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Service

**Southwestern
Region**

Fire Ecology, Fuels & Air Quality Specialist Report

Four-Forest Restoration Initiative

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Submitted by: ___________________________

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Introduction

“Although prescribed fire programs have been underway for several decades, the scale and intensity of these restoration efforts have been inadequate to reverse the overall trends of degradation in southwestern pine forests. Concerns about excessive smoke and the risks of prescribed burning have also constrained public support for the use of fire alone as a restoration treatment.” (Allen et al. 2002)

Treatments designed primarily for fuels objectives differ from treatments designed for restoration objectives. Treatments based on fuel objectives may be effective at reducing fire behavior, but they do not provide the same breadth of benefits as restoration treatments designed to reset treated areas on a trajectory towards a fully functioning ecosystem (Lynch et al. 2000). Restoration treatments mitigate fire behavior and effects, while providing multiple the additional benefits from an increasingly healthy ecosystem (Covington et al. 2001, Omi and Martinson 2004, Fulé et al. 2001). Restoration treatments have been shown to have greater longevity in reducing undesirable fire behavior (Feidler and Keegan 2003, Triepke et al. 2011).

Using fire (wildfire and prescribed fire) as a management tool is difficult to do on a scale that matters because the low severity fires that typify the historic fire regime across most of the analysis area would take days, weeks, or months. The difficulty of using fire on a landscape scale, include narrow burn windows, smoke impacts, and 100,000s of thousands of acres of forests too overgrown to manage with fire alone has sometimes led to mechanical treatments being used in place of fire, but the results are not equivalent. In an interview with the National Fire Protection Association in 2011, noted Fire Historian Stephen Pyne summarized it well, “Fire has a lot of other ecological effects besides consuming surplus fuel. It’s a biochemical reaction-it releases nutrients and it rearranges things. That’s why fire and logging are not equivalent operations. Logging takes the big stuff and leaves the little. Fire burns the little and leaves the big. One doesn’t substitute for the other. It’s the whole sense that these landscapes are now out of sync..”

Fire is a keystone process in healthy ponderosa pine ecosystems as well as the grasslands, aspen and other ecosystems within the analysis area. Fire Ecology includes the symbiotic relationship of fire with all components of an ecosystem, spatially and temporally. These include climate, soil, flora, fauna, hydrology, and anything that affects or is affected by a fire regime. This report focuses on the effects of proposed management alternatives on fire behavior and on the effects of fire on vegetation. The effects of fire include emissions, which have ecological effects as well as effects on air quality.

The objective of the Four-Forest Restoration Initiative is to restore healthy ecological processes by manipulating the patterns, structures, and compositions of ecosystem elements. The following questions were used to guide this analysis regarding the effectiveness of each alternative for moving the analysis area towards the desired condition.

Question 1: Would/how would proposed management actions move the area towards the desired condition of having a resilient forest by reducing the potential for undesirable fire behavior and effects? Metrics used to evaluate differences between alternatives include:

> **Type of fire** (surface or crown): Acres (quantitative measure) of each potential fire type following proposed treatments were evaluated (details on pg. 16).
>
> **Canopy Base Height (CBH) and Canopy Bulk Density (CBD)** (quantitative measures): These canopy characteristics significantly affect the potential fire type (details on pg. 18).

Surface fuel loading for this analysis, includes Coarse Woody Debris >3" diameter (CWD >3"), litter and duff (quantitative measure): Used to qualitatively evaluate potential fire effects (details on pg. 19).

Fire Regime/Condition Class (FRCC) (qualitative measure): FRCC was determined for ponderosa pine and grasslands which make up the largest vegetation types within the treatment area to determine the relative departure of those ecosystems from reference conditions before and following treatments (details on pg. 21 for).

Question 2: What are the expected effects of smoke/emissions from prescribed fire?
Smoke/emissions were evaluated quantitatively by modeled emission quantities in pounds/acre for the most common stand condition under different treatment scenarios. Additionally, changes in those fuel components which produce the greatest percentages of emissions when they burn (litter, duff, and CWD>3 inches) were modeled, and mapped for a qualitative assessment.

Purpose and Need for Action

The purpose and need for proposing an action was determined by comparing objectives and desired conditions in the Coconino NF and Kaibab NF Land Resource and Management Plans to existing conditions related to forest resiliency and forest function. Where plan information was dated or not explicit, local research and the best available science were utilized. The results of the comparison are displayed in narrative, tables, graphs, and photographs. In summary, there is a need for:

- moving vegetation structure and diversity towards desired conditions by creating a mosaic of interspaces and tree groups of varying sizes and shapes
- moving towards a forest structure with all age and size classes represented as identified in the 1996 forest plan amendment for northern goshawk and Mexican spotted owl habitat
- managing for old age (pre-settlement) trees such that old forest structure is sustained over time across the landscape by moving towards forest plan old growth standards of 20 percent at a forest Ecological Management Area scale
- improving forest health by reducing the potential for stand density-related mortality and by reducing the level of dwarf mistletoe infection
- moving towards desired conditions for vegetation diversity and composition by maintaining and promoting Gambel oak, aspen, grasslands and pine-sage
- moving towards the desired condition of having a resilient forest by reducing the potential for undesirable fire behavior and its effects
- moving towards the desired condition of maintaining the mosaic of tree groups and interspaces with frequent, low-severity fire by having a forest structure that does not support wide-spread crown fire
- moving toward desired conditions in riparian ecosystems by having springs and seeps function at, or near, potential
- moving towards desired conditions for degraded ephemeral channels by restoring channel function
- moving towards restoring select closed and unauthorized roads to their natural condition by restoring soil function and understory species

Laws, Regulations and Policy affecting Fire Ecology, Fuels and Air Quality

National Level Direction

Federal laws, regulations, and policies affecting this project include:

- Executive Order 13112; Invasive Species (64 FR 6183, February 8, 1999). The 4FRI proposes ground disturbing activities, such as mechanical thinning, spring/stream restoration, and prescribed fire which may provide opportunities for invasive species to become established. To comply with this Executive Order, 4FRI would monitor populations within the treatment area, and restore native species and habitat conditions in areas that are invaded.

- Organic Administration Act, June 4, 1897 (16 U. S. C. 551). This act authorizes the Secretary of Agriculture to make provisions for the protection of national forests against destruction by fire. The treatments proposed by 4FRI would support the intent of the Organic Administration Act by reducing the potential for undesirable fire behavior and effects.

- National Environmental Policy Act of 1970. Compliance with this act requires analysis of proposed actions. Proposed treatments include prescribed fire, so an analysis of the effects of prescribed fire as well as the resulting emissions will be included as part of the documents.

- Clean Air Act (CAA), as amended 1977 and 1990. This act provides for the protection and enhancement of national air resources by regulating air emissions from stationary and mobile sources. This law authorized EPA to establish National Ambient Air Quality Standards (NAAQS) to protect public health and welfare and to regulate emissions of hazardous air pollutants. NAAQS were established for specific pollutants emitted in significant quantities throughout the country that may be a danger to public health and welfare. If an area does not meet or "attain" the standards, it becomes a non-attainment area and must demonstrate to the public and the EPA how it will meet standards in the future via a State Implementation Plan (SIP). Section 112 of the CAA addresses emissions of hazardous air pollutants, including smoke from wildfires and prescribed fires. Section 160 of the CAA requires measures "to preserve, protect, and enhance the air quality…" in national parks, national wilderness areas, national monuments, and other areas of special national or regional natural, recreational, scenic, or historic value, some are classified as Class I attainment areas. Implementation of the CAA is largely the responsibility of the states which may develop programs that are more restrictive than the CAA requires but never less. The CAA mandates states have a SIP to regulate pollutants. The 4FRI proposes using prescribed fire on 593,211 acres. To ensure compliance with the CAA, emissions from these acres were evaluated to determine potential effects.

The "1995 Federal Wildland Fire Policy" is the principle document guiding fire management on Federal lands. The Policy was endorsed and implemented in 1995. The 1995 Federal Wildland Fire Policy was reviewed and updated in 2001 (Review and Update of the 1995 Federal Wildland Fire Management Policy, 2001). In 2003 the Interagency Strategy for the Implementation of Federal Wildland Fire Management Policy was approved. The 2003 Implementation Strategy was replaced in 2009 with the adoption of the Guidance for Implementation of Federal Wildland Fire Management Policy which states that:

"Fire, as a critical natural process, will be integrated into land and resource management plans and activities on a landscape scale, and across agency boundaries. Response to wildland fire is based on ecological, social, and legal consequences of fire. The circumstances under which a fire occurs, and the likely consequences on firefighter and public safety and welfare, natural and cultural resources, and values to be protected dictate the appropriate management response to fire."

The Four-Forest Restoration Initiative (4FRI) is not intended to dictate the appropriate response to wildfires. Action alternatives should increase the decision space for Agency Administrators to use fire while reducing the potential for undesirable fire behavior and effects. The effects of planned ignitions (prescribed fires) are discussed. This document provides direction, consistent with the forest plans of the Coconino and Kaibab National Forests regarding the use of planned ignitions in the proposed treatment area.

The 2009 Guidance for Implementation of Federal Wildland Fire Management Policy (USDI BLM 2009) provides the terminology related to fire used in this report. 'Wildland fire' is a general term describing any non-structural wildland fires which are categorized in two distinct types:

- **Unplanned ignitions (wildfire)**. Wildfires are unplanned ignitions, including escaped prescribed fires that are declared wildfires. Wildfires may be ignited by natural causes, namely lightning, or human caused (NWCG 2009).

- **Planned ignitions (prescribed fire)**. Planned ignitions are fires initiated by the intentional initiation of a wildland fire by hand-held, mechanical or aerial device where the distance and timing between ignition lines or points and the sequence of igniting them is determined by environmental conditions (weather, fuel, topography), firing technique, and other factors which influence fire behavior and fire effects (NWCG 2009). "Prescribed fire" include pile burning, jackpot burning, broadcast burns or other wildland fires originating from planned ignitions to meet specific objectives identified in a written, approved, prescribed fire plan for which NEPA requirements (where applicable) have been met prior to ignition (NWCG 2009, FSM 5100).

This report discusses effects of unplanned ignitions, but is not intended to provide any direction regarding the management of unplanned ignitions. Planned management ignitions (prescribed fires) are discussed, and this document is intended to provide direction, consistent with the forest plans of both the Coconino and Kaibab regarding the use of planned ignitions in the treatment area.

State Level Direction

Arizona Department of Environmental Quality (ADEQ) air quality regulations: Smoke produced by prescribed fires is subject to regulation by EPA regulations as enforced by the ADEQ. The State of Arizona has a State Implementation Plan that outlines how the State is implementing the goals of the Clean Air Act, and Statutes that regulate burning, including burning on Federal and State lands. Two types of air quality impacts are addressed by these laws and regulations: health hazards from pollutants, and visibility impacts in Class I Air Sheds.

The key policy resulting from the Enhanced Smoke Management Plan pertaining to prescribed burns in Arizona is Arizona Revised Statute Title 18 Chapter 2 Article 15. This law regulates fires managed on Federal and State lands, as well as on Tribal, private, and municipal jurisdictions where there is a Memorandum of Understanding with the Arizona Department of Environmental Quality (ADEQ). This Statute defines the request and approval process for all burns, and provides the mechanisms for tracking emissions from burns. Enforcement of this statute is facilitated by the Smoke Management Group, housed at ADEQ in the Air Quality Division. Prescribed fires implemented as a treatments under the 4FRI will be subject to these same regulatory policies and statutes and meet the Enhanced Smoke Management Plan. The State of Arizona has an Enhanced Smoke Management Plan (ESMP) that is consistent with the Western Regional Air Partnership (WRAP) Enhanced Smoke Management

Programs for Visibility. The State of Arizona conducts annual meetings of all affected parties to discuss smoke management issues and objectives. This approach calls for programs to be based on the criteria of efficiency, economics, law, emission reduction opportunities, land management objectives, and reduction of visibility impacts. An Enhanced Smoke Management Plan (ESMP) comprises a series of key policies and management practices. In general the ESMP must specifically address visibility effects and apply to all fire sources as do all smoke management plans in the State of Arizona. The ESMP should also apply uniformly to source sectors or be tailored to source sectors and/or geographical areas. In addition, the ESMP must provide the opportunity to work collaboratively with state, tribal, local, and federal agencies, and private parties while considering the criteria of efficiency, economics, law, emission reduction opportunities, land management objectives, and reduction of visibility impact.

Problem or Nuisance Smoke is defined by the Environmental Protection Agency (EPA) as the amount of smoke in the ambient air that interferes with a right or privilege common to members of the public, including the use or enjoyment of public or private resources. While there are no laws or regulations governing nuisance smoke, it can limit opportunities of land managers to use fire. Public concerns regarding nuisance smoke often occur long before smoke exposures reach levels that violate NAAQS (Achtemeir et al. 2001). "Probably the most common air quality issues facing wildland fire managers are those related to public complaints about nuisance smoke...about the odor or soiling effects of smoke, poor visibility, and impaired ability to breathe or other health-related effects. Sometimes complaints come from the fact that some people don't like or are fearful of smoke intruding into their lives (Hardy et al. 2001b)." Prescribed fire treatments proposed though the action alternatives are likely to increase Nuisance Smoke.

