber type will have been underburned. Ground fuels will be reduced significantly, resulting in increased range and wildlife forage. Total smoke production on an annual basis will be reduced substantially as a result of fewer and lower intensity wildfires.

The use of prescribed fire as a management tool will be extensive. Underburning (the use of low intensity ground fire) will be common for managing mixed ponderosa pine and associated fir stands to reduce fir encroachment and perpetuate ponderosa pine. By the end of this period, 1,000 acres will be burned as rangeland improvement and another 2,000 to 4,000 acres as wildlife habitat improvement. Smoke from these projects will be visible during spring, early summer, and fall” (USDA Forest Service 1990, page IV-10).

Forest-wide Standards

Forest-wide standard #57: Maintain or enhance quaking aspen stands using clearcutting and prescribed fire as the principal means of regeneration where appropriate. Protect root sprouts where needed and practical (USDA Forest Service 1990, page IV-31).

Forest-wide standard #180: Utilize prescribed fire to meet land management objectives. Normally, plan human ignition sources for prescribed fire; however, when appropriate, utilize lightning ignition sources for prescribed fire (USDA Forest Service 1990, page IV-45).

Forest-wide standard #181: Manage residue profiles at a level that will minimize the potential of high intensity catastrophic wildfires and provide for other resource objectives in individual management areas (USDA Forest Service 1990, page IV-45).

Forest-wide standard #183: Use all methods of fuel treatment as prescribed by site-specific analysis to achieve resource management objectives. Encourage utilization of wood residue as a priority treatment, consistent with long-term site productivity and wildlife habitat needs (USDA Forest Service 1990, page IV-129).

Forest-wide standard #184: Integrate residue treatment with best management practices (USDA Forest Service 1990, page IV-45).

General Forest Management Area 1

See Forest-wide standards.

Rangeland Management Area 2

Management Area 2 standard #6: When appropriate, utilize prescribed fire from planned ignitions (USDA Forest Service 1990, page IV-53).

Riparian Areas (Management Areas 3A, inland fish habitat)

Management Area 3A standard #48: Manage residue profiles to maintain or enhance resident fish and wildlife habitat (USDA Forest Service 1990, pages IV-60 and IV-68).

Management Area 3A standard #49 and Management Area 3B standard #50: A site specific analysis is required for determining removal of activity-generated woody debris from all riparian areas unless non-removal is specifically evaluated and approved in the project-level environmental analysis. Do not allow mechanized treatment of logging debris for site preparation or hazard reduction purposes in all riparian areas, unless evaluated and approved in a project-level environmental analysis. Burning of logging debris below the high waterline is prohibited (USDA Forest Service 1990, pages IV-61 and IV-68).

Management Area 3A standard #50 and Management Area 3B standard #51: Use prescribed fire from planned ignitions to achieve forage production objectives (USDA Forest Service 1990, pages IV-61 and IV-68).

Malheur Forest Plan Amendment 29

Malheur Forest Plan Amendment 29 updated Standards and Guidelines to manage riparian areas to provide large woody debris and riparian vegetation at a rate of input specified by number of pieces per mile of stream in specific forest ecosystems, and percent shade / canopy closure by specific ecosystem (USDA Forest Service 1994).

Inland Native Fish Strategy (INFISH) Standards and Guidelines

Locate water drafting sites to avoid adverse effects to listed anadromous fish and instream flows, and in a manner that does not retard or prevent attainment of riparian management objectives (INFISH Standard RA-5).

Design fuel treatment and fire suppression strategies, practices, and actions so as not to prevent attainment of riparian management objectives, and to minimize disturbance of riparian ground cover and vegetation. Strategies should recognize the role of fire in ecosystem function and identify those instances where fire suppression or fuel management actions could perpetuate or be damaging to long-term ecosystem function or inland native fish (INFISH Standard FM-1).

Design prescribed burn projects and prescriptions to contribute to the attainment of the riparian management objectives (INFISH Standard FM-4).

Immediately establish an emergency team to develop a rehabilitation treatment plan to attain riparian management objectives and avoid adverse effects on inland native fish whenever riparian habitat conservation areas are significantly damaged by a wildfire or a prescribed fire burning out of prescription (INFISH Standard FM-5).

Big Game Winter Range Maintenance Management Area 4A

Management Area 4A standard #27: Manage residue profiles to maintain or enhance big-game habitat and forage production (USDA Forest Service 1990, page IV-72).

Management Area 4A standard #28: Limit treatment activities between December 1 and April 1 to reduce disturbances to wintering elk and deer (USDA Forest Service 1990, page IV-72).

Bald Eagle Winter Roosts Management Area 5

Management Area 5 standard #19: Manage residue to protect the management area from catastrophic wildfire and enhance habitat for bald eagles. Develop site specific residue management objectives in the Bald Eagle Winter Roost Management Plan.

Management Area 5 standard #20: Manage residue profiles to minimize the potential for high intensity fires. Use prescribed fire from planned ignitions to achieve resource management objectives.

Developed Recreation Sites Management Area 12

Management Area 12 standard #22: Prescribe low intensity fire with minimal scorch when appropriate (USDA Forest Service 1990, page IV-103).

Old Growth Management Area 13

Management Area 13 standard #20: Manage residue to maintain or enhance old-growth habitat. Protect old-growth habitat from catastrophic wildfire (USDA Forest Service 1990, page IV-107).

Visual Corridors Management Area 14

Management Area 14 standard #27: Manage residues to provide a natural-appearing landscape in visual corridors (USDA Forest Service 1990, page IV-111).

Management Area 14 standard #28: Plan and time treatments in foreground distance zones to minimize adverse visual effects (USDA Forest Service 1990, page IV-111).

Management Area 14 standard #29: Prescribe low intensity fire with minimal scorch when appropriate (USDA Forest Service 1990, page IV-111).

Wild and Scenic Management Area 22

Management Area 22 Standard # 20/40: Use planned ignitions, when in prescription, to achieve resource management objectives. Prescribed fire from lightning ignitions may be used to allow fire to play its natural ecological role.

National Fire Plan

The National Fire Plan, Managing the Impacts of Wildfires on Communities, and the Environment (USDA and USDI 2000), provides national direction for hazardous fuel reduction, restoration, rehabilitation, monitoring, applied research, and technology transfer. The agencies are developing a common strategy for reducing fuels and restoring land health in fire-prone areas. The Forest Service prepared a document outlining strategies for protecting people and the environment by restoring and sustaining land health: Protecting People and Sustaining Resources in Fire-adapted Ecosystems. The National Fire Plan is focused on firefighting, rehabilitation, hazardous fuels reduction, community assistance, and accountability. The guiding principle for dealing with fire risks is the reduction of hazardous fuel loads threatening communities and wildland ecosystems.

The Forest Service prepared a document outlining strategies for Protecting People and Sustaining Resources in Fire-Adapted Ecosystems, a Cohesive Strategy November 2000: The 10-Year Comprehensive Strategy (USDA Forest Service 2000). The cohesive strategy reflects the views of a broad cross-section of governmental and non-government stakeholders. It outlines a comprehensive approach to the management of wildland fire, hazardous fuels, and ecosystem restoration and rehabilitation on Federal, adjacent State, Tribal, and private forest, and range lands. The hazardous fuel reduction portion of this strategy calls to, “assign highest priority for hazardous fuels reduction to communities at risk, readily accessible municipal watersheds, threatened and endangered species habitat, and other important local features, where conditions favor uncharacteristically intense fires.”

The National Forest Management Act of 1976, including its amendments to the Forest and Rangeland Renewable Resources Planning Act of 1974, state that it is the policy of the Congress that all forested lands in the National Forest System be maintained in appropriate forest cover with species of trees, degree of stocking, rate of growth, and conditions of stand designed to secure the maximum benefits of multiple use sustained yield management in accordance with land management plans.

A National Cohesive Wildland Fire Management Strategy (2011)

The executive summary (USDA Forest Service 2011) states, “Addressing wildfire is not simply a fire management, fire operations, or wildland-urban interface problem — it is a larger, more complex land management and societal issue. The vision for the *next century is to: Safely and effectively extinguish fire, when needed; use fire where allowable; manage our natural resources; and as a Nation, live with wildland fire.*”

Three primary factors have been identified as presenting the greatest challenges and the greatest opportunities for making a positive difference in addressing the wildland fire problems to achieve this vision. They are:

- Restoring and maintaining resilient landscapes. The strategy must recognize the current lack of ecosystem health and variability of this issue from geographic area to geographic area. Because landscape conditions and needs vary depending on local climate and fuel conditions, among other elements, the strategy would address landscapes on a regional and sub-regional scale.
- Creating fire-adapted communities. The strategy would offer options and opportunities to engage communities and work with them to become more resistant to wildfire threats.
- Responding to Wildfires. This element considers the full spectrum of fire management activities and recognizes the differences in missions among local, state, tribal and Federal agencies. The strategy offers collaboratively developed methodologies to move forward.

Oregon Community Wildfire Protection Plans

The purpose of the Community Wildfire Protection Plan is for communities to take full responsibility and advantage of wildland fire and hazardous fuel management opportunities offered under Healthy Forest Restoration Act legislation. The Community Wildfire Protection Plan provides for the U.S. Forest Service, the Bureau of Land Management, and other federal agencies to consider the priorities of local communities for forest and rangeland management as well as hazardous fuel reduction projects.

Grant County Community Wildfire Protection Plan (2013)

Prescribed fire in Grant County could be used to accomplish several resource management purposes, such as reducing the amount of hazardous fuels, improving plant species diversity, increasing livestock forage production, abating noxious and invasive weeds, and improving wildlife habitat. Multiple resource management objectives are often achieved concurrently.

Harney County Community Wildfire Protection Plan (2013)

The Harney County Community Fire Protection Plan Wildland Urban Interface (WUI) boundary is county-wide with emphasis on the communities of Burns, Hines, Drewsey, Crane, Diamond, Frenchglen, Fields, Andrews, Riley, and rural residences throughout the county. The objectives of the plan are to reduce the risk of fire to life, property, and natural resources in the county.

Regulatory Framework for Air Quality

The framework for controlling air pollutants is mandated by the 1970 Clean Air Act, as amended. The Clean Air Act is the comprehensive federal law that regulates air emissions from stationary and mobile sources. Among other things, this law authorizes the Environmental Protection

Agency to establish National Ambient Air Quality Standards to protect public health and public welfare and to regulate emissions of hazardous air pollutants.