Agency Level Direction

USDA Forest Service

Forest Service Manual 5100 (page 9) includes direction on USFS use of prescribed fire to meet land and resource management goals and objectives. The objectives of fire management on lands managed by the USFS are:

1. Forest Service fire management activities shall always put human life as the single, overriding priority.

2. Forest Service fire management activities should result in safe, cost-effective fire management programs that protect, maintain, and enhance National Forest System lands, adjacent lands, and lands protected by the Forest Service under cooperative agreement.

Coconino and Kaibab National Forests' Land & Resource Management Plans (LRMPs)

Forest Plans provide specific goals, objectives, standards, and guidelines for management activities on National Forest lands. The Coconino (USDA 1987, as amended 2012) and Kaibab (USDA 1988, as amended 2008) National Forest has developed forest-wide and location-specific standards and guidelines for reducing the risk of severe fire effects to resources.

The forest plan provides for specific goals, objectives, standards, and guidelines for management activities on the Coconino and Kaibab National Forests. The forest-wide, management area (MA), or geographic area (GA) standards and guidelines referenced in Appendix A have fire-related (management of or reduced risk to resources values from) relevance to this analysis. Directions for other resources aimed at reducing the risk of fire have been incorporated into this analysis as appropriate.

Relevant direction from the 1988 Coconino National Forest Land Management Plan and the 2008 Revision of the Kaibab National Forest Land Management Plan are in Appendix A on page 251.

Alternatives Analyzed

Four alternatives were analyzed and are briefly summarized below.

Alternative A (no action)

Alternative A is the no action alternative as required by 40 CFR 1502.14(c). There would be no changes in current management. Forest plans would continue to be implemented as other NEPA projects are implemented including approximately 82,592 acres of vegetation treatments and 96,125 acres of ongoing prescribed fire projects near, or adjacent to the treatment area. Approximately 86,771 acres of vegetation treatments and 142,869 acres of prescribed fire and maintenance burning would be implemented near or adjacent to the treatment area by the forests in the foreseeable future (within 5 years). Alternative A is the point of reference for assessing action alternatives B-D.

Alternative B

Alternative B would use prescribed fire and mechanical thinning on 388,489 acres and prescribed fire only on 199,435 acres (Table 1). It incorporates comments and recommendations received during an eight-month public involvement period. Alternative B incorporates the key components of the stakeholder-created Old Tree Retention Strategy but does not include the stakeholder-created Large Tree Retention Strategy. Alternative B would use prescribed fire and mechanical treatments in some of the Mexican spotted owl (MSO) protected activity centers (PAC), excluding core areas. On acres proposed for prescribed fire, there would be up to two prescribed fires conducted over the 10 years of this project. Two non-significant forest plan amendments on the Coconino NF and one non-significant forest plan amendment on the Kaibab NF would be required to comply with forest Plans.

Alternative C

Alternative C would use prescribed fire and mechanical thinning on 434,001 acres and prescribed fire only on 159,211 acres (Table 1). Alternative C was developed in response to comments received to the August, 2011 revised proposed action, including Issue #2, Conservation of Large Trees. The key components of the stakeholder-created Large Tree Retention Strategy and Old Tree Retention Strategy are incorporated into the design features, monitoring, adaptive management, and implementation plan of this alternative. It incorporates wildlife and watershed yield research. It proposes more acres of mechanical treatments and prescribed fire than alternative B, and increases the number of MSO protected activity centers that would be treated with prescribed fire, including core areas. Other actions (springs, seeps, ephemeral streams, aspen protective fencing, roads) are similar to Alternative B. About 48,000 acres of mechanical treatments for grassland restoration are included in this alternative. On acres proposed for prescribed fire, there would be up to two prescribed fires conducted over the 10 years of this project. Two non-significant forest plan amendments on the Coconino NF and two non-significant amendments on the Kaibab NF would be required.

Alternative D

Alternative D would mechanically treat (with no prescribed fire) 388,489 acres and dispose of slash, chipping, shredding, mastication, with biomass removed from the site, and use prescribed fire only on 178,790 acres (Table 1). Alternative D was developed in response to Issue #1, Prescribed Fire

Emissions. On any given acre for which a treatment is proposed, there would either be mechanical thinning or prescribed fire, never both. Mechanical treatments would be implemented in a select number of MSO protected activity centers, but none would be treated with prescribed fire. Other actions (springs, seeps, ephemeral streams, aspen protective fencing, and roads) are similar to alternative B. On acres proposed for prescribed fire, there would be up to two prescribed fires conducted over the 10 years of this project. Two non-significant forest plan amendments on the Coconino NF and one amendment on the Kaibab NF would be required to comply with the plans.

Table 1.Summary of those Alternatives that were analyzed in detail

<table>
<tr><th>Proposed Activity (acres)</th><th>Alt. A</th><th>Alt. B</th><th>Alt. C</th><th>Alt. D</th></tr>
<tr><td>Vegetation Mechanical Treatment</td><td>0</td><td>388,489</td><td>434,001</td><td>388,489</td></tr>
<tr><td>Prescribed Fire (all)</td><td>0</td><td>587,923</td><td>593,211</td><td>178,790</td></tr>
<tr><td>Burn Only</td><td>0</td><td>199,435</td><td>159,211</td><td>178,790</td></tr>
<tr><td>MSO PAC Habitat Treatments</td><td>N/A</td><td>Mechanically thin up to 16-inch dbh in 18 PACs (excluding core areas),

Prescribe burn 72 MSO PACs (excluding core areas)</td><td>Mechanically thin up to 18-inch dbh in 18 PACs (excluding core areas),

56 MSO PACs would be treated with prescribed fire including core areas,

16 MSO PACs would be treated with prescribed fire, excluding core areas</td><td>Mechanically thin up to 16-inch dbh in 18 PACs (excluding core areas)</td></tr>
<tr><td>Mechanical grassland Restoration</td><td>0</td><td>0</td><td>48,161</td><td>0</td></tr>
<tr><td>Springs/Seeps Restored (number)</td><td>0</td><td colspan="3">74</td></tr>
<tr><td>Springs Protective Fence Construction (miles)</td><td>0</td><td colspan="3">Up to 4</td></tr>
<tr><td>Aspen Protective Fencing (miles)</td><td></td><td colspan="3">Up to 82</td></tr>
<tr><td>Ephemeral Stream Restoration (miles)</td><td>0</td><td colspan="3">39</td></tr>
<tr><td>Road and Route Decommission* (miles)</td><td>0</td><td colspan="3">904 (This category combines existing roads and unauthorized roads proposed for decommissioning)</td></tr>
<tr><td>Temporary Road Construction and Decommission **(miles)</td><td>0</td><td colspan="3">517 (This category includes temporary roads and previously decommissioned roads that are proposed for temporary construction and decommission when the project is complete.)</td></tr>
<tr><td>Road Reconstruction (miles)</td><td>0</td><td colspan="3">40</td></tr>
</table>

Methodology

To complete a useful analysis of the 4FRI project, potential fire behavior, potential emissions, and fuel characteristics that affect fire behavior and emissions were modeled. Results were analyzed to evaluate the effectiveness of each action alternative against the “No-Action” Alternative. Concepts that are necessary for a thorough understanding of this analysis are discussed briefly in this section or when they are first presented. Additional information may be found in Appendix G.

Metrics

The following five metrics were used to evaluate the effectiveness of the alternative/s in meeting the purpose and need of the project:

1. **Fire Type** in ponderosa pine and most of its associated vegetative communities is a good indicator of the health and resilience of the ecosystem. Crown fire in ponderosa pine produces high severity fire. Desired condition is for less than 10 percent of the treatment area to support crown fire under the conditions modeled. In grasslands, desired conditions are for less than 3 percent crown fire. Types of fire include active crown fire, passive crown fire, and surface fire as described below.

   a. **Active Crown fire:** A fire that advances from crown to crown in the tops of trees or shrubs (NWCG 2008). Active crown fires generally produce high severity effects and are considered 'stand replacing' because they topkill, kill and/or consume most of the dominant overstory vegetation. Active crown fire is linked to surface fire, perpetuated by a combination of surface and canopy fuels.

      i. **Conditional Crown Fire:** Conditional crown fire is a crown fire that moves though the crowns of trees, but is not linked to surface fire. Crown fire must initiate in an adjacent stand and spread through canopy fuels alone. Conditional crown fires burn in areas where canopy base heights are too high for crown fire to initiate within the stand, but there is sufficient horizontal continuity of canopy fuels to carry a crown fire if initiated.

   b. **Passive Crown Fire:** Individual trees or groups of trees 'torch', as fire moves up into the canopy, ignited by the passing front of a surface fire. The fire climbs up ladder fuels (low branches, shrubs, or herbaceous vegetation that can produce flame lengths long enough to allow a fire to 'climb' into the crown of a tree) into the crown of a tree, igniting the crown ('torching' it), but does not spread very far into adjacent crowns (NWCG 2008).

   c. **Surface Fire:** These are fires that burn in surface fuels only. Such fires consume surface fuels such as litter, duff, dead/down woody fuels, and herbaceous or shrubby fuels that are cured enough to be available fuel. Surface fire can be beneficial or detrimental in ponderosa pine, depending on the fuel loading, and the conditions under which the fire burns.

   Fire behavior was analyzed down to the subunit (SU) in order to facilitate a more thorough analysis of specific fire effects to different areas. Fire behavior was also evaluated at the vegetation/habitat level in order to determine potential effects by ecosystem characteristics as well. For example, 100 acres of active crown fire in a 200,000 acre unit may not be considered a problem. If those 100 acres occurred on a 400 acre PAC, that would be more likely to be a concern. Therefore, fire behavior is considered at the project scale (all treatment areas), the restoration unit, and the subunit, as well as the vegetation type/habitat type.

   Roccaforte et al. (2008) showed that, as wind speed is increased in modeling, additional areas of extreme fire behavior are likely to be in the same vicinity. This can identify opportunities to break up larger areas of potential undesirable fire behavior that would show up with more extreme conditions. Given the scale of this project, it was desirable to identify areas most at risk, rather than larger swaths of areas at slightly lesser risk. To that end, fire type was analyzed using the weather parameters from the Schultz Fire. The Schultz Fire was a wind driven fire that burned in 2010 within the EIS analysis area.

Fuel moisture and weather parameters were modeled using readings from the weather station at the Flagstaff airport on June 20th, 2010 (day one of the Schultz Fire, the day that burned the most acres and produced the majority of the high severity fire) (Table 2). These conditions are not extreme, and occur on many days every year. Areas that show crown fire behavior under these conditions represent those areas at greatest risk of undesirable fire behavior and effects.

Table 2. Schultz fire weather conditions used for modeling

Variable	Weather
Maximum Temperature (°F)	77
Minimum RH (%)	14
Maximum Wind speed (20 ft) – miles per hour	25 (steady, not gust)
1 hour fuel moisture (%)	3
10 hour fuel moisture (%)	3
100 hour fuel moisture (%)	6
Direction	200°

Fire behavior for existing conditions was modeled for the project area using default Landfire Refresh 08 data. Results were reviewed by local fire experts (district, forest, National Park Service and non-federal firefighters and managers), and adjustments made to improve model accuracy. The process was repeated to further improve results.

Fire behavior for post-treatment conditions was modeled using FlamMap and a combination of Landfire Refresh 2008 data and FVS-FFE data (LANDFIRE 2010a, LANDFIRE2010b). Post-treatment canopy characteristics and fuel loading were determined using the Fire and Fuels Extension (FFE) (Reinhardt and Crookston 2003) to the Forest Vegetation Simulator, FVS (Dixon 2002).

In fire modeling, outputs (such as fire type and fireline intensity) are determined, in part, by the fuel models used. Post treatment fuel models need to take into account changes in total fuel loading and fuel structure.

Landfire data must be manipulated to produce post-treatment conditions for fire modeling, so outputs from FFE were used to develop post-treatment fuel models. The modeled post-treatment fire behavior data are the result of combined stand data from the Forest Vegetation Simulator (FVS) and Landfire Refresh 2008 data. Post-treatment fire type was modeled by using outputs from FVS-FFE to adjust the percent of change to canopy characteristics and surface fuel loading and to inform the assignation of post-treatment fuel models. Details of the process for assigning post-treatment fuel models for modeling fire type is included in Appendix D.

FVS outputs used were stand averages that were used to give a general idea of what stand conditions would look like, but could not address the spatial distribution of specific metrics on the same scale as the Landfire data. Landfire/FlamMap data are gridded (raster) data, with a resolution of 30 meters. FVS/FFE data is vector based, with smallest units being the size of individual stands. The 'hills and valleys' of the stand characteristics were smoothed out when the stand data were averaged, resulting in the fire behavior also being 'smoothed out' somewhat.