The Clean Air Act was designed to “protect and enhance” the quality of air resources and encourage reasonable actions for pollution prevention. State Implementation Plans are developed to implement provisions of the Clean Air Act, specifically the National Ambient Air Quality Standards. Section 160 of the Clean Air Act requires measures “to preserve, protect, and enhance the air quality in national parks, national wilderness areas ... and other areas of special national or regional natural, recreational, scenic, or historic value” (42 United States Code 7470, 2020). Stringent requirements are established for areas designated as class 1 airsheds, which include wilderness areas over 5,000 acres in existence before August 1977. Designation as a class I area allows only very small increments of new pollution above existing levels.

The Regional Haze Rule (40 Code of Federal Regulations 51.308-309) requires states to establish goals for improving visibility in class 1 airsheds and to develop long-term strategies for reducing emissions of air pollutants that cause visibility impairment. The Regional Haze Rule requires smoke management programs to address visibility impairment in mandatory class 1 airsheds due to emissions from prescribed fire activities. The State has designated all class 1 airsheds sensitive to smoke during the visibility protection period, which is defined as July 1 to September 15, during which restrictions on burning apply for purposes of visibility protection.

Prescribed burning in Oregon is managed by the Oregon Department of Forestry under the Oregon Smoke Management Plan (Oregon Administrative Rule 629-048-0130-3). The Oregon Smoke Management Plan is intended to minimize smoke impacts by conducting forest burning under weather conditions that disperse smoke and direct smoke away from populated areas. Burning on National Forest System lands only occurs with prior approval granted by Oregon Department of Forestry.

Resource Elements, Indicators and Measures

The resource indicators used in this report are:

- Flame length: The length of flame measured in feet. Increased flame lengths reduce fire suppression strategies and effectiveness and increases the likelihood of torching events and crown fires.
- Crown fire activity: Fires that burn in the crowns of trees and shrubs and are usually ignited by a surface fire. Crown fires are common in coniferous forests. There are two types of crown fire: active and passive. An active crown fire is one in which the entire fuel strata¹ is involved in flame, but the crowning phase remains dependent on heat released from surface fuel for continued spread. A passive crown fire is one in which the crowns of individual trees or small groups of trees burn, but solid flaming in the canopy cannot be maintained except for short periods.
- Smoke emissions: Over 90 percent of emissions from fires are small enough to enter the respiratory system. Inhaling carbon monoxide decreases the body's oxygen supply. Fine particles in the air can travel deep into the respiratory tract and cause shortness of breath or worsen pre-existing medical conditions such as asthma. Exposure can depress the immune system and damage the layer of cells in the lungs that protect and cleanse the airways.

¹ Fuel strata is a horizontal layer of fuels of similar general characteristics. Three fuel strata are recognized: ground, surface, and canopy (Scott and Reinhardt 2001).

Smoke emissions also contain greenhouse gasses which are a contributor to climate change. Specific compounds most commonly found in smoke emissions that contribute to health concerns and climate change are particulate matter (PM_{2.5} and PM₁₀), methane (CH₄), carbon dioxide (CO₂), carbon monoxide (CO), nitrous oxide (N₂O), ozone (O₃), and sulfur oxide (SO₂).

These are appropriate indicators for this analysis because they give information about potential fire behavior, fire effects, and smoke emissions. Risks to firefighters, workers, and the public can be assessed from potential fire behavior and smoke emissions. The fuel load not only determines whether a fire would grow, but together with the type of fuel they determine the fire intensity and effects. Flame length and crown fire influence suppression strategies and tactics by firefighters and mechanical equipment. Smoke emissions contribute to health concerns and climate change.

Table 1. Measures and indicators for assessing fuels resource effects

Resource element	Resource indicator	Measure	Source
Flame length	Length of flame (feet)	Feet	Andrews and Rothermel 1982
Crown fire activity	Surface, passive, active	Acres	Andrews and Rothermel 1982
Smoke emission	Particulate matter (PM _{2.5}), methane (CH ₄), carbon monoxide (CO), carbon dioxide (CO ₂), nitrous oxide (N ₂ O), and sulfur dioxide (SO ₂).	Tons released	Environmental Protection Agency 2019

Affected Environment

Methodology

Field inventories were conducted to measure attributes of existing vegetation in the planning area. Treatments units within the planning area were inventoried using on-site photo interpretation and Landfire data. These treatment units are representative of the planning area and the planning areas to be treated in the action alternatives. Data was collected on live and dead trees. This data was used in the following analysis, data tables, graphs, and charts and are incorporated by reference. Geographic information system LandFire data² and onsite visits were used to determine fuel models, as was a study conducted in 2005 (Scott and Burgan 2005). *A Comprehensive Set for Use with Rothermel's Surface Fire Spread Model* was used for fire modeling. Analysis for fire behavior was calculated using the 90th percentile fire weather factors from Antelope Remote Automated Weather Station during 1995-2018 (5,500 feet elevation; April 30-Oct 31).

The dynamics between vegetation and fire and fuels are inherently linked. Fire has a profound effect on vegetation establishment and development, and vegetation treatments (and the absence thereof) have a profound effect on fuels accumulations and fire behavior. The analysis considers forest vegetation, fuels, and fire at the stand level.

The Clean Air Act lists 189 hazardous air pollutants to be regulated. In 1994 and 1997, 18 air toxins were assessed relative to the exposure of humans to smoke from prescribed and wildfires. The six toxins most commonly found in prescribed and wildland fire smoke were:

² See <https://www.landfire.gov/>.

- Particulate matter (PM) – Particulates are the most prevalent air pollutant from fires and are of the most concern to regulators. Research indicates a correlation between hospitalizations for respiratory problems and high concentrations of fine particulates (PM_{2.5}, fine particles that are 2.5 microns in diameter or less). Particulates can carry carcinogens and other toxic compounds. Overexposure to particulates can cause irritation of mucous membranes, decreased lung capacity, and impaired lung function
- Methane (CH₄) – Methane is an odorless, colorless flammable gas. Short-term exposure to methane may result in headaches or feeling tired or dizzy. There are no long-term health effects currently associated with exposure to methane.
- Carbon monoxide (CO) – Carbon monoxide reduces the oxygen carrying capacity of the blood, a reversible effect. Breathing air with a high concentration of CO reduces the amount of oxygen that can be transported in the blood stream to critical organs like the heart and brain. Exposure can lead to heart attacks, especially for persons with heart disease. At very high levels, CO can cause dizziness, confusion, unconsciousness, and death.
- Carbon dioxide (CO₂) – Carbon dioxide exposure can lead to dizziness, headache, visual and hearing dysfunction, unconsciousness, and death. Carbon dioxide is the most significant long-lived greenhouse gas in Earth's atmosphere
- Nitrous oxide (N₂O) – Nitrous oxide, N₂O, is a greenhouse gas that contributes to climate change. Small levels can cause nausea, irritated eyes and/or nose, fluid forming in the lungs and shortness of breath. Breathing high levels can lead to rapid, burning spasms, the swelling of the throat, reduced oxygen intake, a larger buildup of fluids in lungs, or death.
- Sulfur Dioxide (SO₂) – A precursor to PM_{2.5}, affects human health irritating the nose, throat, and airways usually within fifteen minutes of exposure.

Existing Condition

The project is within the Grant County Community Wildfire Protection Plan Prairie City Zone. The Prairie City Zone is rated as a “high” hazard for wildfire risk. This zone is vulnerable to wildfire due to the vegetation type, and topography. The planning area lies about 20 miles southeast of the community of Seneca, Oregon. The city of Seneca, Oregon is within the Grant County Community Wildfire Protection Plan (2013) and is rated with the highest wildfire risk in the assessment mainly because it has no city fire department.

The Harney County Community Fire Protection Plan wildland urban interface (WUI) boundary is county-wide with emphasis on the communities of Burns, Hines, Drewsey, Crane, Diamond, Frenchglen, Fields, Andrews, Riley, and rural residences throughout the county. Drewsey is located 13 miles south of the planning area and is the nearest community within Harney County. Drewsey is rated high hazard within the Harney County Community Wildfire Protection Plan due to wildland fuel proximity to structures, terrain, and lack of structure fire protection.

The historical fire regime in the Cliff Knox planning area was characterized by frequent fires of low to mixed severity known as fire regime I. Fire return intervals in the blue mountains of Oregon in mixed conifer and ponderosa pine forests ranged from 7 to 24 years with some stands having return intervals up to 47 years. The fires burned with higher severities in the denser sites and during drier years. (Agee 1996, Johnston et al. 2017, Juran 2017).

Past forest practices, including active fire suppression, grazing, and timber harvest have changed the composition and structure of vegetation in the planning area. Current conditions include increases in tree density, encroachment of shade-tolerant tree species, and encroachment of pine

and juniper into shrub steppes and mahogany stands, or high loss of shade-intolerant tree species. This creates fuel conditions above historical fire behavior and effects.

Current fire behavior conditions under 90th percentile weather conditions are expected to have flame lengths of 4 to 8 feet with some areas exceeding 11 feet. These conditions have created a concern over potential fire behavior, fire effects on public and private lands, and threats to forest resources and potential impacts to air quality.

Cliff Knox Fire History

Within the planning area there has been one documented large fire since 1960. The Miller Flat Fire occurred in 1986 and was caused by lightning. This fire was located in the south-central portion of the planning area.

During a fifty-seven-year period between 1960 and 2017 there were 119 fires within the planning area that burned approximately 780 acres. The majority of these fires were less than 1 acre in size, and four fires were greater than 100 acres. As noted in Table 2 below, of the 119 fires within the planning area, 102 fires were started by lightning, 11 were caused by campfires, three were miscellaneous starts, two were caused by arson, and one was caused by debris burning.

Table 2. Cliff Knox fire history, small fire starts reported from 1960 to 2017

Cause	Number of fires	Average Size (Acres)	Largest Size (Acres)
Lightning	102	0.1	390
Campfire	11	0.1	6
Miscellaneous	3	0.1	0.1
Arson	2	0.5	0.8
Debris burning	1	0.3	0.3
Total	119	N/A	N/A

Fire Regime and Condition Class

A natural fire regime is a general classification of the role fire would play across a landscape in the absence of modern human mechanical intervention but including the influence of Native American burning (Agee 1993, Arno 1996). Coarse scale definitions for natural (historical) fire regimes have been developed by Morgan et al. (2001) and Schmidt et al. (2002) and interpreted for fire and fuels management by Hann and Bunnell (2001). The five natural (historical) fire regimes are classified based on average number of years between fires (fire frequency) combined with the severity (amount of replacement) of the fire on the dominant overstory vegetation.

These five regimes include:

- I – 1-35-year frequency and low (surface fires most common) to mixed severity
- II – 1-35-year frequency and high (stand replacement) severity
- III – 35-100+ year frequency and mixed severity
- IV – 35-100+ year frequency and high (stand replacement) severity
- V – 200+ year frequency and high (stand replacement) severity

A Fire Regime Condition Class is a landscape classification that describes the amount of departure from the natural (historical) fire regime. They include three condition classes for each fire regime. This departure results in changes to one (or more) of the following ecological components:

- Vegetation characteristics (species composition, structural stages, stand age, canopy closure, and mosaic pattern)
- Fuel composition
- Fire frequency, severity, and pattern
- Other associated disturbances (e.g., insect and disease mortality, grazing, and drought)

All vegetation and fuel conditions or wildland fire situations fit within one of the three classes. The three classes are based on low (Fire Regime Condition class 1), moderate (Fire Regime Condition class 2), and high (Fire Regime Condition class 3) departure from the central tendency of the natural regime. Low departure is considered to be within the natural range of variability, while moderate and high departures are outside. Characteristic vegetation and fuel conditions are considered to be those that occurred within the natural fire regime. Uncharacteristic conditions are considered to be those that did not occur within the natural fire regime. Determination of amount of departure is based on comparison of a composite measure of fire regime attributes, as listed above.

Table 3. Fire regime condition classes

Fire Regime condition class	Description	Species composition and structure	Potential risk
1	Within the natural (historical) range of variability of vegetation characteristics; fuel composition; fire frequency, severity, and pattern; and other associated disturbances	Species composition and structure are functioning within their natural (historical) range at both patch and landscape scales.	• Fire behavior, effects, and other associated disturbances are similar to those that occurred prior to fire exclusion (suppression) and other types of management that do not mimic the natural fire regime and associated vegetation and fuel characteristics. • Composition and structure of vegetation and fuels are similar to the natural (historical) regime. • Risk of loss of key ecosystem components (e.g., native species, large trees, and soil) is low. • Fire behavior, effects, and other associated disturbances are moderately departed (more or less severe).
2	Moderate departure from the natural (historical) regime of vegetation characteristics; fuel composition; fire frequency, severity and pattern; and other associated disturbances	Species composition and structure have been moderately altered from their historical range at patch and landscape scales. For example: Grasslands – Moderate encroachment of shrubs and trees and/or invasive exotic species. Shrublands – Moderate encroachment of trees, increased shrubs, or invasive exotic species. Forestland/Woodland – Moderate increases in density, encroachment of shade tolerant tree species, or moderate loss of shade intolerant tree species caused by fire exclusion,	• Fire behavior, effects, and other associated disturbances are moderately departed (more or less severe). • Composition and structure of vegetation and fuel are moderately altered. • Uncharacteristic conditions range from low to moderate. • Risk of loss of key ecosystem components is moderate. • Fire behavior, effects, and other associated disturbances

Fire Regime condition class	Description	Species composition and structure	Potential risk
		logging, or exotic insects or disease. Replacement of surface shrub/grass with woody fuels and litter.	are highly departed (more or less severe).
3	High departure from the natural (historical) regime of vegetation characteristics; fuel composition; fire frequency, severity and pattern; and other associated disturbances	Species composition and structure have been substantially altered from their historical range at patch and landscape scales. For example: Grasslands – High encroachment and establishment of shrubs, trees, or invasive exotic species. Shrublands – High encroachment and establishment of trees, increased shrubs, or invasive exotic species. Forestland/Woodland – High increases in density, encroachment of shade tolerant tree species, or high loss of shade intolerant tree species caused by fire exclusion, logging, or exotic insects or disease.	• Composition and structure of vegetation and fuel are highly altered. • Uncharacteristic conditions range from moderate to high. • Risk of loss of key ecosystem components is high

Of the Cliff Knox planning area, 70 percent falls within Fire Regime Group 1 (Figure 1), which is characterized as generally low-severity fires replacing less than 25 percent of the dominant overstory vegetation and can include mixed-severity fires that replace up to 75 percent of the overstory (Rollins 2009). The fire frequency is 0-35 years on average and locally up to 47 years in the moister sites (Johnston et al. 2017).

Air Quality

According to the Environmental Protection Agency Green Book updated February 2020, the closest designated non-attainment³ area is the city of Oakridge, Oregon which is 189 air miles west of the Cliff Knox planning area. The community of John Day is listed in the Oregon Smoke Management Plan as a smoke-sensitive receptor area, and thus protected by the highest standard in the plan. The Strawberry Mountain Wilderness is a class 1 airshed within 20 air miles of the planning area.

Air quality current conditions in surrounding sensitive areas is limited to short-term impacts resulting from wood burning, prescribed burning, and field burning. The greatest impact to the wilderness area is from field burning in the Willamette Valley and Central Oregon and from summer wildfires that occur to the south and west. These sources contribute to haze and can last for several days in spring and summer.

Desired Condition

The desired condition would be to restore and maintain an ecosystem that would thrive with the recurring disturbance of wildfire within the planning area and decrease the probability of uncharacteristically severe wildland fire. Specifically, this means a reduction in surface fuels, duff or litter depth, ladder fuels, and crown bulk density, and an increase in canopy base heights. Fire adapted ponderosa pine and western larch, which were historically dominant in this area would be

³ A non-attainment area is an area considered to have air quality worse than the National Ambient Air Quality Standards.

promoted. In shrub steppe and mountain mahogany stands, ponderosa pine and juniper would be cut in areas where they are encroaching. Areas with a heavy representation of non-fire tolerant grand fir would be returned to a more fire resilient species composition. The growth of aspen and other fire-adapted vegetation would be stimulated. Both mechanically treated and untreated stands would be exposed to prescribe burning as fire is reintroduced into the planning area.

The desired condition from a fire perspective would be fire behavior representative of a fire regime 1: Generally low intensity surface fire which results in less than 25 percent replacement of the dominant overstory vegetation to mixed severity in the moister sites. Additionally, the desired conditions would be a safe environment for firefighters, forest visitors, and the public; strategic road treatments along designated roadways; and fire reestablished to its natural role in the ecosystem. This desired condition would be achieved while continuing to provide habitat for wildlife species dependent upon late and old forest. Less biomass would be available to burn under a wildfire thereby reducing potential health hazards from smoke emissions. Less greenhouse gasses would be released in the planning area during a wildfire event which would not significantly contribute to climate change (Grant County 2013, USDA Forest Service 1990, USDA Forest Service 2017).

Environmental Consequences

Methodology

The analysis considers forest vegetation, fuels, and fire at the stand level.

The effects of treatments (or lack thereof) on fire behavior, fire effects, and fire suppression capability were analyzed for each alternative. The analysis of fire effects used flame length and crown fire activity. Flame lengths were based on fuel models. Dead and live fuels used in fuel models are described by size. For example, 1-hour fuels are typically fine, flashy fuels smaller than 0.25 inches in diameter, 10-hour fuels are 0.25 to 1 inch in diameter, 100-hour fuels are 1 to 3 inches in diameter, and 1000-hour fuels are often termed coarse woody debris and are greater than 3 inches in diameter. Fuel models are described by the volume of 1-hour, 10-hour, 100-hour, and 1000-hour dead fuels; herbaceous and woody live fuels; fuel bed depth; and moisture of extinction⁴. Coarse woody debris is 1,000-hour dead fuel, with a minimum diameter (or an equivalent cross section) of 3 inches at the widest point and includes sound and rotting logs, standing snags, stumps, and large branches (located above the soil) (Enrong et al. 2006). Crown fire activity level is based on fuel models, canopy base heights, and canopy bulk density. Fuel models are used to determine the flame length. Flame length and the distance to the canopy base height determines crown fire initiation. The density of the canopy determines the type of crown fire the stand may have under a certain weather percentile. Fuel conditions resulting from implementation of each of the alternatives would have associated effects on fire behavior.

Fire effects are estimated as the predicted flame length (feet), and the crown fire activity (surface, passive, or active). Increased flame lengths can increase the likelihood of torching events and crown fires. Flame length is influenced in part by fuel type, fuel arrangement, fuel moisture, and weather conditions. Flame length influences suppression actions including types of resources that can be used to effectively suppress fires. Flame lengths over 4 feet may present serious control

⁴ The quantity of moisture in fuel expressed as a percentage of the weight when thoroughly dried over all the fuel classes, at which the fire would not spread.

problems and are typically too dangerous to be directly contained by hand crews (Schlobohm and Brain 2002, Andrews and Rothermel 1982). Flame lengths over 8 feet are generally not controllable by ground-based equipment or aerial retardant, and present serious control problems including torching, crowning, and spotting. Flame length directly affects suppression tactics. Crown fire activity limits suppression resources, and firefighters must wait until fire comes back to the ground to be effective at suppressing fires. Table 4 outlines how flame lengths influence fire suppression actions (Andrews et al. 2011).

Table 4. Predicted average surface fire flame length and suppression actions

Flame length (feet)	Suppression actions
<4	Fires can generally be attacked at the head or flanks by persons using hand tools. Hand line should hold the fire.
4 – 8	Fires are too intense for direct attack on the head by persons using hand tools. Hand line cannot be relied on to hold the fire. Equipment such as dozers, pumpers, and retardant aircraft can be effective.
8 – 11	Fires may present serious control problems—torching, crowning, and spotting is common. Control efforts at the fire head will probably be ineffective.
>11	Crowning, spotting, and major fire runs are probable. Control efforts at head of fire are ineffective.

The BehavePlus fire modeling system is a computer program that is based on mathematical models that describe wildland fire behavior and effects, and the fire environment. It is a flexible system that produces tables, graphs, and simple diagrams. It can be used for a host of fire management applications, including projecting the behavior of an ongoing fire, planning prescribed fire, assessing fuel hazard, and training. For each forest type, the highest number of treatment acres (alternative 2) was used as the baseline acreage to model each alternative, in order to compare fire effects. Untreated acres in alternative 3 were assumed to have similar mortality rates as untreated acres in alternative 1. Predicting the potential behavior and effects of wildland fire is an essential task in fire management. Mathematical surface fire behavior and fire effects models and prediction systems are driven in part by fuelbed inputs such as load, bulk density, fuel particle size, heat content, and moisture of extinction. To facilitate use in models and systems, fuelbed inputs have been formulated into fuel models (Scott and Burgan 2005).

FlamMap (Finney 2006) is designed to examine the spatial variability in fire behavior assuming that fuel moisture, wind speed, and wind direction are held constant in time, thereby allowing for more direct comparison of fuel treatment effects. FlamMap's features allow the user to easily characterize fuel hazard and potential fire behavior, as well as analyze fire movement and fuel treatment interactions. The fuel models that were used are estimates of what the fuel loading and fire behavior are currently and what is predicted in the future allowing for vegetation regrowth.