A stand is ‘typed’ as a single vegetation type, though it may have a mix, for example, of pine forest and grassy openings. Habitat types (e.g. core areas, restricted habitat, etc.) were classified at the stand level to facilitate silvicultural analysis. Fire behavior was modeled at the 30 meter scale. The resolution for modeled fire behavior is 30 meters.

Canopy Characteristics and fuel loading

The ability of a forest to maintain its resilience to fire depends, in part, on how close it is to threshold conditions. Canopy characteristics and surface fuel loading combine to produce combinations of surface fire intensity (flame length is a good proxy for fireline intensity – the higher the intensity, the longer the flame length) and physical structure (the height, density, and horizontal and vertical continuity of canopy fuels) that can produce crown fire under a given set of conditions. The closer conditions are to a threshold, the faster it will deteriorate to a point where crown fire is possible.

Reducing canopy fuel loading can increase surface fire behavior because more wind and sunlight can reach the surface, however overall fire behavior is more significant:

> “Modifying canopy fuels as prescribed in this method may lead to increased surface fire intensity and spread rate under the same environmental conditions, even if surface fuels are the same before and after canopy treatment. Reducing CBD to preclude crown fire leads to increases in the wind adjustment factor (the proportion of 20-ft windspeed that reaches midflame height). Also, a more open canopy may lead to lower fine dead fuel moisture content. These factors increase surface fire intensity and spread rate. Therefore, canopy fuel treatments reduce the potential for crown fire at the expense of slightly increased surface fire spread rate and intensity. However, critical levels of fire behavior (limit of manual or mechanical control) are less likely to be reached in stands treated to withstand crown fires, as all crown fires are uncontrollable. Though surface intensity may be increased after treatment, a fire that remains on the surface beneath a timber stand is generally controllable” (Scott 2003).

2. **Canopy Bulk Density (CBD)** for ponderosa pine and pine-oak stands. CBD is a good indicator of potential active crown fire (Stratton 2009, Scott 2003; Keane et al, 2005). The desired condition is for average CBD to be less than 0.05 kg/m^3 in ponderosa pine.

3. **Canopy Base Height (CBH)** is a critical factor in crown fire initiation, and can be used as an indicator of the potential for crown fire initiation (Agee and Skinner 2005, Stratton 2009, Scott 2003). The desired condition is for CBH to be greater than 18 feet in ponderosa pine.

   Canopy Cover (CC), along with CBD and CBH, is an important component for modeling and evaluating potential fire behavior and/or effects, affecting the potential for active crown fire. There are no desired conditions for CC, but the trends shown in modeling, combined with CBH and CBD are a good indicator of the improvement or deterioration of forest health in regard to potential fire type.

   Fuel models (see glossary), used for modeling fire behavior, rarely use measured canopy characteristics. Modeling fire behavior entails ‘gaming’ fuel models, adjusting various characteristics until the modeled fire behavior most closely represents known fire behavior (such as the Schultz Fire). In this manner, canopy characteristics are adjusted by the percentage change indicated by FVS (McCusker, 2012). Canopy characteristics contribute significantly towards the type of fire that can occur (Scott and Reinhardt 2001). CBD, CBH, and canopy cover directly affect the incidence and behavior of crown fires and are used for modeling potential fire behavior (Scott 2003, Scott and Reinhardt 2005, Agee and Skinner 2005).

Stand data were used with FVS (see below) to simulate post-treatment changes for the different alternatives (McCusker 2012). Canopy characteristics were evaluated by desired openness (see Silvicultural Specialists' Report, McCusker, 2012).

The desired conditions are written for silvicultural stand averages and therefore allow for some areas within a stand to be outside of the desired condition range but surrounded by conditions closer to overall desired conditions. For example the desired conditions for crown bulk density (CBD) in ponderosa pine is an average that is below .05 kg/m^3. This could mean that many patches within the stand have much higher CBD but have interspaces between these dense groups of trees where CBD is much lower than .05 and therefore the average for the stand is within acceptable limits. Where CBD is high it is important to also have higher crown base height (CBH) (Nicolet 2012).

4. **Surface fuel loading**. There is no desired condition for surface fuel loading, though it can contribute significantly to fire effects, fire behavior, and emissions production. There is forest guidance for coarse woody debris based on wildlife and soil needs. However, there are additional considerations that contribute either directly or indirectly to meeting desired conditions and forest plan guidance, including fire hazard, reference conditions, and soil heating (Brown et al. 2003, Passovoy and Fulé 2006). In order to allow a wide buffer for modeling error, and variability on the landscape, in this analysis, 20 tons/acre was used as a 'recommended' average maximum for surface fuel loading totals of CWD, litter, and duff.

   Surface fuel loading contributes significantly to fire behavior and effects (both direct and indirect), and can indicate potential high severity effects are likely even if crown fire is not indicated by modeling. Additionally, Coarse Woody Debris >3" diameter (CWD >3"), litter, and duff contribute significantly to emissions. Current forest plans set a narrow range of desired conditions (5 – 7 tons/acre) for CWD >3", but there is no direction regarding litter, duff, or other surface fuel load components. Therefore, in this analysis, CWD >3" litter, and duff were combined as 'surface fuel loading" in tons/acre, and is considered and evaluated both qualitatively and quantitatively regarding potential fire effects.

   Site specificity varies tremendously in fuel loading so recommendations regarding fuel loading must be considered as averages. Litter, duff, and CWD >3" were combined to provide a rough evaluation of the expected effects of surface fuel loading on fire effects. In dry, warm forests of the northwest, a desirable range for CWD >3 inches is between 5 and 20 tons/acre (Brown et al. 2003). Graham et al. (1994), recommended 5 – 13 tons/acre of CWD in ponderosa pine, including sites within the EIS analysis area. Forests in the EIS analysis area are assumed to be slightly warmer and drier than those in the northwest, so slightly lower numbers would apply (Brown et al. 2003, Graham et al.1994). Brown et al. (2003) further recommend that, from a fire hazard perspective, the recommended level of CWD would be lower where there is more than 8-10 tons/acres of small woody debris (<3 inches diameter). Passovoy and Fulé (2006) found that post fire conditions from a number of wildfires, including several within the EIS analysis area, did not exceed these recommendations. Duff loadings of <2.4 tons/acre (~1/2 inch deep) have been considered to be an average that represents historic conditions in ponderosa pine stands with frequent fire. Combining maximum recommended fuel loadings from the Forest Plan (7 tons/acre of CWD); duff loadings of not more than 4.8 tons/acre of duff (to allow for a wide range of conditions) and; up to 5 tons/acre for litter (allowing some decay for the production of ~1.8 tons/acre of litter annually in a healthy ponderosa pine forest that historically burned on average at least once every 5-10 years (see 1st paragraph in Litter and Duff below)), 20 tons/acre seems like a reasonable average for the combined weight of these three components (CWD>3", litter, and duff). It is reasonable to assume that if these three total >20 tons/acre, the potential direct and indirect fire effects could include sufficient heat to increase tree mortality, consume organic matter in the top layers of soil, including living roots, seeds, mycorrhizae, or cause other undesirable fire effects, such as the impacts of emissions on humans and wildlife if those areas burn under conditions that are not optimum for smoke dispersal. While this does not represent a 'desired condition', it can inform a discussion on the potential fire effects from surface fuel loading. This does not specifically relate to wildlife requirements, but includes other fuel loading components and considerations.

FVS data were used to model fuel loading for each alternative for post-treatment (2020) and thirty years later (2050, and assuming no fire or mechanical treatments following 2020).

Litter and Duff

One of the more difficult problems to address in the restoration of a ponderosa pine forest from which fire has been excluded is the accumulation of litter and duff. The frequent surface fires that characterized the historic fire regime would have consumed much of these fine fuels, as well as small twigs and branches every few years. Historically, larger fuels would have been consumed as well, particularly the rotten logs (Covington and Sacket 1984), although herbaceous fuel loading is probably greatly reduced in the contemporary forest (Fulé et al. 1997a). The ratio of larger woody fuels to litter and duff would be very different in a forest that burns frequently than in a forest that burns on a frequency of 20 or more years. A Southwestern ponderosa pine forest can produce up to 1.8 tons per acre of litter annually (Sackett 1996, Biswell et al. 1966). The litter layer contributes to fire *intensity*, while the duff layer contributes to fire *severity,* (Hood, 2008). These layers cannot be addressed by mechanical means across the entire area proposed for treatment under any of the action alternatives, even if it was ecologically sound to do so. Mechanical treatments may move duff and litter around, creating temporary discontinuities in the surface litter layer, but the biomass remains onsite. Decades of fire suppression have allowed litter and duff layers to accumulate to levels that cause a multitude of problems that include direct and indirect fire effects and behavior, effects on soil productivity, interception of precipitation before it can reach the soil, nutrients locked up in organic matter, changes to soil chemistry, emissions, and physically suppressing surface vegetation with a decrease in species diversity (Covington and Sackett 1984, Moir 1988, Abella et al. 2007).

Historically, fine surface fuel loads were made up primarily of herbaceous material. Herbaceous litter is loosely arranged, and fire burning though it would move relatively quickly, with a short residence time and a high rate of consumption. Repeated fires would consume dead/down woody fuels a little at a time, allowing natural recruitment of more from branches or snags to maintain and equilibrium. Currently, across much of the EIS analysis area, surface fuels are dominated by needle litter and duff. Several years to decades of accumulated needle litter is more closely packed than herbaceous fuels, and duff layers still more so. Fire burning through these fuels will have a longer residence time than in herbaceous fuels, and the lower layers are likely to smolder for extended periods, allowing heat to transfer to the soil, roots, and boles of trees. The longer residence time is also likely to consume a greater portion of dead/down fuels in a single fire. Additionally, litter and duff, when combined with Coarse Woody Debris, produce the majority of emissions.

Fire naturally regulates the pattern and density of seedlings, a necessary ecological function that cannot be duplicated by mechanical thinning operations**.** Needle litter accumulating under larger trees can provide sufficient fuel in just a few years to prevent germination or seedling survival when it burns (Cooper 1961), naturally regulating the pattern and density of seedlings as they regenerate following thinning or fire, and creating a natural, sustainable mosaic.

Litter and duff cones have accumulated around the base of many large and/or old trees in the project area (Figure 1) and are likely to cause undesirable mortality if they burn under some wildfire conditions (Eagan 2011) and some prescribed fire conditions. The 'duff cone' under the tree in Figure 1 has built up because of a lack of fire. If it burns under extreme conditions (very hot and very dry), the heat may be sufficient to damage or even kill the tree, although large trees may take 2-3 years to die.

Prescribed fire can produce fire behavior that is less likely to cause lethal damage. These fuels cannot be effectively treated by mechanical methods across the ~600,000 acres proposed for treatment. In areas where litter has accumulated, it affects how fires burn. Fungii often colonize layers of old needles, decreasing their flammability under all but the driest conditions, often in dense thickets of pine or the lower layers of the deepest litter. This may affect the mosaic fire creates when it burns. When fire burns though these areas, most of the fungi are destroyed, so needles that fall after the fire aren't likely to become infected, and the next fire can burn with higher intensity and will consume a greater amount of surface litter (Sackett and Haase 1998). When deep layers of duff do burn, they generally have long residence times, conducting excessive heat into the soil if they burn completely. Duff that does not burn acts as an insulator and duff that does burn acts as a conductor (USDA 2005). Conversely, litter that has accumulated for just a few years, will burn almost completely, and quickly, with little detrimental impact from heat (Garlough and Keys 2011, Covington and Sackett 1992, Sackett and Haase 1998).

Figure 1. Duff cone under ponderosa pine in Restoration Unit 6

Fire Regime/Condition Class (FRCC) is an ecological evaluation protocol developed to support planning and risk assessments, particularly in regards to fire (Barrett et al. 2010, Hardy et al. 2001, Schmidt et al. 2002, Hann et al. 2004). It is a largely a qualitative measure using three classes for describing the relative degree of departure from reference conditions, particularly in regards to fire regimes. Acres in FRCC 3 are at high risk of losing key ecosystem components in the event of a disturbance, such as a fire. Acres in FRCC2 are at a moderate risk. FRCC1 acres are within their historic range of condition. The desired condition is for the treatment area to be in a Condition Class 1(Table 3). This method of evaluation was originally developed for use at a large scale to facilitate landscape-level planning, because ecosystem trends are not always discernible at smaller scales. In this assessment, it will be used only at the landscape scale.

Fire Regime/Condition Class Software Application Version 3.0.3.0 (Havalina et al. 2010) was used (NIFTT 2010) to evaluate changes to FRCC for each alternative. Inputs included average fire frequency and average fire severity for both reference conditions and for the condition being analyzed. For ponderosa pine, the Biophysical Setting (BpS) used was Ponderosa Pine (Colorado Plateau) (PPIN5) because all of the ponderosa pine in the analysis area is on the Colorado Plateau and this BpS best described desired conditions for ponderosa pine in the treatment area. For grasslands, the BpS used was Mountain Grasslands with Trees (MGRA2). Reference fire frequency, severity, and percent of seral stages were compared with modeled post-treatment data to determine FRCC for the ponderosa pine and grasslands for each alternative (details in Appendix D).

Table 3. Condition classes (adapted from Schmidt et al. 2002)

	Departure from historic Fire Regime
Condition Class 1	Fire regimes are within historical ranges. Risk of losing key ecosystem components is low. Vegetation attributes are intact and functioning within historical ranges.
Condition Class 2	Fire regimes moderately altered from historical range. Risk of losing key ecosystem components is moderate. Fire frequencies have departed from historical ranges by one or more return intervals. This has resulted in moderate changes to one or more of the following: fire size, intensity, severity, and/or landscape patterns. Vegetation attributes have been moderately altered from their historical range.
Condition Class 3	Fire regimes significantly altered from historical ranges. Risk of losing key ecosystem components is high. Fire frequencies have departed from historical frequencies by multiple return intervals resulting in dramatic alterations to: fire size, intensity, severity, and landscape patterns, and/or vegetation attributes.

Fire Regime/Condition Class (FRCC) was calculated for ponderosa pine and grassland areas in the proposed treatment area using acres of crown fire as modeled with Schultz Fire conditions as a surrogate for severity in ponderosa pine and severity/encroachment in grasslands. In ponderosa pine, a true FRCC1 would include dominance of old and/or large trees, and it would take more than 20 years, whatever the treatments applied, to move areas lacking in large and/or old trees to a Condition Class 1. It is not possible to evaluate the number of large, old trees, vs. large trees, so a crosswalk was developed to using VSS classes from the Silvicultural database (McCusker 2012) as surrogates for the BpS seral stages (details in Appendix D). Fire return intervals were determined by using the initial calculated fire return intervals and adjusting them to the proposed treatment area, as described above.

FRCC was analyzed at the project area scale for ponderosa pine and grasslands because they make up 90 percent of the project area. The 4FRI was intended to focus on ponderosa pine, which occupies the majority of the treatment area. No treatments of any kind were model from 2020 to 2050 so, there is a shift ‘down’ a class for many acres, though not back to pre-treatment levels. The data that were used for this assessment distinguished by size class rather than age, so FRCC1 acres are probably overestimated a bit.

Scales of analysis

This analysis is classified in three ways; size, vegetation/habitat, and treatment type.

1. Size. In order of decreasing size, with the largest first:
    a. **EIS analysis area:** The area that was evaluated for the first 4FRI EIS (Figure 2).
    b. **Project Area**: 988,764 acres that were analyzed to identify areas with the greatest need for change. It includes the 'core' area of ponderosa pine in the EIS analysis area, and well as aspen, oak, pinyon/juniper, and grasslands. Acres having special designations (Wilderness, Special Interest Areas, state/county/private etc.), or covered by other planning efforts were only included in Cumulative Effects Figure 2.
    c. **Treatment area**: The footprint of the treatments proposed for each alternative. If used in a context that is not specific to an alternative, the area referenced is the maximum area (593,211 acres) for which treatments are proposed.
    d. **Restoration Unit (RU)**: Restoration Units are divisions of the EIS analysis area delineated by roads or natural barriers. RUs range from 43,578 acres (RU6) to 165,803 acres (RU4). RU2 had so few acres of ponderosa pine available for treatment that the team made the decision to exclude it from this analysis (Figure 2).
    e. **Subunit (SU):** Subunit s are divisions of Restoration Units and are delineated primarily by roads and 6th level watersheds. There are 19 SUs, ranging from 3,870 acres (SU6-4) to 81,541 acres (SU4-4) (Figure 2).
2. **Vegetation/habitat type:** This scale of analysis discusses the expected effects of proposed actions to a specific vegetation or habitat type. These are sometimes small areas on the landscape (such as aspen at a total of ~1,500 acres), but have greater ecological and/or social values than some of the larger areas, or have different legal requirements (such as those relating to the Mexican Spotted Owl).
3. **Desired Openness:** This is an indication of the relative desired post treatment interspace/tree group condition. For example, 'High', indicates a more open condition, with a mosaic of groups and interspaces. 'Very Low (Core Areas)' indicates a more closed condition with very few discernible interspaces (McCusker, 2012).

Data sources and models

The models and data listed below were used as described for modeling potential fire behavior and effects. More detailed descriptions are in Appendix C.

FRCC Software Version 3.0.3.0 – this software automatically computes FRCC at various scales, generating reports with the percent and acres in each of Condition Classes 1, 2, and 3. For this analysis, it was used to determine FRCC for ponderosa pine and grasslands within the project area (Havalina et al. 2010).

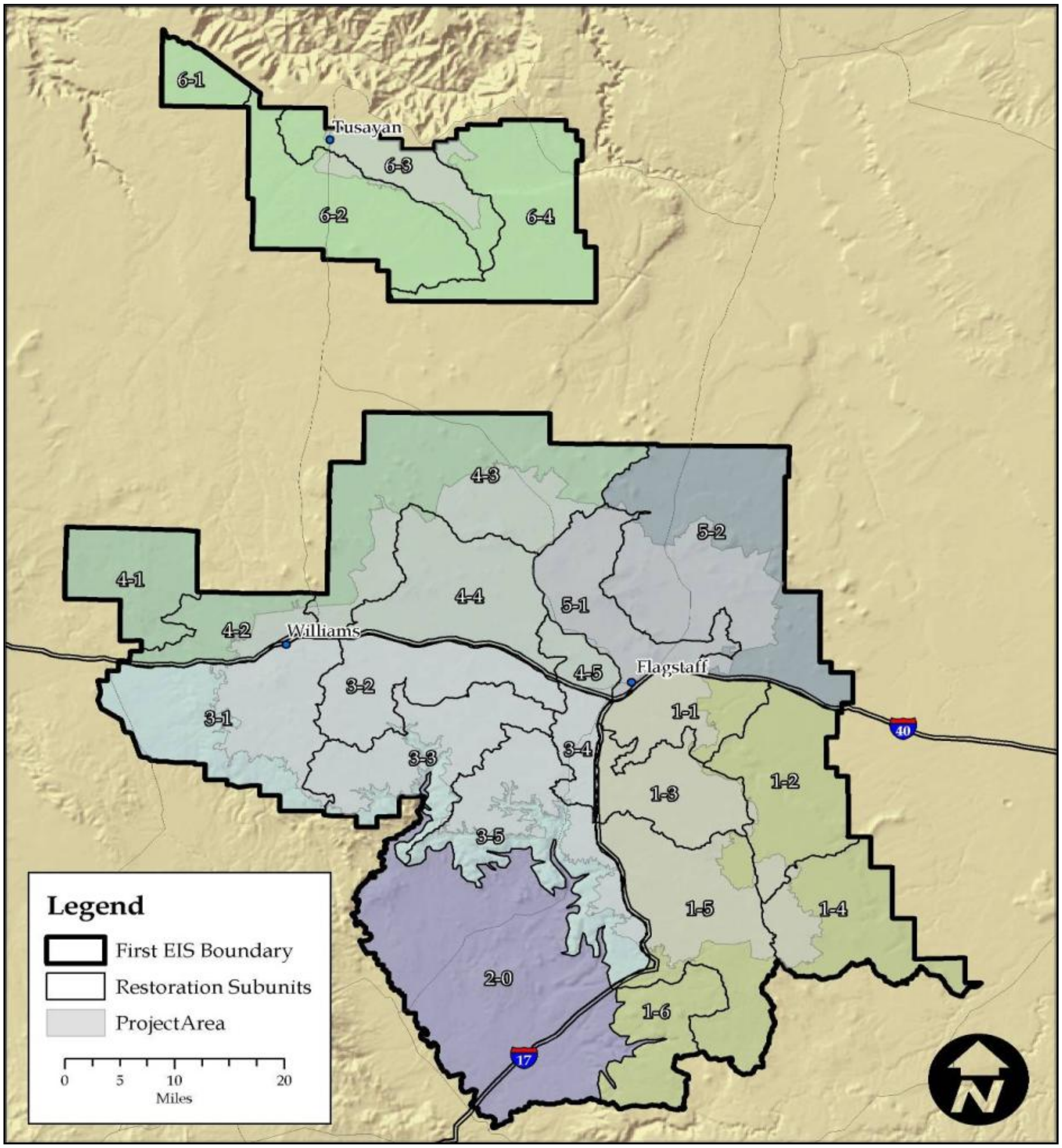

Figure 2. The EIS area showing the project area, restoration units, and subunits

Farsite – Used to generate input files for wind, fuel moisture, and weather, as well as for making adjustments needed for calibrating landscape (.lcp) file layers. These files were then loaded into FlamMap to model potential fire type (Finney 2004).

FireFamilyPlus – Used to determine what the percentile weather (Appendix C) was during the Schultz Fire using data from the Flagstaff Remote Automated Weather Station (RAWS).

FlamMap – FlamMap was used to model fire type (Finney 2006). Scott and Burgan(2005) fuel models were used to model fire type relative to each management alternative.

Forest Ecosystem Restoration Analysis Project (ForestERA) generated spatial data – ForestERA produced spatial layers that were used to update the fire type data to reflect vegetation/fuels changes that occurred between 2008 and August of 2010 (ForestERA 2010).

Forest Vegetation Simulator – Fire/Fuels Extension (FVS-FFE) – The Fire and Fuels Extension (FFE) to the Forest Vegetation Simulator (FVS) links models of fire behavior, fire effects and fuels loading to tree growth metrics (Reinhardt and Crookston 2003). For more details on the FVS-FFE modeling, see the Silviculture Specialists' Report (McCusker 2012). Used to produce post-treatment stand data that was used to model fire type, FRCC, fuel loading, and CBH/CBD.

Landfire – LANDFIRE products are designed to be used at a landscape-scale in support of strategic vegetation, fire, and fuels management planning to evaluate management alternatives across boundaries (LANDFIRE 2010). Landfire is the only existing source of the type of data needed for this type of analysis that is consistent across ownership boundaries.

Stand data – Input data for running FVS-FFE (McCusker 2012).

Emissions Modeling

Air impacts are felt and measured by the concentration of emissions at a given location, be it a town, a house, or an air quality monitor. There are no reliable methods of predicting concentrations at specific locations years in advance of a prescribed fire. This analysis does not attempt or pretend to predict the actual total emissions that would be produced under each alternative. Rather it aims to present a rationale for which alternatives are likely to produce "less" or "more" emissions. It assumes that, over time, there is some degree of correlation between total emission production, and total air quality impacts. Impacts are measured and evaluated based on the concentration of emissions at a specific location, not the total amount of emissions. Though meteorological conditions vary immensely by time of day, time of year, and from one weather system to the next, over the course of years the averaging effect over time of these varying conditions supports a correlation between total emissions and total impacts (Kleindienst 2012).

Smoke/emissions were evaluated both qualitatively and quantitatively by modeled emission quantities in pounds/acre for the most common stand condition under different treatment scenarios. Additionally, changes in those fuel components which produce the greatest percentages of emissions when they burn were modeled, and mapped. These include litter, duff, and CWD>3 inches. Canopy fuels were no modeled to allow for a more accurate comparison because, while canopy fuels can make up the bulk of the initial burst of emissions from a crown fire, they are not a significant contributor in prescribed fires.

Emissions were modeled with the First Order Fire Effects Model (FOFEM) for a group of stands that represent one of the most common conditions on the landscape. These conditions have some of the highest emissions potential of all stands within the proposed treatment area.

Concepts applied to analysis

An understanding of some concepts is important for understanding the details of this analysis. Some are summarized below. More details and additional information can be found in Appendix g.

Fire Regime

A simple definition for 'fire regime' describes the role fire plays in an ecosystem. Fire interacts with other disturbances, such as insects, drought, wind and other weather related events to create spatial and temporal patterns that maintain an ecosystem within a certain range of conditions. Table 4 describes the classifications of fire regimes most commonly used (Havalina et al. 2010, adapted from

FRCC 2010 Guidebook, page 15). Note: 'severity' is not a reference to mortality, though there is often a correlation (see discussion, next section). Over 90 percent of the treatment area historically was a Fire Regime 1 or II, with some aspen and PJ that is more likely to be Fire Regime III, IV or V.

The cumulative impacts of frequent, low severity surface fires can be difficult to identify after just one or two fires. However, the fire *regime* is what maintains an ecosystem, not just one or two fires, and the fire *regime* has a profound influence on ecosystem dynamics, including tree seedling dynamics, low and mid-level canopy structure dynamics, understory plant species diversity and mosaics, nutrient cycling and other soil properties, plant growth, the diversity of vertebrate and invertebrate fauna, and many other ecosystem properties including (Swetnam and Baison, 1996).

Across the 4FRI landscape, the disruption of the Fire Regime by fire suppression over the last century, has been largely responsible for the deteriorating health of the ecosystems within the project area. Evaluating the departure from the natural fire regime was part of the process used to determine FRCC for the project area. Data used to calculate the FRCC is located in Appendix D of this report.