Weather Data

Table 5 displays a summary of the 90th percentile weather data from the Antelope Station Remote Automated Weather Station. In this analysis fire season was defined as April 30 to September 30. Weather data from 1995 to 2018 was used. The Forest uses 90th percentile weather to define high fuels and weather conditions that drive fire growth. The 90th percentile indicates the weather and fuel values which are only exceeded an average of 10 percent of the days in a year based on

weather observations from these weather stations between the average fire seasons, April 30 to September 30.

Table 5. Antelope weather parameters for high conditions (90th percentile weather) fuel moistures and wind speed

Parameter	Value
1-hour fuel moisture (0 to 0.25-inch diameter)	5%
10-hour fuel moisture (0.25 to 1-inch diameter)	5%
100-hour fuel moisture (1 to 3-inch diameter)	8%
1000-hour fuel moisture (3 inch plus diameter, coarse woody debris)	10%
Herbaceous fuel moisture	28%
Woody fuel moisture	64%
20-foot wind speed	18 miles per hour
Air Temperature	72 °F

Air Quality Methodology

Smoke emissions, including greenhouse gas emissions, were calculated for pile burning, understory burning, and wildfires.

Emissions were calculated using the formula [Ei (tons) equals (A multiplied by FL multiplied by percent C multiplied by EFi) all divided by 2,000 to convert pounds to tons]; where:

- Ei equals emissions in tons for the emission type (for example, PM2.5, NOx, or CH4);
- A equal's area in acres;
- FL equals fuel loading in tons per acre;
- Percent C equals percent fuel consumed; and,
- EFi equals emission factor for the type (in pounds per ton of dry fuel consumed).

Additionally, it is assumed that:

- Combustion under pile burning would be 100 percent.
- Combustion under jackpot burning would be 60 percent.
- Combustion with prescribed burning would be 75 percent.
- Emission factors for pile, understory burns, and jackpot burns were derived from Prichard et al (2017): PM2.5 average (12.6), CH4 average (5.78), CO average (128.2), CO2 average (1,564), N2O average (0.27), and SO2 average (0.88).
- Global warming potential factor for greenhouse gas conversion to CO2 tons is derived from Stocker (2013).
- Wildfire emissions were based on a wildfire burning under 90th percentile weather conditions at year 30 for all scenarios.
- Data sources used for assessing the effects to air quality are derived from the first order fire effects monitoring program (Reinhardt et al. 1997), EPA (2020), and Stocker (2013).

Spatial and Temporal Context for Effects Analysis

The spatial boundaries for analyzing the direct and indirect effects are the geographic treatment area boundary. The project is located on the Prairie City and Emigrant Creek Ranger Districts of the Malheur National Forest. The northern portion of the planning area is located in Grant County and the southern portion crosses in Harney County. The planning area is approximately 25 miles southeast of Prairie City, Oregon. The Cliff Knox Project is comprised of the Bluebucket Creek

subwatershed (10,980 acres) and the Cliff Creek-Malheur River subwatershed (29,340 acres), which includes the entire Malheur River Inventoried Roadless Area and a section of the Malheur Wild and Scenic River corridor.

The Cliff Knox planning area ranges in elevation from 4,600 feet along the Malheur River to 6,800 feet at the top of Knox Mountain.

The temporal boundaries for analyzing the direct and indirect effects are 30 years. This is due to the fact that, disturbance and climate variability, the number of stand structure possibilities becomes more difficult to quantify the further into the future you go. Thirty years is reasonable amount of time based on current modeling capabilities. Project implementation would begin in the spring of 2021 and may continue for about twenty years; however, vegetation would continue to grow, and maintenance would be needed to maintain the desired condition.

The air quality analysis considers potential impacts to communities within 20 miles of the planning area as these are the communities that would be most impacted by any activities within the alternatives. The temporal bounds are limited to the implementation phase of the project as direct, indirect, and cumulative effects would be limited to the timeframe in which proposed activities would occur.

Past, Present, and Foreseeable Activities Relevant to Cumulative Effects Analysis

The direct, indirect, and cumulative effects analyses are based on a temporal scale. Documented past projects ranging as far back as 1860s, including timber harvesting, wildfires, watershed improvements, and other activities described in Cliff Knox Final Environmental Impact Statement Appendix D – Past, Ongoing, and Reasonably Foreseeable Actions, were considered within the analysis area. This vegetation structure and composition includes attributes of the current landscape including existing vegetation types, fuel treatments, burned areas, past sanitation harvest, and plantations.

To understand the contribution of past actions to the cumulative effects of the action and no action alternatives, this analysis relies on current environmental conditions as a proxy for the impacts of past actions. This is because existing conditions reflect the aggregate impact of all prior human actions and natural events that have affected the environment and might contribute to cumulative effects.

This cumulative effects analysis does not attempt to quantify the effects of past human actions by adding up all prior actions on an action-by-action basis. Focusing on individual actions would be less accurate than looking at existing conditions, because there is limited information on the environmental impacts of individual past actions, and it is not reasonably possible to identify every action over the last century that has contributed to current conditions. By looking at current conditions, the Forest Service is likely to capture all the residual effects of past human actions and natural events, regardless of which action or event contributed those effects. The Council on Environmental Quality issued an interpretive memorandum on June 24, 2005, regarding analysis of past actions, which states, “Agencies are not required to list or analyze the effects of individual past actions unless such information is necessary to describe the cumulative effect of all past actions combined. Agencies retain substantial discretion as to the extent of such inquiry and the appropriate level of explanation. Generally, agencies can conduct an adequate cumulative effects analysis by focusing on the current aggregate effects of past actions without delving into the historical details of individual past actions. (Council on Environmental Quality 2005).

Present activities within the planning area that would have a cumulative effect on the alternatives are the livestock grazing, and firewood cutting.

Livestock grazing is occurring throughout the planning area. Grazing would continue to affect fine fuels, which can impact the implementation of prescribed fire and the meeting of objectives if it removes the fuel (grasses) to carry fire. The timing of grazing may reduce rates of spread and flame lengths during wildfire events.

Firewood cutting is occurring throughout the planning area. The removal of dead trees reduces fire behavior and fire effects.

Undeveloped areas within the project area do not contain any special or unique fuels resource values. Effects to fuels and air quality from proposed project treatment activities would not differ based on the description of land (undeveloped). Therefore, the description of effects are not differentiated further in the analysis.

Alternative 1 – No Action

Direct and Indirect Effects

No action implies conditions within the planning area might remain static. This assumption is incorrect since forest ecosystems are dynamic and would continue to produce vegetation that competes for available sunlight, moisture, and nutrients. As time progresses, the conifer stands would produce heavier understories of shade-tolerant, fire-intolerant trees (fuel ladders), dead and down woody debris would continue to accumulate, and mortality would increase, creating the potential for an uncharacteristic scale of tree mortality from wildfires burning outside the range of variability. Hazardous fuel conditions within the planning area would remain untreated and constitute a potential uncharacteristically severe wildfire threat, not only for the proposed planning area, but also for adjacent lands.

Surface fuel loadings would increase over time as shrubs grow and competition-created snags fall. Although competition would naturally thin the stand, shade-intolerant species would continue to grow in the understory. This would keep height-to-live crown low and crown density high. The large fire-resistant trees in the stand would remain as long as they successfully compete for limited resources. These trees would continue to be competition-stressed and at risk from insects, disease, and wildfire.

There would be no change to the road system under alternative 1. Therefore, the use of fuelbreaks along strategic roads as ingress or egress routes during a wildfire would remain the same as current conditions.

The proposed forest and unique habitat restoration, and fuels treatments would not be implemented. Custodial activities would continue, such as routine maintenance and response to emergencies, including wildfire suppression. The forest would continue to grow which would increase non-fire-dependent tree species, shrub and grass species, snag creation, and dead and down material accumulation. However, this alternative would not change expected fire behavior under 90th percentile weather conditions within 30 years. Flame lengths would remain at 4 to 8 feet with some areas exceeding 11 feet (Figure 5). The majority of the planning area would sustain passive crown fire (Figure 2).

Fire effects under alternative 1 would result in higher stand loss, as seen in the Canyon Creek Complex, Easy, and Rail Fires, which burned in similar fuels profiles on the Malheur National Forest in 2015, 2002, and 2016. It is expected that some fires, both human and lightning caused, would continue to escape initial attack under increasingly severe weather conditions over the next 20 to 30 years. These fires are expected to kill forest stands, including larger trees.

There would be no significant change in expected fire behavior on the landscape in 30 years. Stands would continue to be at risk from stand-replacement fire. With continued surface fuel accumulation, it is likely that surface fire intensity and crown fire potential would increase over the longer-term.

Wildfire starts currently have the potential to produce severe stand-replacement type fires under severe fire weather conditions as seen in the Canyon Creek Complex, Rail, and Easy Fires, presenting a threat to firefighters and the public. Alternative 1 would do nothing to mitigate this situation, allowing the already hazardous fire conditions to increase going into the future.

Table 6 displays predicted flame lengths, crown fire activity, and suppression actions under 90th percentile weather conditions for alternative 1. Under alternative 1, most of the planning area would sustain passive crown fire, and average flame lengths are expected to exceed 4 feet. These flame lengths, and passive crown fire are a direct result of high fuel loadings and high stocking levels. Fires burning in stands under 90th percentile weather conditions in alternative 1 are expected to result in control problems and uncharacteristically high tree mortality.

Table 6. Alternative 1 predicted average surface fire flame length, crown fire activity, and suppression action under the 90th percentile weather condition

Flame length (feet)	Crown fire activity	Suppression actions
4 - 8	Passive crown fire	Fires may present serious control problems torching, crowning, and spotting. Control efforts at the fire head would probably be ineffective.
8 – 11	Passive or active crown fire	Fires may present serious control problems—torching, crowning, and spotting is common. Control efforts at the fire head will probably be ineffective.

Alternative 1 would have the least immediate impact on air quality, as there would be no prescribed burning or pile burning. All biomass would remain available for consumption by wildfires and would continue to accumulate, increasing the potential for large amounts of wildfire smoke during the summer months, when diurnal inversions can concentrate smoke at low elevations. Because wildfires tend to occur at the driest time of the year, fuels are more completely consumed and typically produce three to five times more emissions than early or late season prescribed fires. There is a potential during a wildfire for approximately 0.6 tons per acre of particulate matter emissions and 32 tons per acre of carbon dioxide to be produced. These smoke concentrations can have high particulate levels that can cause health problems or violate summertime class 1 air quality visibility standards for wilderness areas. The communities of Drewsey, Seneca, and Burns could be impacted by smoke from a wildfire in this area.