Table 4. Frequency and severity characteristics of fire regime groups and applicable areas

Group	Frequency	Severity	Severity Description	Vegetation types that would be affected by treatments proposed under 4FRI
I	0 – 35 years	Low/ mixed	Mostly low severity replaces less than 25% of dominant overstory vegetation. May include mixed-severity fires that replace up to 75%	In pure ponderosa pine, pine/oak, and savanna ponderosa pine is the dominant species, so the severity of a burn is related to the fire effects on the pine.
II	0 – 35 years	Replacement	High severity replaces greater than 75 percent of dominant overstory (grasslands).	Grasslands. The herbaceous layer (grasses and forbs) are the dominant species. Greater than 75 percent of these are generally topkilled by a fire, so it is considered high severity.
III	35 - 100 years	Mixed/ low	Generally mixed-severity; may also include low severity fires.	Mixed conifer falls into this category. Mixed conifer is not being treated under 4FRI, but its adjacency means it may affect or be affected by 4FRI treatments (see cumulative effects).
IV	35 - 200 years	Replacement	High severity.	Aspen often falls into this category.
V	200+ years	Any severity	Any severity may be included, but mostly replacement severity; may include any severity with this frequency	Much of the Piñon/Juniper (PJ) falls into this category, though there are different types of PJ systems and the fire return intervals vary.

Fire Return Interval (FRI)

FRI is a characteristic of a fire regime that can be quantified based on spatial and temporal data. It is the average length of time between fires for a given area. Across the project area, the desired FRI would be 10 years, though it would vary somewhat between the southern and northern portions of the project area. FRI is one of the inputs used to determine FRCC (see Appendix D).

Maintenance Fire Return Interval

There is evidence that shows that a FRI that is longer than what is generally considered historical, desirable or natural can maintain a relatively open, crown-fire resistant forest structure (Fulé and Laughlin 2007, Fulé 2011 personal communication, Covington 2011 personal communication), although other components of the area, such as species composition, would be affected. A 'maintenance' FRI does not represent a fully restored ecosystem; it represents a minimal level of fire that is needed to keep woody growth and fuel loading below a level at which they are likely to produce undesirable fire effects and behavior (including controlling woody species encroachment into grasslands). In the project area, this is a larger and more immediate problem than unnatural understory vegetative components because of the potential results of uncharacteristic fire in these areas. It is not intended to represent an FRI that would maintain historic habitat/plant communities. Its true range will vary with precipitation, masting years, and the coincidence of growing conditions with cone/seed production. Some level of maintenance with surface fire is critical to retaining open forest conditions and relatively low crown fire hazard into the future (Roccaforte et al 2008).

Fire Intensity versus Fire Severity

Fire intensity and fire severity are often confused, though both are commonly used in descriptions of fire regimes. Fire severity is used to determine FRCC and in evaluating the desirability of a fire's effects. Fire intensity was used as one input to determine which parts of the project area are currently at the greatest risk of undesirable fire effects and behavior (see Appendix D). Fire intensity is a *quantitative* measure of fire behavior. Fire severity is a *qualitative* evaluation of the effects of a fire as produced by the heat pulse on the biotic and abiotic components of an ecosystem (Keeley 2009).

Flame length is a good surrogate for fireline intensity. Above the flames of the surface fire in a forest, there is a zone within which foliage will be scorched and killed by hot gasses rising from the flames. To die by cambial damage alone, a tree must be girdled, and any fire intense enough to girdle a large tree is usually intense enough to scorch all of its foliage as well, even without any crown fire (Figure 3). Death follows quickly from complete crown scorch in ponderosa pine, but may take several years following girdling (Van Wagner 1973).

Figure 3. Lethally scorched trees from a high severity, low intensity surface fire. Note the lack of crown fire.

Crown fire is always high intensity fire, but high intensity fire is not always crown fire. A low intensity fire that is creeping slowly across a forest floor that has decades of accumulated fuels may produce high severity effects because the residence time is sufficient to allow lethal levels of heat to transfer into the soil, tree and shrub cambiums, and roots/seeds/biota in the upper layer of soil (Valette et al. 1994, Lata 2006). When a fire burns on the surface of a forest with a closed canopy, even with low to moderate intensity fire that does not crown, sufficient heat can build up under the canopy to lethally scorch trees.

Historically, in healthy ponderosa pine forests of the southwest, low severity surface fires were prevalent, passive crown fire occurred under some conditions, but active crown fire was rare (Cooper 1960, Covington and Moore 1994, Fulé et al. 2003, Moir and Deterich 1988). Evaluation of severity for existing conditions was based on fire type, surface fuel loading, and vegetation type.

Affected Environment

Existing and Desired Conditions

Existing and desired conditions are discussed as follows:

1. Background and history of the 4FRI area
2. Fire behavior at the treatment area scale
3. Potential fire behavior by vegetation type
4. Within Restoration Units and Subunits, fire behavior is broken out by vegetation/habitat types
5. Canopy characteristics and fuel loading and how they affect fire behavior, fire effects and air quality are presented by desired openness
6. Fire Return interval/FRCC by treatment area
7. Air Quality

Historic conditions affecting the 4FRI analysis area

In the latter part of the 19th century, unsustainable practices in fire management, grazing, and logging began to change spatial and temporal patterns on the landscape, as well as the structure and composition of landscape components. These practices combined to shift ecosystems within the project area out of their Natural Range of Variability, so that ecological functions are now impaired across the landscape of northern Arizona (Leopold, 1924, Heinlein et al. 2005, Covington et al. 200, Fulé et al. 1997c).

The typical climate of the project area includes an adequate, annual amount of moisture for good vegetative growth and conditions favorable for frequent early summer fires (Harrington and Sackett 1992). Winters are relatively mild, averaging a little above 30° F, and precipitation (as snow) saturates the soil (Schubert 1974). Rainfall minimums occur in May and June, with some areas receiving less than 0.5 inches. The spring dry season is accompanied by increasing air temperatures, low humidity, and persistent winds, and is broken in early to mid-July with development of almost daily thunder and lightning storms; July and August are the wettest, warmest months. A second dry season occurs in the fall. This climatic pattern is particularly conducive for development of a pine-grass savanna maintained by frequent surface fires (Dahms et al. 1997).

Historically, both lightning and human-caused fires, once started, could burn until extinguished by rain, or until they ran out of fuel (typically when they reached an area that had recently burned). Fires could burn for months and cover thousands of acres (Swetnam 1990, Swetnam and Baisan 1996). As a result, most ponderosa pine in the southwest burned every 2 to 22 years as low-severity, often area-wide fires. The disruption of historical fire regimes by introduced ungulates has been well documented for southwestern ecosystems. Montane grasslands were utilized as summer range for large numbers of sheep and cattle (Leopold 1924). Grazing removed much of the fine fuels that competed with pine seedlings for water, nutrients and light and allowed surface fire to regularly recycle nutrients, scarify seeds, reinvigorate shrubs, and thin seedlings/saplings. This unintentional fire suppression, initiated in the early 19th century through grazing by sheep and cattle, transitioned in the early 1900s to active fire suppression through the construction of fire lines and roads in the mid-20th century. By the early 1900s, fire exclusion had begun to alter ecosystem structure and fire regimes in Northern Arizona (Covington et al. 1994). Settlers saw fire as a threat, and actively suppressed it whenever they could. Fire exclusion was very successful initially, but subsequent accumulation of fuels, through litter-fall and logging debris accumulation, and development of ladder fuels that are capable of conveying surface fires in to the crowns and canopies of forests (Covington et al. 1994) made fire suppression more difficult. Initially, fire suppression was very successful because of low fuel loadings, open forests with high canopy base heights that did not support crown fire, surface fuel loading composed of some needle litter, but mostly grasses/forbs – often overgrazed. Without fires to consume them, pine litter accumulated over time, and the character of the fuels changed from light flashy fuels that supported low severity surface fires, to compact needle litter and duff and dead/down woody debris. This changed the character of the fires as well, allowing less frequent fires that had more fuel to burn at once when they did burn, putting more heat into the soil, and increasing crown fire. Fire suppression allowed seedlings and saplings to survive that would have naturally been thinned out by fire. The disruption of fire regimes is likely to be an important variable in the composition of vegetative communities. Uncharacteristically long periods without fire may allow species to become established that could not under the historic fire regime (Swetnam, 1990).

As Europeans settled into the area, roads and trails broke up the continuity of forest fuels and further contributed to reductions in fire frequency and size (Covington and Moore 1994). Logging removed much of the large tree component across the landscape, allowing younger and smaller trees to survive in unnaturally dense stands. Concerted efforts with fire brigades, ground crews, and air tankers, functioned as the primary mechanisms for excluding fire from southwestern forests (Covington and Moore 1994, Swetnam and Baisan 1996).

Logging, grazing, and fire suppression are the primary factors that, when combined, have allowed landscape patterns to become homogenized, shifting fire regimes across much of the project area from frequent, low-intensity/low severity surface fires to infrequent, high-intensity/high severity crown fires. In addition to being a primary cause of the decline of healthy ponderosa pine forests, woody species have encroached into grasslands and savannas, and conifer encroachment is contributing to the decline of aspen.

Across the treatment area, desired conditions include landscape patterns (temporal and spatial), and composition and structure of the components of pine, pine/oak, aspen, pinyon/juniper, and grassland systems that support healthy ecological functions across the landscape. Fires would maintain and enhance, but not degrade habitat for listed, rare, and sensitive species. Fires would recycle nutrients stored in duff, litter, and vegetation, including dead, down woody debris. Aboveground biomass would not be present in amounts that intercept inordinate amounts of precipitation, preventing it from reaching mineral soil. Fires would prevent woody encroachment into grasslands and savannas and contribute to the health of aspen. Smoke and heat from fire would scarify seeds and promote a diverse herbaceous vegetative community and help limit infestations such as mistletoe to acceptable levels (Alexander and Hawksworth 1976, Abella 2009).

Across the treatment area, the desired condition would allow the use prescribed fires to supplement unplanned ignitions, producing an average annual Fire Return Interval (FRI) in the ponderosa pine of no more than 20 years, with a 10 year FRI being preferred unless monitoring indicates a change is warranted. The FRI the southern end of the project would average less than 10 years because the higher precipitation produces faster regeneration and growth (Puhlick et al. 2012), while the northern, drier portion of the project area could go for 20 – 30 years, depending on environmental conditions affecting fuel accumulations, regeneration, and initial condition (Fulé and Laughlin 2007). Across the treatment area, forest conditions would allow for the use of fire as addressed in the land and resource management plan. Frequent surface fires would rarely move up into tree crowns and, when crown fire did occur, it would be passive crown fire, limited to the tree or the group within which it started. Restored sustainable fire regimes, from a combination of planned and unplanned ignitions, would regulate landscape structure, pattern, and composition, aligning forest changes with climate changes.

Currently, the size and extent of high severity fires are much larger than historic data indicates was typical of ponderosa pine in the southwest (Swetnam 1990, Covington and Moore 1994; Swetnam and Betancourt 1998, Westerling et al. 2006) and, while the number of fires reported in and adjacent to the project area has decreased over the last 40 years, the average size has increased (Figure 4). Figure 4 shows the results of a query of reported fires using FireFamilyPlus including those districts of the Coconino and Kaibab National Forests south of the Grand Canyon that are largely ponderosa pine. These fires include some PJ and some mixed conifer, but are primarily ponderosa pine.

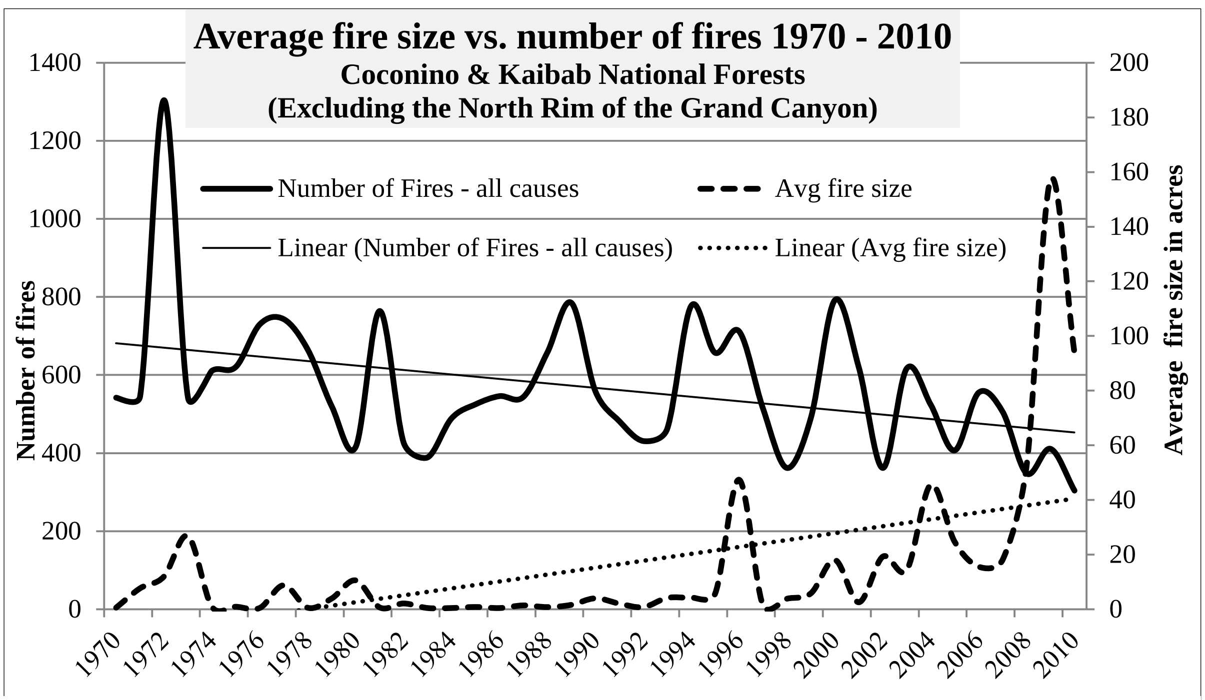

Figure 4. Wildfires on the Coconino and Kaibab National Forests by size and number of fires

Areas of high severity fire have detrimental impacts that extend far out from the actual burn itself, both temporally and spatially. The degree of the effects depends on the slope, proximity, and extent of the area of high severity. Such fires can remove most surface cover all at once, consuming decades of accumulated surface fuels in one fire. Instead of just top-killing vegetation that would normally resprout or scarify seeds, these fires can kill plants and incinerate all or most organic matter in the top inches of soil, including the seed bed and fine roots, affecting the potential for vegetation recovery.