Cumulative Effects

Because there are no direct or indirect effects, there would be no cumulative effects.

Alternative 2 and 3

Alternatives 2 and 3 are similar in fuels treatments and fuels objectives. The difference is in the acres treated in each alternative. Both alternatives 2 and 3 include a suite of forest and unique habitat restoration activities (dry pine, mixed conifer, pine savannah habitat, old growth habitat and connectivity enhancement, aspen riparian, mountain mahogany, shrub steppe, meadow enhancement, strategic roads treatments, and prescribed burning) to maintain and improve landscape resiliency, promote forest conditions that allow for the reintroduction of fire upon the landscape, improve aquatic resource conditions, improve wildlife habitat, improve one or more of the nine roadless area characteristics, and contribute to the social and economic health of those enjoying multiple uses in the planning area.

Fuels Treatments

Following forest and unique habitat restoration treatments and strategic roads treatment, one or a combination of fuels treatments may be implemented to reduce fuel loading within approximately 27,300 acres in alternative 2 and 26,4000 in alternative 3. These treatments may include small diameter thinning, hand piling, machine piling, pile burning, jackpot burning, underburning, lop and scatter, chipping, and mastication. Not all of these treatments would need to be implemented on every acre to achieve desired outcomes.

After scoping comments were received, a concern with treating too much in the connectivity corridors along strategic roads resulted in a suggestion to have a narrower road buffer instead. Alternative 3 has a 100-foot buffer along the strategic roads units that overlap connectivity corridors.

Unplanned ignitions within the planning area would be managed when appropriate to meet the purpose and need. The managed fire would be within the historical fire regime of low to mixed severity fire. This would take place on approximately 40,250 acres in both alternatives.

Alternative 2 would have prescribed fire on approximately 40,250 acres while alternative 3 would implement prescribed fire on 32,970 acres. The 7,280 acres not being prescribed burned in alternative 3 were removed from prescribed fire after scoping comments received from the public voiced concerns with prescribed fire in the Malheur River Inventoried Roadless Area.

Prescribed burning would occur in four prescribed fire burn blocks in alternative 2 and five prescribed fire burn blocks in alternative 3, which vary in size from approximately 8,560 to 11,770 acres with boundaries identified along natural fuel breaks, such as existing roads and ridgetops. The size, in acres, of a particular burn block does not represent how much of the landscape would be burned or blackened. Within each identified burn block there would be several unburned acres. Examples include open scabby areas, wet riparian areas, and north-facing slopes. Additionally, much of the area where prescribed fire would carry is expected to burn in a mosaic pattern due to variations such as fuel moisture, shading, grazing, lack of continuous fuelbeds, and others.

Another factor limiting actual burned acres is design criteria limiting where active ignitions can occur within a particular burn block. Depending on weather conditions, fuel characteristics, and design criteria, the number of acres burned could vary from 50 to 80 percent of the proposed burn block size.

The following definitions describe common fuel treatment types and the conditions under which they may be implemented.

Small Diameter thinning: Cutting trees less than 9-inch diameter at breast height to a 20-foot non-variable spacing within fuels units and within a 150-foot buffer along strategic roads in all activity units in alternative 2 and a 100-foot buffer in alternative 3. The result is a reduction in crown fire initiation and crown fire. This creates more opportunity for safe ingress and egress route as well as more suppression options during a wildfire event.

This treatment can be done alone or incorporated into other activities.

Pruning: Removing the lower limbs of trees up eight feet to reduce crown fire initiation. The result of pruning is to isolate the surface fire from the crowns of trees. This is done in areas where removing the entire tree would negatively impact the ecosystem or removing the shade could potentially change the understory or overstory species or composition out of the desired condition.

This treatment can be done alone or in combination with other treatments.

Jackpot burning: A modified form of underburn or broadcast burn where the target fuels to be ignited are the concentrations (or jackpots) of vegetative fuel. The result is a mosaic burn pattern. This technique works well when surface fuel loading is very high but not continuous following vegetation treatments.

This treatment can be done in the spring or fall depending on the size of fuels needing to be reduced. Spring burning targets smaller diameter material less than 3 inches and retains much of the larger than 3-inch material. Fall burning would consume more material in all size classes.

This treatment can be done immediately post-harvest or as one of the last treatments in the unit.

Underburning: A prescribed fire ignited under the forest canopy, via natural or human ignition, which focuses on the consumption of surface fuels but not the overstory vegetation.

Underburning is generally used following a pre-treatment such as harvesting, thinning, pile burning, or any combination to further reduce the surface fuels, help maintain the desired vegetation conditions and enhance the overall health and resiliency of the stand. Underburning is also used to meet silvicultural prescriptions to thin smaller trees to a more mosaic and natural site.

This treatment can be done in the spring or fall depending on the size of fuels needing to be reduced. Spring burning targets smaller-diameter material less than 3 inches and retains much of the larger than 3-inch material. Fall burning would consume more material in all size classes.

This treatment can be done immediately post-harvest or as one of the last treatments in the unit.

Pile burning: A prescribed fire used to ignite hand or machine piles of cut vegetation resulting from vegetation or fuel management activities.

Piles are generally burned during the wet season to reduce damage to the residual trees and to confine the fire to the footprint of the pile. Pile burning allows time for the dead vegetative material to dry out and would produce less overall smoke by burning hot and clean.

Pile burning treatments need to be implemented within one to three years of cutting treatment to be most efficient as needles start to fall off, making piles harder to burn.

Swamper burning: A modified form of pile burning where personnel feed material (or swamp material) into small, ignited burn piles. The result is fewer piles per acre and can be used to lessen impact on fragile soils and plant and animal species. Swamper burning is generally burned during the wet season.

Hazard tree felling: Cutting of trees that pose a threat to forest visitors, contractors, and firefighters.

Hazard tree felling would happen any time a hazard tree was recognized.

Handpile: A pile of slash constructed by a crew, not by machine. Piles would be constructed post timber harvest and after secondary thinning work. Handpiles are typically less than 10 feet high and less than 12 feet in diameter. Piling takes place during the field season (spring, summer, or fall).

Machine Pile: A mechanical type of treatment. Piles of slash (vegetative debris) constructed using vehicular machines of such size and at such distance from trees so that burning shall not result in unnecessary damage to residual timber. Piling takes place during the field season (spring, summer, or fall).

Lop and Scatter: Cutting branches, tops, and unwanted boles into lengths and spreading debris evenly over the ground. This includes logging slash or fuel reduction debris cut and scattered to reduce slash concentrations. Slash is scattered into openings away from and without unnecessary damage to residual trees. Lop and scatter can occur at any time but is usually implemented post thinning operations. Lop and scatter is also used when there are not enough ground fuels to carry a fire to enhance prescribed fire objectives.

Mastication: A mechanical type of treatment. Chopping, grinding, mowing treatments, or any combination, usually by mechanical means, to reduce fuel bed depth or crowning potential. The primary target is usually live fuels, such as brush and small trees, but this treatment can also be used in light loadings of dead fuels. Vegetation is usually left in place.

Chipping: A mechanical type of treatment. Woodchips are small to medium sized pieces of wood formed by cutting or chipping larger pieces of wood such as trees, branches, logging residues, stumps, roots, and wood waste. The primary target is usually live fuels, such as brush and small trees, but this treatment can also be used in light loadings of dead fuels. Chips usually left in place.

Direct and Indirect Effects

Forest and unique habitat restoration activities, strategic roads treatments, and prescribed burning have the effect of increasing the height-to-live crown and retaining the largest trees, which reduces crown fire initiation. Crown density would also be reduced, lowering active crown fire potential. The surface fuel treatments change the size and arrangement of available fuel and/or reduce the amount of fuel that is available to burn, reducing flame lengths, crown fire activity, and emissions.

Treatments would reduce the horizontal and vertical fuel loading. Direct attack with hand tools would be sufficient to contain fires when necessary. Fire could be reintroduced into the planning area. The fuelbreaks along strategic roads would allow safe travel for the public and suppression forces should the need arise to escape from an emerging wildland fire. Strategic road treatments can also be used to contain fires.

To sustain the desired fuels strata, follow-up treatments would be necessary to maintain fuel loading levels. Conditions would be evaluated and prescribed following implementation (anticipated to be 15 to 20 years after initial entry). These maintenance treatments can include:

- Prescribed burning (jackpot, underburn, piles), which lowers fuel loading in all size classes
- Felling of hazard trees, which reduces the risk to firefighters and the public
- Mastication, which reduces fuel bed depth and breaks up fuel continuity
- Piling excess fuels, which breaks up fuel continuity

Thinning trees from below would raise canopy base heights, thereby reducing crown fire initiation which would increase the likelihood that fires would stay as surface fires and not become crown fires. Surface treatments should lower flame lengths. Suppression forces could enter these areas and take appropriate actions as needed to manage fires (Brown et al. 2003). The treatments in alternatives 2 and 3 are expected to slow horizontal and vertical fire movement in 90th percentile weather conditions.

Creating and maintaining fuelbreaks along strategic roads to break up large expanses of continuous fuels would provide for firefighter access and safety, increase suppression opportunities, increase ingress and egress safety for communities, and provide pre-existing control points to contain fires.

In alternative 3 under wildfire conditions, the Malheur River Inventoried Roadless Area would burn similar to alternative 1 as fuels treatments would not occur in this area. Managed fires would have limited opportunity and most fire starts would need to be suppressed in these areas as the resource benefits may be difficult to achieve.

Table 7 displays predicted flame lengths, and crown fire activity and suppression actions after all treatments are complete. Under alternatives 2 and 3, crown fire activity on average would be kept to surface fires (Figure 3 and Figure 4). Flame lengths would average 4 feet in height (Figure 6 and Figure 7). These lower flame lengths, and surface fires are a direct result of lower fuel loadings, lower canopy bulk densities, and higher canopy base heights. Fires burning in stands under 90th percentile weather conditions in alternatives 2 and 3 can generally be attacked at the head or flanks by persons using hand tools. Fire behavior and effects would be like historical conditions within fire regime I, allowing for fire to burn naturally within the planning area. The effect on fire suppression forces would depend on the continued maintenance of the stands. Stands that are maintained and managed to achieve the desired condition would not adversely impact future suppression

Table 7. Alternatives 2 and 3 predicted average surface fire flame length, crown fire activity, and suppression action under 90th percentile weather conditions within treatment units.