These high severity fires can consume enough soil organic matter and nutrients that it becomes difficult for soil-stabilizing plants to take root, leaving the surface soil layers vulnerable to erosion. In addition to the destruction of soil-stabilizing components, hydrophobic soils, and the associated debris flows and floods may permanently change the potential of the source site because of the loss of surface soils, while having severe, long term effects on downstream, downslope, and adjacent areas, regardless of whether or not they burn. These surface layers of soil are essential to natural vegetative communities and, when removed from the site (by erosion), can take hundreds or thousands of years to recover, effectively changing the site potential.

Current conditions inhibit the survival and recruitment of large trees through competition and threaten the maintenance of ecological systems by fueling increasingly extensive crown fires. These fires have the potential to alter the successional trajectories of post-burn vegetation, creating entirely different communities than those existing before such events (Savage and Mast 2005, Kuenzi et al. 2008, Strom and Fulé 2007). Figure 5 displays dense forest conditions (numerous trees with dense, contiguous canopy fuels) that are common within the project area and would support active crown fire. Even without crown fire, high intensity surface fire burning though this area could do enough damage to trees to cause widespread mortality (VanWagner 1973).

Figure 5. Dense canopy conditions that would support crown fire (Coconino NF, 2010)

Fire models show that, in its existing condition, potential fire behavior in the proposed treatment areas includes 202,902 acres (34 percent) of crown fire, of which 25 percent (149,362) is active crown fire (Figure 6).No fire” acres includes areas on which there were insufficient fuels to carry fire, including water, rock, cinders, areas of sparse vegetation, etc.

Wildland urban interface (WUI) areas are spread across the EIS analysis area, though areas of the greatest concern are relatively focused, Flagstaff, Williams, Doney Park, Munds Park, Kachina, Tusayan, Parks, Belmont and scattered developments within or adjacent to the project area (see Cumulative Effects). Fuel treatments have been, and continue to be implemented in WUI closest to major population centers, but much of the landscape is still vulnerable to undesirable fire behavior and effects, including changes in site productivity, loss of critical habitat, flooding, erosion, weed infestations, damaged infrastructure, and the longer term effects of having thousands of acres of dead trees nearby for decades. Other areas of concern include water resources, such as the Lake Mary watershed and Oak Creek. The Lake Mary watershed includes Upper and Lower Lake Mary, and is a source of water for the city of Flagstaff, as well as being a popular recreation site. Oak Creek itself, though it is mostly outside the project area, is surrounded by restoration units 3-4 and 3-5, is a popular recreation site, and there are dozens of homes along Oak Creek (Figure 6 and Figure 7).

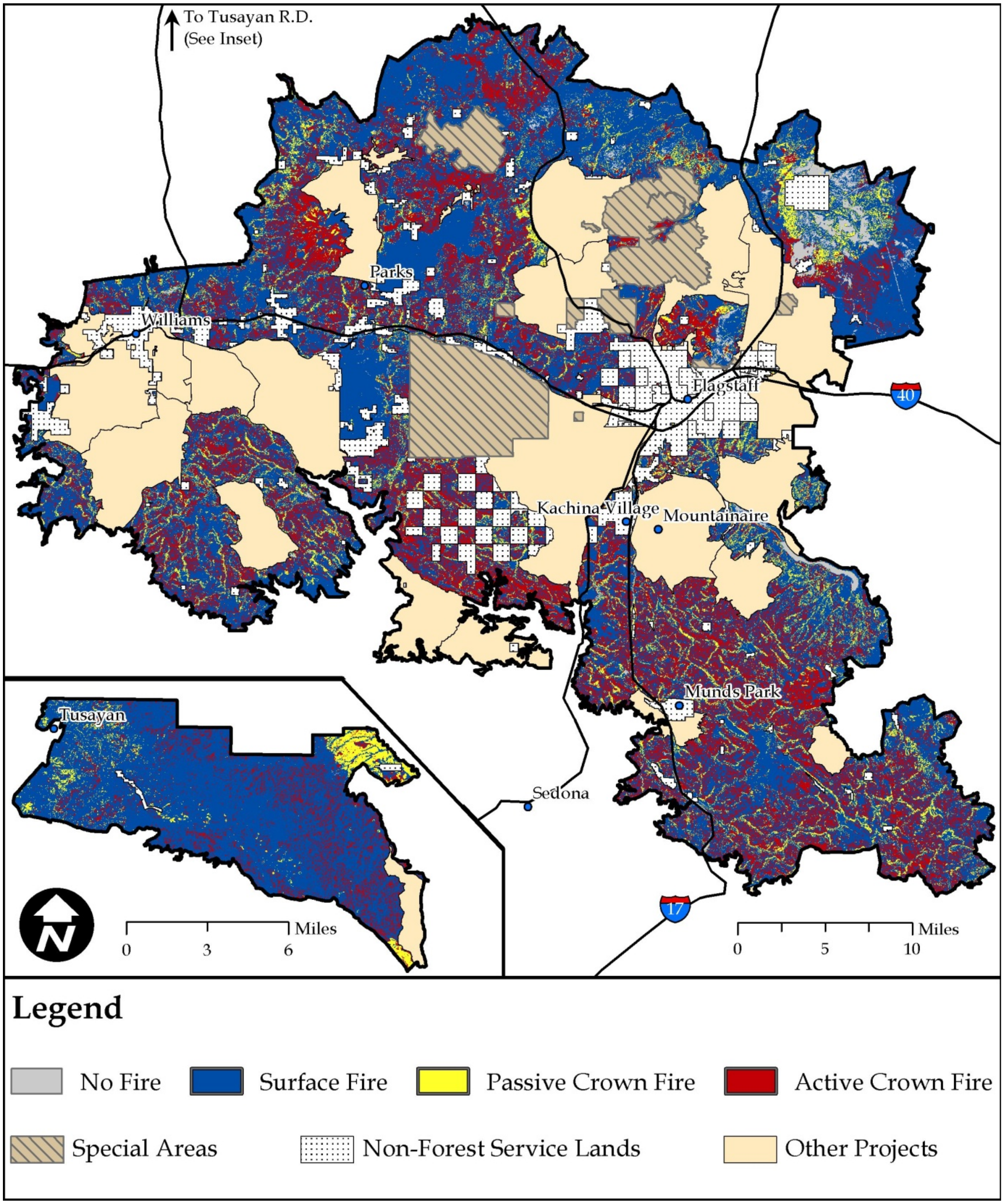

Figure 6. Modeled fire type for existing condition

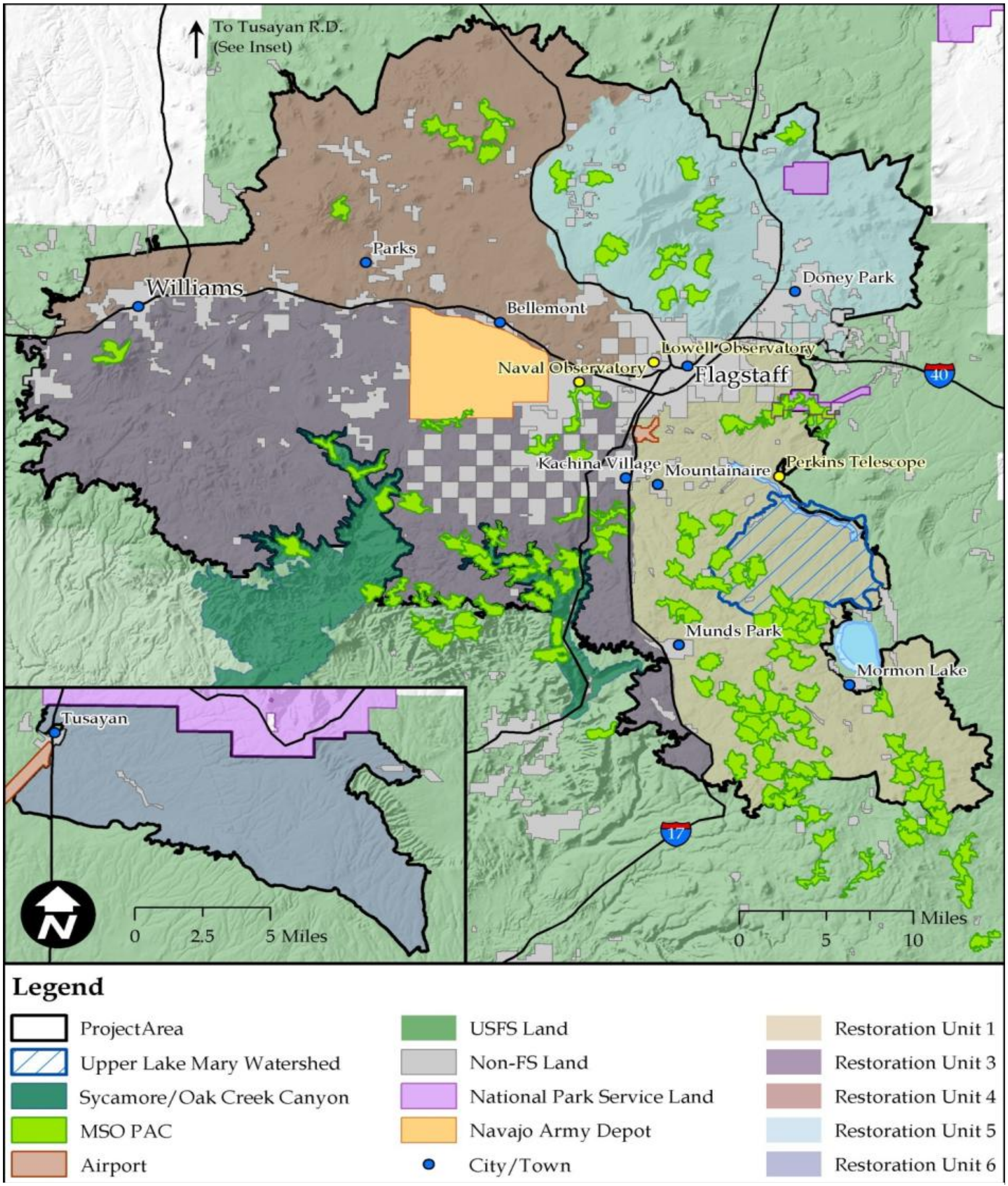

Figure 7. Some of the resources at risk in the Project Area

Ponderosa Pine

The denser and younger stand structures of the historic ponderosa pine forest were the result of special circumstances in the interaction of climate, site, and disturbances. Even though ponderosa pine reproduction was negligible in some years, there were occasional wet cycles as long as 15 to 20 years without fires when ponderosa pine could regenerate (Swetnam and Dieterich 1985). The regeneration cycle required seed production, establishment, and survival to an age at which the young tree could successfully compete and endure surface fires. In the historic period, most large trees were killed by lightning fires, dwarf mistletoe, bark beetles, windthrow, or senescence. When single or small groups of trees died and fell, they were inevitably consumed by surface fires. This more severe, but localized, fire produced mineral soil seedbeds, reducing grass competition, and creating a favorable microsite for establishment (Cooper 1960). Within these severely burned microsites with little competition and fuel, seedlings could survive, grow, and develop their competitive ability and resistance to fire. Note the lack of crown fire and the increase in canopy base height (with a corresponding decrease in canopy bulk density) in Figure 8. Figure 8 illustrates the variability in fire effects even within a relatively small area. In Figure 8, most of the seedlings were left untouched. In Figure 9, most were killed. Both photos were taken one year post-Wallow fire about 100 feet apart in an area that supported only low severity fire that was highly beneficial to the system.