Alternatives 2 and 3	Flame length (feet)	Crown fire activity	Suppression actions
Post-activity	≤4	Surface fire	Fires can generally be attacked at the head or flanks by persons using hand tools. Hand line should hold the fire. ¹

1. Continued maintenance and prescribed fire rotation would be required every 15-20 years.

Prescribed burning would follow the guidance provided by the Oregon Smoke Management Plan and all other applicable federal, state, and local air quality regulations. Emissions from a wildfire are generally three to five times greater than from prescribed burning. Pile burning occurs in the fall and winter and underburning occur in the spring and fall, there is little overlap from these two treatments, there may be short- term impacts to communities and residences downwind and in drainages adjacent to prescribed fire, this may include the communities of Drewsey, Seneca, and Burns. Experience of prescribed burning in this area has shown that diurnal winds settle smoke in low areas and valley bottoms.

Prescribed burning may impact highway and forest roads visibility, and potentially impact driver safety. Signing would reduce the risk, lasting for around three to four days. If driving conditions warrant, the Oregon Department of Transportation or Grant County Road Department would be contacted to flag traffic or use pilot cars.

Emissions produced from burning under alternatives 2 and 3 would maintain air quality standards.

Smoke sensitive areas including John Day, Oregon (approximately 20 air miles southwest of the planning area), the La Grande Basin, Oregon (approximately 45 air miles to the northeast of the planning area) and the north half of Ada County, Idaho (approximately 160 air miles southeast of the planning area) may be affected by prescribed burning because of transport winds, but it is expected to be minimal because of smoke dilution over time and space. Weather forecasts would be obtained prior to burning to ensure the Strawberry Mountain Wilderness would not be affected by prescribed burning during the visibility protection periods of July 1 to September 1.

Table 8. Predicted prescribed fire and pile burn smoke emissions within alternative 2 and 3

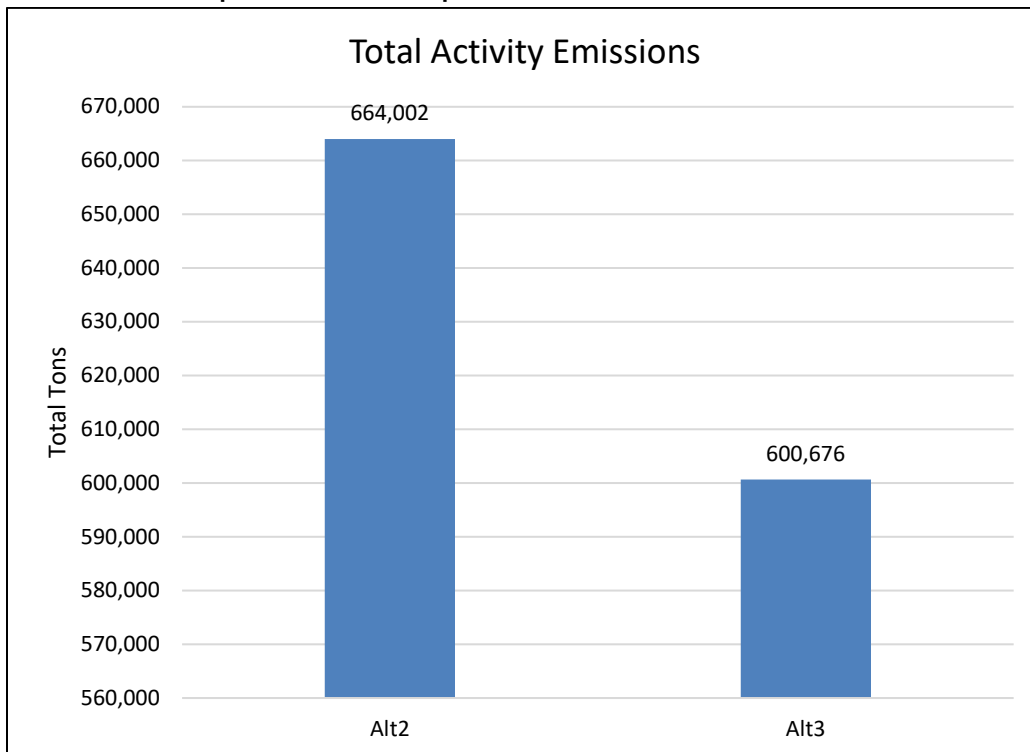
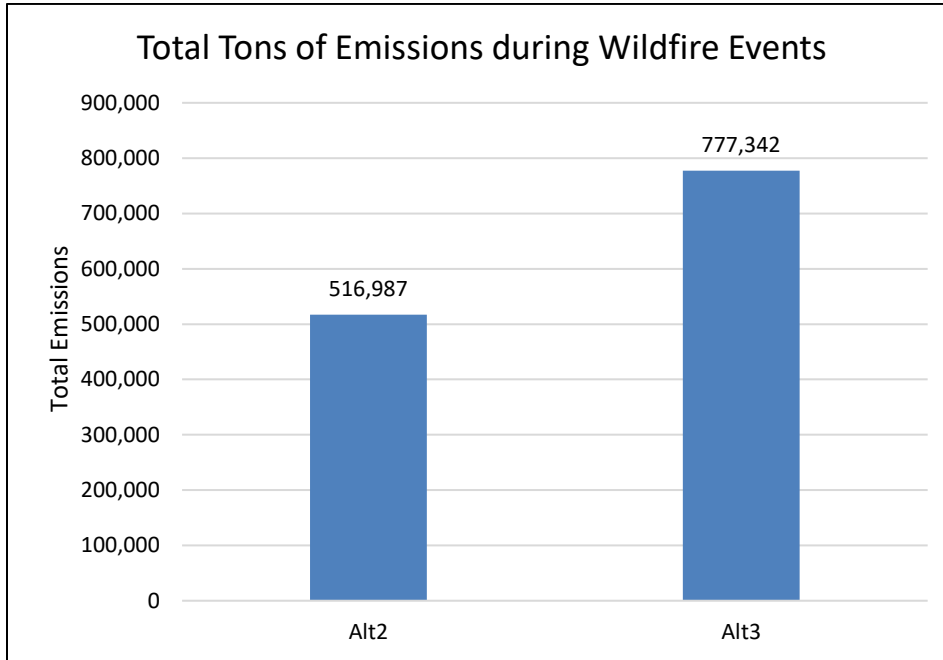
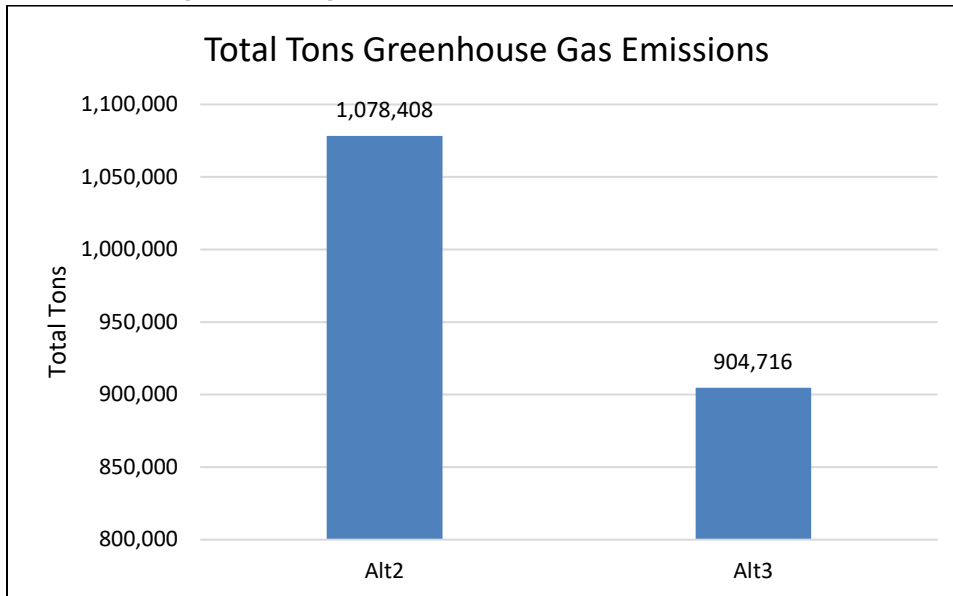


Table 9. Wildfire smoke emissions under 90th percentile weather within alternative 2 and 3**Table 10. Total greenhouse gas emissions within alternatives 2 and 3**

Planned road activities would have little effect on fire suppression efforts or fuel loading. Many of the roads in the planning area would remain open; however, some roads would be closed but available for fire suppression activities. The roads planned for decommissioning would not have a major affect for fire suppression access. Roads proposed for decommissioning were evaluated and determined to be not needed for suppression activities.

Cumulative Effects

Present activities within the planning area that would have a cumulative effect on the alternatives are the present grazing, and firewood cutting.

Treatments from this project when combined with grazing and firewood cutting activities would improve stand survivability during a wildfire event by reducing canopy bulk density, canopy base heights, and fuel loading. Treatments would improve the planning area by reducing fire behavior and fire effects, as well as creating safe travel routes along a main road within the planning area boundary. In the event of a wildfire, the planning area would be conducive to allow a fire to be a natural disturbance and move across the landscape as a predominantly surface fire within its historical fire regime.

Roads are commonly used as control points for containing wildfire and are often used as the fireline. Fuels treatments would provide a continual break in the fuel profiles crossing the planning area. This fuels treatment, when combined with existing projects, would further break up fuel continuities in the area, creating more opportunities for future suppression actions. As managers continue to move the Forest toward the desired condition, fire would be able to resume its natural role in developing and sustaining these ecosystems. Continued management practices can and would alter the effects of wildland fire (Agee and Skinner 2005).

Grazing is occurring within approximately 40,000 acres of the planning area boundary. Grazing would continue to affect fine fuels. This can impact the implementation of prescribed fire and meeting objectives if it removes the fuel (grasses) to carry fire. During a wildfire event grazing reduces fire spread and flame lengths since it removes fine fuels.

Firewood cutting is occurring throughout the planning area. The removal of dead trees and dead large wood reduces fire behavior and fire effects.

There is a potential for cumulative effects from prescribed burning occurring at the same time from nearby units. Currently, four projects are located near the Cliff Knox Project (Wolf, Summit Creek, Elk, and Knox, which are being implemented), Total emissions produced from concurrent projects on National Forest System lands would meet air quality standards. It is likely that only a few projects, in isolated areas, would undergo burning at the same time. The dilution of smoke over time and space from concurrent burning would limit the cumulative effects. All burning would be coordinated to reduce cumulative effects and meet all applicable laws and regulations. Therefore, the cumulative effects of multiple prescribed burning projects would not cause air quality to decline outside of standards.

Comparison of Alternatives

There would be a sizable reduction in flame length and crown fire activity within the planning area with alternatives 2 and 3 compared to alternative 1. Overall emissions would be reduced in the action alternatives compared to the no action alternative. The action alternatives would also limit the daily emissions to meet the Clean Air Act. The action alternatives would limit smoke into communities as prescribed fire treatments would occur when smoke would be directed away from these areas. Alternative 3 has potentially fewer overall emissions but more emissions during a wildfire event. Wildfires regularly exceed Clean Air Act standards, and the direction of the smoke cannot be managed, potentially sending smoke into communities, and wildernesses.

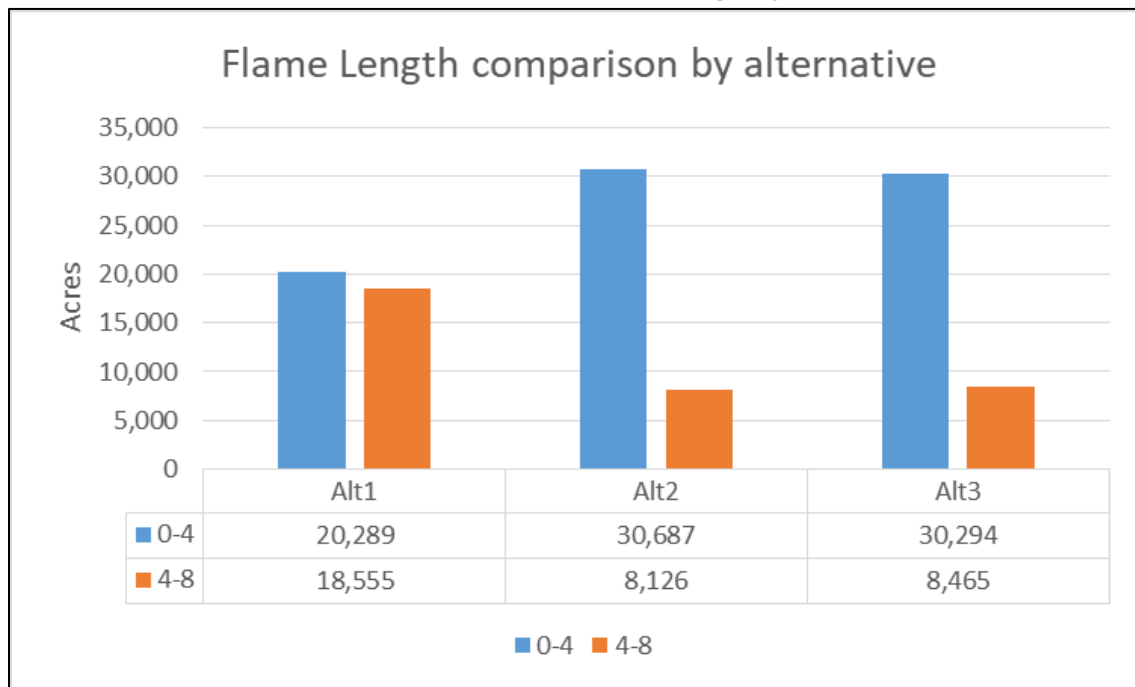
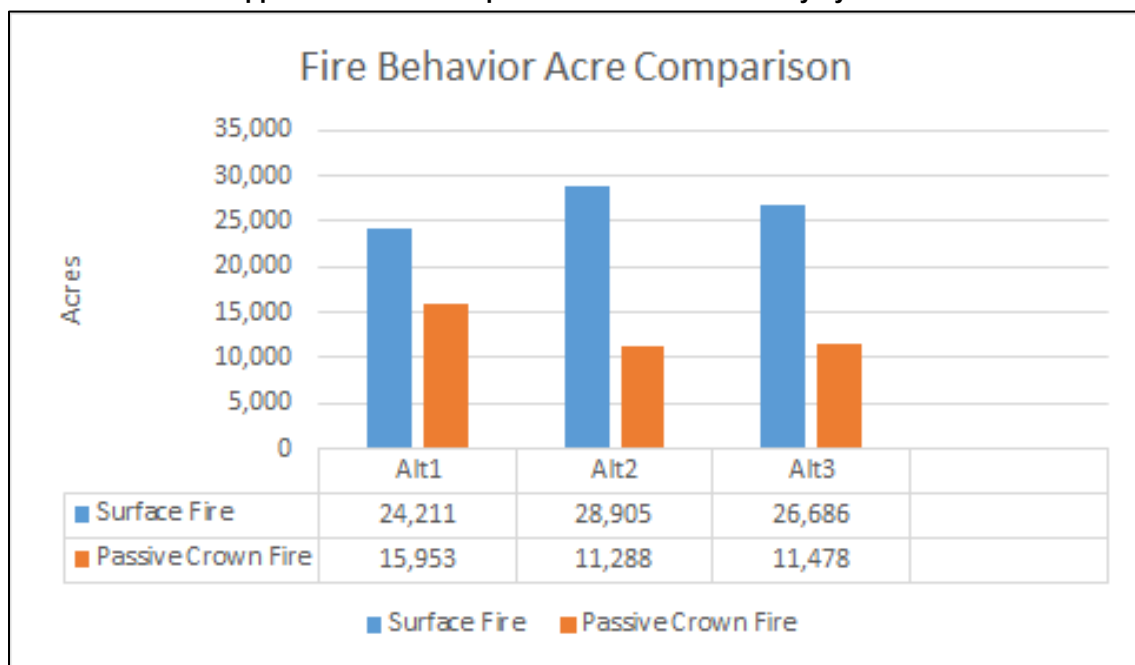
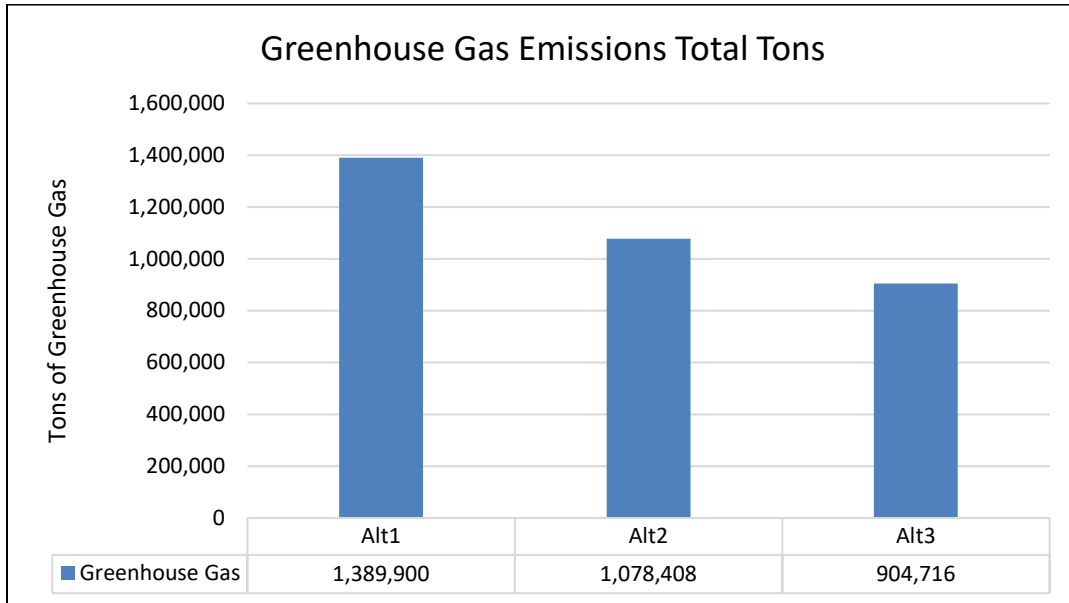
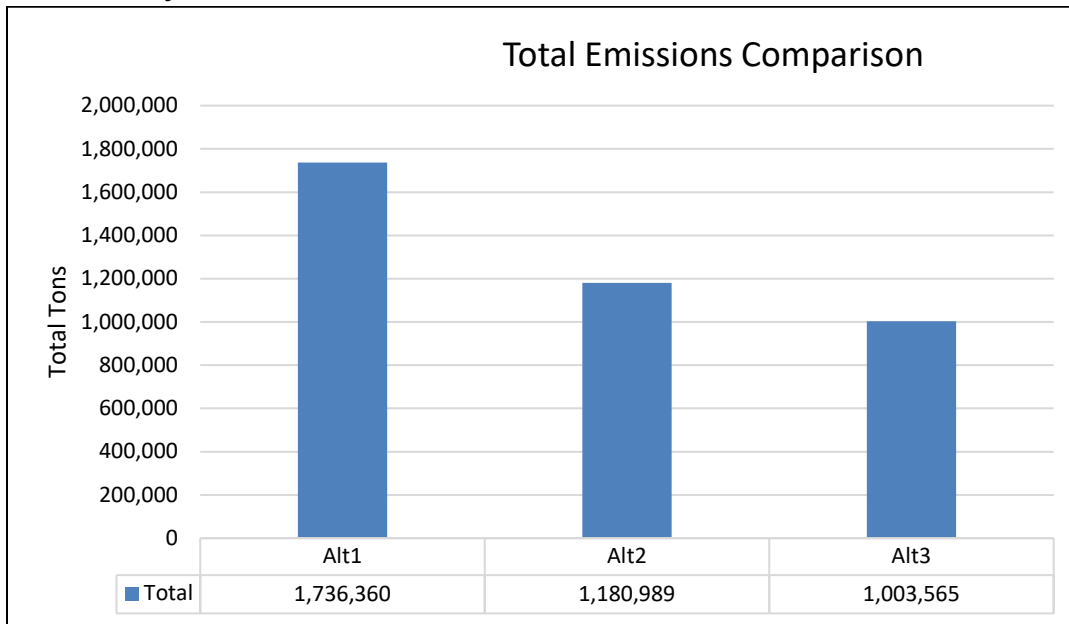
Table 11. Predicted approximate acre comparison of flame length by alternative**Table 12. Predicted approximate acre comparison of crown fire activity by alternative**

Table 13. Predicted approximate comparison of greenhouse gas emissions by alternative including wildfire event post treatment**Table 14. Predicted approximate comparison of total smoke emissions including greenhouse gasses in total tons by alternative**

Differences in fire behavior between alternative 1 and the action alternatives is a reduction in emissions and a reduction in overall fire behavior in the action alternatives. There would be more opportunity for suppression actions and managing fire on the landscape in alternatives 2 and 3 compared to alternative 1. Alternative 2 would allow for lower fire behavior over a larger portion of the planning area since more treatments would occur in the Malheur River Inventoried Roadless Area and connectivity corridors. Alternative 3 does not propose prescribed burning in the inventoried roadless area, and should a wildfire occur, those areas may burn similarly to alternative 1. Differences in emissions between action alternatives and alternative 1 are fewer

overall emissions and less greenhouse gasses released during treatments and a subsequent wildfire event. The direction of emissions can be mitigated during prescribed fire events which can lessen the effect on local communities. Alternative 3 has slightly fewer total emissions than alternative 2 but higher total emissions from a wildfire event. Therefore, there is a higher probability of emissions affecting communities than alternative 2. During pile burn and prescribed fire emissions we are required to follow the Clean Air Act and not exceed National Ambient Air quality standards. These treatments would release fewer overall emissions daily and would less likely impact smoke sensitive areas.