Figure 8. Post-Wallow Fire variability in seedling survival

Open stands of ponderosa pine under a frequent fire regime are capable of supporting a contiguous understory of herbaceous fuels, up to 1,600 pounds per acre in frequently burned stands. These high levels are the result of surface fires which increase nutrient cycling and reduce competition from woody reproduction. Frequent, surface fires kill small trees, but most grasses and forbs survive, and large trees escape damage because of their high crowns and thick barks (Biswell et al. 1973).

Although fires would have burned at higher intensities during drier, warmer, windier conditions, they would have produced primarily low severity effects in southwestern ponderosa pine forests (Swetnam and Baison 1996) (see page 27 for intensity and severity). These processes, along with soil types, aspect, topography, and other physical geographic features, contributed to heterogeneous spatial patterns at all scales, with some patterns shifting through time within a natural range of variability (Allen et al. 2002). Numerous documents (e.g. Biswell et al.1973, Brown and Davis 1973, Cooper 1960) refer to historic ponderosa pine stands as open, park-like, and with a vigorous and abundant herbaceous understory. Captain Sitgreaves in 1854 describes an apparently typical ponderosa pine scene where "the ground was covered with fresh grass and well- timbered with tall pines" (in Dahm et al.1997). Photographic and written records of historic forest conditions and archaeological reconstructions suggest that the characteristic vegetation was a grass matrix with individuals, groups, and stringers of large and variously-sized trees of almost exclusively ponderosa pine.

Figure 9. Post-Wallow Fire variability in fire effects to seedlings

An area now within the Coconino National Forest is described in a U. S. Geological Survey (1904) report as: "A yellow-pine forest, as nearly pure as the one in this region, nearly always has an open growth, but not necessarily as lightly and insufficiently stocked as in the case in this forest reserve. The open character of the yellow-pine forest is due partly to the fact that the yellow pine flourishes best when a considerable distance separates the different trees or groups of trees. It is very evident that the yellow-pine stands, even where entirely untouched by the ax, do not carry an average crop of more than 40 per cent of the timber they are capable of producing. The yellow-pine forest in the reserve is, broadly speaking, a forest long since past its prime and now in a state of decadence. Apparently there has been an almost complete cessation of reproduction over very large areas during the past twenty or twenty-five years (due mostly to sheep use), and there is no evidence that previous to that time, it was at any period, very exuberant "(in Dahms et al. 1997).

Although the popular early descriptions of the ponderosa pine forest call attention to the park-like stands, there are also descriptions which refer to dense cover (Woolsey 1911 in Dahms et al. 1997). An accurate picture of the pre-settlement ponderosa pine forest would most likely describe a mosaic not only with an open, grass savanna and clumps of large, yellow-bark ponderosa pine, but also with a few dense patches and stringers of small, blackjack pines (young ponderosa pine). Ponderosa pine naturally regenerates rarely, but then reproduces with an overabundance of seedlings and a high rate of juvenile mortality (Pearson 1931).

Ponderosa pine has many fire-resistant characteristics. Even seedlings and saplings are often able to withstand fire. The development of insulative bark, meristems shielded by enclosing needles, and thick bud scales contribute to the heat resistance of pole-sized and larger trees. Propagation of fire into the crown of trees pole-sized or greater, growing in relatively open stands (dry sites), is unusual because of three factors. First, the tendency of ponderosa pine to self-prune lower branches keeps the foliage separated from burning surface fuels. Second, the open, loosely arranged foliage does not lend itself to combustion or the propagation of flames (compare this with the dense, foliage of spruce or fir). Third, the thick bark is relatively unburnable and does not easily carry fire up the bole or support residual burning. Resin accumulations, however, can make the bark more flammable and may occur if trees have been fighting off insects, or sustained damage such as broken branches or deep abrasions on the bole. Understory ponderosa pine may be more susceptible to fire damage where crowded conditions result in slower diameter growth. Such trees do not develop their protective layer of insulative bark as early as do faster growing trees. They remain vulnerable to cambium damage from surface fires longer than their counterparts in open stands. The thick, overcrowded foliage of young stands or thickets also negates the fire-resisting characteristic of open, discontinuous crown foliage commonly found in this species. Ponderosa pine seedling establishment is favored when fire removes the forest floor litter and grass and exposes mineral soil. Fire resistance of open, park-like stands is enhanced by generally light fuel quantities of flashy fuels. Heavy accumulations of litter at the base of trunks increase the intensity and duration of fire, often resulting in a fire scar or "cat face" when a fire does burn through the area and that part of the bole next to the fuel accumulation is subjected to more heat. Flammable resin deposits around wounds can make an individual tree susceptible to fire damage and can enlarge existing fire scars.

Extensive stand-replacing fires are unreported in the documentary records prior to circa 1950 (Cooper 1960, Allen et al. 2002). There are few data available to indicate how much high severity fire was typical across the ponderosa pine in northern Arizona, but simulations suggest that presettlement forest structure would have supported none to very little crown fire, passive or active (Roccaforte et al. 2008, Covington 2002). Ponderosa pine does not sprout, so crown fire generally produces 100 percent mortality (high severity). Historically, passive crown fire produced only small patches of high severity effects. Extrapolating results from Roccaforte et al. (2008) to those conditions used for modeling 4FRI, patches of high severity, in the form of passive crown fire, would have been no more than 50 acres under those conditions modeled for 4FRI. This could occur in areas with windthrow, disease/insect infestation, area ecotones between ponderosa pine and mixed conifer or PJ, or other site specific situations that would allow crown fire initiation. Modeled historic conditions in Southwestern ponderosa pine indicate that as much as ~17 percent may have supported active crown fire under extreme conditions (high temperatures, high winds, and low humidities) (Roccaforte et al. 2008), with none under conditions close to those modeled for this analysis. Frequent surface fires, combined with competition from abundant grasses and other understory plants, maintained an open structure.

Ideally, the average Fire Return Interval would average 10 years (Weaver, 1951, Cooper, 1960; Fulé 2003, Heinlein et al. 2005, Diggins 2010), across the project area with the vast majority of acres burning with low severity surface fire. In the project area, a 20-year maintenance Fire Return Interval (almost doubling the historic Fire Return Interval) should be the maximum,with most areas burning more frequently under current climate conditions. Twenty years would be an average across the ~600,000 acres proposed for treatment. However, differences in soils and precipitation produce much more rapid growth of seedlings and saplings on the southern part of the Coconino National Forest (COF) (Figure 10) than on the Kaibab National Forest (KNF), particularly restoration unit 6. Therefore, the maintenance return interval for the southern COF should be shorter than for the KNF. A delay of more than 20 years between fires or treatments, areas currently showing potential for passive crown fire could potentially transition to potential active crown fire. On the south rim of the Grand Canyon (adjacent to restoration unit 6), fire has been observed to burn with low severity, thinning regeneration and keeping the system open with significantly more than 20 years between fires where forest conditions are close to historic conditions (Fulé and Laughlin 2007). Diggins et al. (2010) also showed that, under some scenarios, 20 years would be an acceptable fire return . Other evidence shows that an interval of more than 10 years may not be sufficient, if fire is the only tool and mechanical treatments could increase the longevity (Strom and Fulé 2007). The condition of the forest at the start of the maintenance interval is important, with healthier, more open forests in dry areas able to go longer without fire without supporting extensive high severity fire when it does burn.

Figure 10. Regeneration in the Clear Creek Watershed on the southern Coconino NF

In the ponderosa pine across the treatment area, current crown fire potential is shown below in Table 5. Ponderosa pine is a Fire Regime 1 (fire return interval <35 years, and <25% high severity). However, data specific to the project area and ponderosa pine in Arizona indicate a more frequent fire return interval and a lower level of severity is appropriate, particularly under the conditions modeled. Desired conditions for ponderosa pine in the project area are for no more than 10 percent of the ponderosa pine (under conditions modeled) in the treatment area to be prone to crown fire or high severity fire, with high severity acres spatially distributed (Cooper 1962, Swetnam and Baison 1996, Roccaforte et al. 2008).

Table 5. Modeled fire type in ponderosa pine and savanna by restoration unit (RU)

Existing Condition (acres/%)*	RU 1	RU 3	RU 4	RU 5	RU 6	Totals
	146,037	129,225	134,301	61,730	41,188	512,481
Surface fire	81,276/56	72,734/56	83,435/62	42,304/70	33,675/82	313,423/61
Passive crown fire	15,967/11	12,629/10	10,614/8	7,104/12	2,219/5	53,540/9
Active crown fire	48,300/33	43,227/33	39,806/30	8,532/14	5,247/5	145,113/28

Table 6 represents potential fire behavior for ponderosa pine and savanna, as modeled under moderate (Schultz) fire conditions across the treatment area. In the ponderosa pine, 37 percent (198,653 aces) of the treatment area currently has potential for crown fire, with 28 percent (145,113 acres) of it being active crown fire.

There are no desired conditions relating to fire behavior for ponderosa pine habitat classified as Protected, Target/Threshold, Restricted, or PFA/ dPFA/ nest stand, however, these areas show crown fire potential ranging from 51 percent (Target/Threshold) to 39 percent (PFA/ dPFA/ nest stand) across the treatment area (Table 6). Crown fire in MSO habitat is unlikely to maintain key habitat components (Noble, 2012).

Table 6. Modeled fire behavior for ponderosa pine by habitat type for existing conditions

Vegetation Type		Fire Type	Existing Condition	
			Acres	Percent
Ponderosa Pine	**All Pine**	Surface	313,423	62
		Passive crown	48,523	10
		Active crown	145,113	29
	Protected	Surface	18,610	51
		Passive crown	3,141	9
		Active crown	14,847	41
	Target/ Threshold	Surface	4,292	49
		Passive crown	926	11
		Active crown	3,479	40
	Restricted	Surface	35,465	53
		Passive crown	6,608	10
		Active crown	25,187	37
	PFA/ dPFA/ nest stand	Surface	18,737	62
		Passive crown	2,952	10
		Active crown	8,756	29
	Landscapes outside of PFAs	Surface	236,320	65
		Passive crown	34,896	10
		Active crown	92,844	26

Pine/sage

Desired conditions are to maintain and enhance the sage understory and restore the historic overstory/understory pattern within the pine-sage mosaic. There are few sources that describe this association. One that does is the Terrestrial Ecological Survey (Brewer et al. 1991). According to the survey, there are approximately 16,064 acres found in RU6 with potential vegetation that could include both ponderosa pine and big sagebrush. Monitoring on the KNF identified primarily *Artemisia tridentata* var. (big sage), and monitoring at the adjacent Grand Canyon National Park identified *A. nova* (black sage), though it was far less common than big sage (GRCA 2011).

There are no baseline data available that represent current conditions within the project area though, based on the ecology of the species present and a 1991 survey (Brewer et al. 1991), some assumptions can be made. The desired condition for the sage component of the pine/sage community is a shifting mosaic of sagebrush with a mix of age classes which is regulated primarily by fire. Fire scar analysis that included ponderosa pine on one of the soil four types that support pine and sage indicated an average fire return interval of roughly seven years for surface fires (Huffman et al. 2006). A study that included one of the four soil types suggests that ponderosa pine density has increased substantially since 1887 (Huffman et al. 2006) on an area within RU6 that included one of these soil types. As far as we have knowledge of the system, we can assume that very frequent fire suppresses big sagebrush establishment, while long fire return intervals promote tree invasion into big sage communities (outside of drainages).

Data from the Grand Canyon (GRCA, 2011) show that populations of big sage respond better to fires that occur from July through December, and average stem counts from burns at all times of the year may recover to pre-burn levels within 5 - 10 years (Figure 11). Figure 11 summarizes data from the south rim of the Grand Canyon. Out of 41 plots, 5 were unknown severity, 2 were moderate/low severity, 1 was moderate/high severity, and 33 were low severity (GRCA 2011).