Required Monitoring

Monitoring of work conducted under thinning, grapple, and hand piling contracts would consist of periodic inspections while work is in progress and after completion to determine compliance with contract standards. Monitoring of prescribed burning and unplanned ignitions would include weather, flame length, and smoke dispersal to ensure burning is conducted within the parameters stated in the burn plan.

Compliance with Forest Plan and Other Relevant Laws, Regulations, Policies and Plans

Alternative 1 is not in compliance with the Malheur Forest Plan (USDA Forest Service 1990a) and the above regulatory framework. Alternative 1 would not allow fire to play a natural role in the planning area. Fire behavior would not be a low intensity surface fire over much of the planning area.

Alternative 1 would not manage residue profiles, and fire would have the potential to be an uncharacteristically severe wildfire. Alternative 1 would not use prescribed fire to reduce encroachment of non-fire-tolerant species, stocking levels, and fuel loading; this would maintain the existing change from the natural fuels strata in the planning area, potentially losing key features in these areas should a wildfire occur. Alternative 1 would not use fuels treatments in developed recreation sites and visual corridors; this would potentially create safety concerns from high fuel loadings and decreased sight distances. Alternative 1 would not preserve, protect, and enhance the air quality during wildfire events. Alternative 1 does not meet the Grant County or Harney County Community Wildfire Protection Plan goals to reduce hazardous fuels.

Alternatives 2 and 3 are in compliance with the regulatory framework. After treatments from alternatives 2 and 3, flame lengths across the planning area would average less than four feet. Fires would burn as surface fires with occasional small group torching, and less emissions would be produced during a wildfire event.

Oregon smoke management regulates the amount of smoke that can be produced daily and the direction that smoke can travel. Prescribed burning would be meeting the Clean Air Act by controlling the amount and direction of emissions. During a wildfire event, the emissions would exceed regulations and potentially be in smoke sensitive areas. The difference between the action alternatives is that alternative 2 would create more emissions during prescribed fire events than alternative 3. Alternative 3 would create more emissions during a wildfire event because less emissions would have been created during prescribed burning. Alternative 3 would potentially send emissions into smoke sensitive areas at higher quantities than alternative 2.

References

- Agee, J.K. 1993. Fire ecology of Pacific Northwest forests. Washington, DC: Island Press. 433 p.
- Agee, J.K. 1996. Fire in the Blue Mountains: a history, ecology, and research agenda. Search for a solution: sustaining the land, people and economy of the Blue Mountains. Washington, DC: American Forests, pp.119-146.
- Agee, J.K. and C.N. Skinner. 2005. Basic principles of forest fuel reduction treatments. *Forest Ecology and Management* 211: 83-96.
- Andrews, P.L. and R.C. Rothermel. 1982. Charts for interpreting wildland fire behavior characteristics. General Technical Report INT-131. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station.
- Andrews, P.L., F.A. Heinsch, and L. Schelvan. 2011. How to generate and interpret fire characteristics charts for surface and crown fire behavior. General Technical Report RMRS-GTR-253. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 40 p.
- Arno, Stephen F. 1996. The seminal role of fire in ecosystem management-impetus for this publication. In: Hardy, Colin C.; Arno, Stephen F., eds. The use of fire in forest restoration. Gen. Tech. Rep. INT-GTR-341. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. p. 3-5.
- Brown, J.K., E.D. Reinhardt, and K.A. Kramer. 2003. Coarse woody debris: managing benefits and fire hazards in recovering forest. General Technical Report RMRS-GTR-105. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.
- Code, United States. Title 42 - The Public Health and Welfare Chapter 85-Air Pollution Prevention and Control Subchapter I-Programs and Activities Part C-Prevention of Significant Deterioration of Air Quality subpart i-clean air.
- Connaughton, J.L., 2005. Guidance on the consideration of past actions in cumulative effects analysis. Council on Environmental Quality. June 24.
- Council on Environmental Quality. 2000. Managing the Impact of Wildfire on Communities and the Environment: A Report to the President in Response to the Wildfires of 2000 (National Fire Plan).
<https://www.forestsandrangelands.gov/documents/resources/reports/2001/8-20-en.pdf>.
- Council, W.F.E., 2014. The national strategy: The final phase in the development of the National Cohesive Wildland Fire Management Strategy. Washington, DC.
<https://www.forestsandrangelands.gov/documents/strategy/strategy/CSPhaseIIINationalStrategyApr2014.pdf>.
- Enrong Y., W. Xihua, and H. Jianjun. 2006. Concept and classification of coarse woody debris in forest ecosystems. *Frontiers of Biology in China*. 1(1): 76-84.
- Environmental Protection Agency, Title 40, Code of Federal Regulations 51.308-309. *Regional haze program requirements*.

- Environmental Protection Agency. 2019. Nonattainment Areas for Criteria Pollutants (Green Book). <https://www.epa.gov/green-book>.
- Finney, M.A. 2006. An overview of FlamMap fire modeling capabilities. Pages 213-220 in: Andrews, P.L., and B.W. Butler (comps.). 2006. Fuels management-how to measure success: conference proceedings. 28-30 March 2006; Portland, OR. Proceedings RMRS-P-41. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.
- Grant County. 2013. Community Fire Protection Plan. Grant County, OR. Available online: http://www.grantcountycwpp.com/pdf_final/cwpp_final.pdf.
- Hann, W.J. and D.L. Bunnell. 2001. Fire and land management planning and implementation across multiple scales. *International Journal of Wildland Fire* 10: 389-403.
- Johnson, C.G., Jr. 1994. Forest health in the Blue Mountains: a plant ecologist's perspective on ecosystem processes and biological diversity. Gen. Tech. Rep. PNW-GTR-339. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 23 p. (Quigley, Thomas M., ed.; Forest health in the Blue Mountains: science perspectives).
- Johnston, J.D., J.D. Bailey, C.J. Dunn, and A.A. Lindsay. 2017. Historical fire-climate relationships in contrasting interior Pacific Northwest forest types. *Fire Ecology* 13(2): 17-36.
- Juran, Ashley G. 2017. Fire regimes of conifer forests in the Blue Mountains. In: Fire Effects Information System, [Online]. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Missoula Fire Sciences Laboratory (Producer). Available: https://www.fs.fed.us/database/feis/fire_regimes/Blue_Mts_conifer/all.html.
- Morgan, Penelope, Colin C. Hardy, Thomas W. Swetnam, Matthew G. Rollins, and Donald G. Long. "Mapping Fire Regimes across Time and Space: Understanding Coarse and Fine-Scale Fire Patterns." *International Journal of Wildland Fire* 10, No. 4 (2001): 329-42. <https://doi.org/10.1071/wf01032>.
- Oregon Administrative Rules 629-048-0130
<https://secure.sos.state.or.us/oard/viewSingleRule.action?ruleVrsnRsn=162166>
- Reinhardt, E.D., R.E. Keane, and J.K. Brown. 1997. First order fire effects model: FOFEM 4.0, user's guide. General Technical Report INT-GTR-344. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station.
- Rollins, Matthew G. "LANDFIRE: A Nationally Consistent Vegetation, Wildland Fire, and Fuel Assessment." *International Journal of Wildland Fire* 18, No. 3 (2009): 235-49. <https://doi.org/10.1071/wf08088>.
- Schlobohm, P. and J. Brain. 2002. Gaining and understanding of the national fire danger rating system. PMS-932, NFES#2665. May 2002. Washington, DC: National Wildfire Coordinating Group.
- Schmidt, K.M., J.P. Menakis, C.C. Hardy, W.J. Hann, and D.L. Bunnell. 2002. Development of coarse-scale spatial data for wildland fire and fuel management. General Technical

- Report RMRS-GTR-687. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.
- Scott, J.H. and E.D. Reinhardt. 2001. Assessing crown fire potential by linking models of surface and crown fire behavior. USDA Forest Service Research Paper, p.1.
- Scott, J.H. and R.E. Burgan. 2005. Standard fire behavior fuel models: a comprehensive set for use with Rothermel's surface fire spread model. General Technical Report RMRS-GTR-153. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.
- Solomon, S., D. Qin, M. Manning, M. Marquis, K. Averyt, M. Tignor, H. Miller, and Z. Chen. 2007. Climate change 2007: the physical science basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.
- Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.), 2013: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1535 pp.
- USDA Forest Service. 1990. Malheur National Forest Land and Resource Management Plan. John Day, OR: U.S. Department of Agriculture, Forest Service, Malheur National Forest. Available online: <http://www.fs.usda.gov/main/malheur/landmanagement/planning>.
- USDA Forest Service. 1994. Decision Notice Finding of No Significant Impact and Forest Plan Amendment for Incorporation of the Columbia River Basin Anadromous Fish Habitat Management Policy and Implementation Guide into the Malheur National Forest Land and Resource Management Plan [Amendment 29]. U.S. Department of Agriculture, Forest Service, Pacific Northwest Region, Malheur National Forest.
- USDA Forest Service. 2000. Protecting people and sustaining resources in fire-adapted ecosystems—a cohesive strategy. Available online: http://www.fs.fed.us/publications/2000/cohesive_strategy10132000.pdf.
- USDA Forest Service. 2011. A national cohesive wildland fire management strategy. U.S. Department of Agriculture, Forest Service; Department of the Interior, Office of Wildland Fire Coordination. Washington, DC: Wildland Fire Leadership Council. 43 p
- USDA Forest Service. 2017. Forest service's plan for addressing Climate Change. Office of Inspector General.
- USDA Forest Service. 2019. Malheur National Forest Strategic Road Fuels Breaks. U.S. Department of Agriculture, Forest Service, Pacific Northwest Region, Malheur National Forest.

Appendix