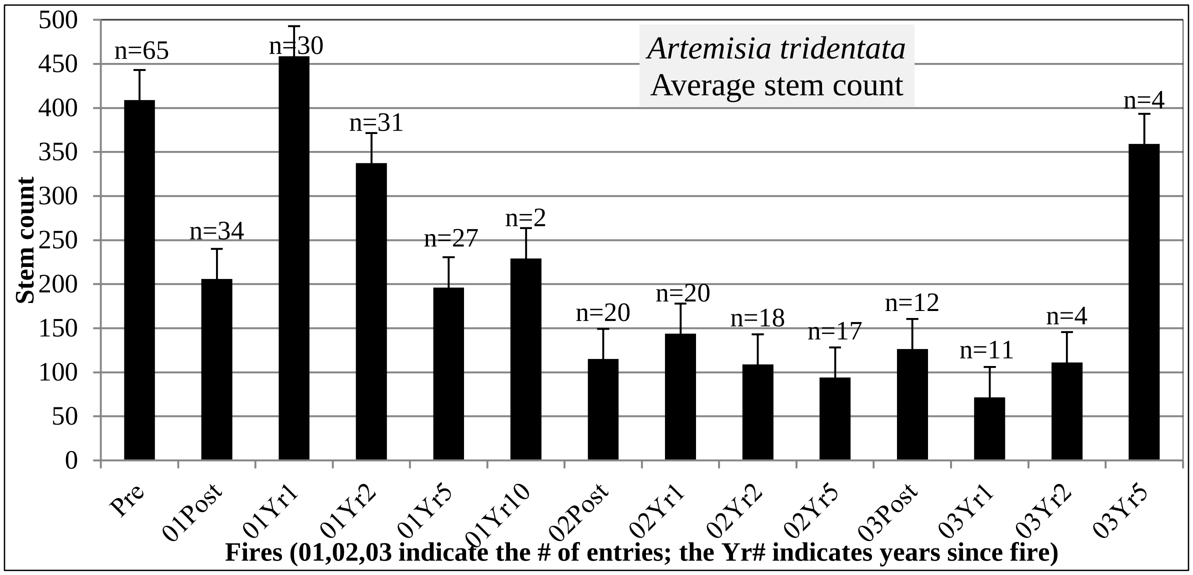

Figure 11. *Artemisia tridentata* pre- and post-burn average stem counts, all age classes

It should be noted that 'n' for 03YR2 and 03Yr5 n is only 4. Time between the 1st and 2nd entry burns averaged 6.5 years, and time between 2nd and 3rd entry burns was 7.9 years. As with many plants, survival appears to be highly dependent on other factors such as pre/post precipitation, temperature, and humidity. Pine-sage provides valuable habitat for several species of wildlife including migratory birds. Shrub species that co-occur with sage, providing further diversity include Fendler's ceanothus, snakeweed, and Gambel Oak, as well as three species that are rare in this PPC, including mountain mahogany, bitter brush, and Oregon boxleaf.

Currently, sage cover under ponderosa pine varies from ~2 percent cover[1] where it burned with high intensity surface fire, or where it has been shaded out by pine to well over 35% cover in areas where fire has been excluded (Figure 13).

In the context of the TES Survey Brewer et al. (1991) used 'canopy cover' as criterion describing the relative dominance of each species, of potential productivity, of the influence of plants on precipitation interception and soil temperatures, and of the value of vegetation to animals.

Figure 12. Post-treatment pine/sage east of Tusayan

Figure 12 displays a condition that is sustainable approximately 6 years after a low intensity prescribed fire. Sagebrush and pine are both present in various age classes, along with a diversity of other vegetation and an herbaceous layer. This image shows the scarcity of fine, herbaceous fuels within the sagebrush clumps, allowing only minimal fire to impact the sage

under most conditions (Tisdale and Hironaka 1981 in McArthur and Taylor 2004).

Figure 13 shows a current condition that is either out of the Historic Range of Variability, or a late seral stage for this pine/sage association. If it is within the HRV, this would represent a late seral stage, with sage outcompeting other shrubs, and ponderosa pine saplings not yet shading it out. The primary contiguous fuel is needle litter, which would do minimal damage to sage unless there was a wind. A moderate to high intensity fire burning with a moderate to strong wind at the right time of the year would be required to kill enough trees for fire alone to reset the area in to an earlier seral stage. There are insufficient data to determine if this is a late seral stage, or if this is out of the historic range of variability.

Large/old trees

Large/old ponderosa pines within the project area are threatened by the increasing size and severity of wildfires. Across the west, the increasing severity of wildfires and the ensuing death of large/old ponderosa pines has been linked to fuel accumulation resulting from a century of fire exclusion (Covington et al.1997, Haase and Sackett 1998; Sackett et al. 1996). Some of these fuels are deep duff and organic soil layers at the surface. When they burn, they burn by smoldering combustion and,

Figure 13. Pine/sage at either a later seral stage, or out of the Historic Range of Variability

although temperatures are lower than in flaming combustion, residence times are much longer so more heat is transferred (Hartford and Frandsen 1992). These low intensity fires can cause root and basal stem injury by consuming fine roots growing in the duff layer and through long-term heating of the soil and cambium at the tree base (Hungerford and others 1994, Ryan and Frandsen 1991).

Crown damage (scorch) is thought to be the most important factor in the mortality of old trees that are attributed to fire (Fowler and Sieg, 2004). The proximity of dense young trees and ladder fuels is problematic because it is so wide spread. Figure 14 shows a large ponderosa pine that was killed because it was at the head of a deep draw that was choked with dense young pines. When the fire came up the draw, it wasn't all crown fire (as can be seen by the red needles remaining on the trees on the right side of the photo), but the heat was sufficient to cause the large tree to 'torch'.

The desired condition for large/old trees would be low levels of surface fuels (litter, duff, organic soil, CWD) in the immediate vicinity of old trees, and no ladder fuels sufficiently close for flame impingement should the ladder fuels ignite. This would decrease potential fire-caused mortality in large and/or old trees. Currently, across much of the project area, fuel loads of all kinds in the immediate vicinity of large and/or old trees are such that mortality would be high in the event of a wildfire burning under undesirable conditions.

Aspen

The desired condition for aspen is to maintain and/or regenerate existing aspen stands or clumps. Fire has been a fundamental, necessary, beneficial disturbance in aspen of the western US for hundreds of years (DeByle 1985, Amacher et al. 2001, Strand et al. 2009, Margolis et al.2011).

Figure 14. Large ponderosa pine near Lockett Meadow 3 months after the Schultz Fire (2010)

The unique fire ecology of aspen (i.e. its' high sensitivity to fire and its ability to vigorously re-sprout following even high severity fire) supports this theory, and aspen is highly competitive on burned sites, with multiple adaptations for fire. Thin bark with little heat resistance means it is easily top-killed by fire but, fire triggers physiological changes that initiate sprouting for several years following fire, while removing canopy shading (aspen is not shade tolerant). Combined with profuse sprouting for several years after a fire that topkills an aspen tree, this strategy is effective. Following fire, the decrease in surface albedo increases soil temperature and effectively increases the length of the growing season, and the rate of growth (Hungerford 1988). Combined with a flush of nutrients, suckers are stimulated to grow quickly following a fire. This allows them to quickly reach a height which makes them competitive for sunlight, furthering the survival of suckers, and allowing them to out-compete most other woody species (Amacher et al. 2001).

The fire regime in aspen varies from ~10 to ~150 years (Jones and DeByle 1985, DeByle et al.1987; Strand et al. 2009, Margolis et al. 2011), with fire limiting conifer encroachment and rejuvenating decadent stands. Fire in aspen stands varies from low severity surface fire to mixed or high severity, with vigorous suckering a common response of the species (DeByle et al. 1987). Aspen can appear in dense thickets after infrequent moderate to high severity fire, even if only a little aspen was apparent before a fire (Jones and DeByle 1985) (Figure 15).

Stable aspen is considered to be "properly functioning" and "self-replacing" (Bartos 2001). In many instances, these clones exist with a "skirt" or "fairy ring" of young regeneration around the edge and numerous larger stems in the interior. The stems are a various ages resulting from pulses of

Figure 15. Aspen and bracken fern in a high severity area one year after the Wallow Fire

regeneration that occurred at various times in the past. Increased shading towards the center of such clones would decrease the flammability of the center, so the outer ring would continue to sucker and resprout as it periodically burned. Aspen succeeding to conifers are responding to natural forces. Some of these forces (primarily fire) have been altered by human intervention, which has given shade-tolerant conifers a marked advantage (Bartos 2001). In most aspen stands ladder fuels are absent or only moderately present, in the form of conifers or shrubs. Fuels generally consist of herbaceous material, fallen leaves, downed timber, and any shrubs or conifers that may be present. These fuels are not in a condition to burn as frequently as those in adjacent grasslands or ponderosa forest. When conditions are dry enough in aspen stands with ladder fuels of conifers or shrubs, the abundance, chemistry, and vertical distribution of the fuel may favor a hot fire with rapid spread. Aspen are the most flammable in the fall.

Based on evidence of repeated surface fire in aspen on south aspects of the San Francisco Peaks, it is likely that the present stand structure for some clones, dominated by >20 m tall, mature aspen stems (>120 years old) may be in part an artifact of fire exclusion. These fire-sensitive aspen stems would have been historically exposed to frequent fires, thus the same stands likely looked very different in the nineteenth century. One hypothesis is that they were smaller diameter aspen “thickets” that were top-killed and regenerated after each fire (Allen 1989 in Margolis et al. 2011). Alternatively, some larger diameter stems at the center of the stand may have been protected from being girdled by fire, creating a multi-cohort age and stand structure.

Aspen in the entire EIS analysis area have been declining since at least the late 1990’s. The decline has been attributed, at least in part, to changes in the frequency and intensity of both fire and ungulate grazing (DeByle 1985, Amacher et al. 2001, Fairweather et al. 2007). Many stands now have decadent stems and conifer encroachment (Figure 16). Fire would have been the dominant disturbance, along with some ungulate browsing and some blow-down of decadent stems. Moderate browsing has some, but not all, of the same effects as fire but, as with fire, when it is too frequent, it is detrimental to the health of the stand (Amacher et al. 2001, Fairweather et al. 2007).

Currently, aspen stands, as delineated in the FVS data (McCusker 2012) have some of the highest surface fuel loadings of CWD so that, in the event of a wildfire mature stems would be top-killed and, though in most areas aspen would be expected to sucker quickly following fire, in small, highly stressed stands, fires could be more detrimental than beneficial.

In Figure 16 note the decadent stems on the right of the photo. Fire would have killed most of the encroaching pine, consumed some of the decadent aspen (snags and dead/down stems), and stimulated suckering. Management strategies include mechanically cutting encroaching conifers, and implementing prescribed fire at levels of intensity that would be site-specific, depending on the condition of the stand/s being burned.

Figure 16. Aspen northwest of San Francisco Peaks with the beginnings of pine encroachment

Gambel Oak

Within the project area, Gambel oak occurs as the dominant component of a woodland and as a component of Pine/Oak.

The oak woodlands community consists of Gambel oak thickets containing various diameter stems, and low-growing, shrubby oak. Some areas contain oak trees with relatively large hollow boles or limbs. When present, coniferous trees are widely scattered and are frequently mature or old. Within the project area, oak woodlands generally occur at elevations between 6,000 and 8,500 feet. There aree no desired conditions for Oak Woodlands.

Where Gambel oak is a component of Pine/Oak, it is likely to be the only deciduous tree in otherwise pure southwestern ponderosa pine forests, adding diversity to these forests. Some of the stands have a large enough component of Gambel oak to be considered pine-oak habitat for the Mexican Spotted Owl (as described in the forest plan and MSO Recovery Plan). As with pure ponderosa pine forests, pine-Gambel oak forests have become altered since Euro-American settlement in the late 1800s, so that current conditions are outside of the historic range of variability (Abella 2008a, Abella and Fulé, 2008a). Frequent fire was part of the historic environment, with historic fire return intervals averaging less than 10 years (Abella and Fulé 2008b). Fire exclusion has contributed to a shift in oak densities, with multiple studies indicating there have been increases in small-diameter oak and basal area since Euro-American settlement in the late 1800's (Abella 2008a, Fulé et al 1997a). The majority of this increase, however, is from small and medium-sized stems, and a more simplified forest structure (Abella 2008).

Pre-settlement conditions may not be realistic to try to replicate, but densities of small-diameter oak could be reduced and surface fire eventually reestablished for restoring oak to within a range of historical variability (Abella 2008a).Oak management strategies within this project includes conservation of all existing large, old oaks, maintaining a variety of growth forms and managing for densities similar to the range of variability of oak's evolutionary environment.

In the project area, Gambel oak generally occurs as a tree or a large, open shrub (Figure 17). In most situations, Gambel oak resprouts vigorously the 1st growing season following fire (Ffolliott and Gottfried 1991, Kunzler and Harper 1980, Brown 1958). If successive fires occur at this stage, Gambel oak stands may be reduced to a grass-forb stage (Crane, 1982, Mitchell 1984). As sprouts continue to grow, natural thinning occurs, adding dead stems to the fuel. Fire occurring at this stage may send Gambel oak stands back to a seral grass-forb stage. In absence of high to moderate severity fire, sprouts form young poles. Pole-sized growth forms may be self-thinning in younger clumps (Abella 2008b). At this stage fires are stand replacement, either creating openings within stands for colonization by resprouts or a complete recycling back to a grass-forb stage.

Figure 17. Pole-sized clone of Gambel oak on the Tusayan Ranger District (Restoration Unit 6)

In the absence of high severity fire, Gambel oak stands reach maturity in 60 to 80 years. Fire response in mature stands is similar to that in young poles. A severe fire will recycle the stand; low-severity fires create openings for resprouts. Under extreme burning conditions, dense understories of Gambel oak may serve as ladder fuels that carry fire to overstory tree crowns, increasing fire risk to ponderosa pine, but this is not common. The form of Gambel oak that dominates the oak of the Mogollon Rim is rarely the shrubby type that is found further east, but is most often of a small tree form and rarely produces crown fire. Differences in litter, soil, and species composition beneath Gambel oak as compared with ponderosa pine are well documented. Compared to pine litter, oak litter is looser, less resinous and with moisture, potentially resulting in lower fire intensity near boles (Abella and Fulé 2008). Large oaks have high ecological and aesthetic value (Abella and Fule 2008a) but were often cut because they were highly prized as firewood and building. In Figure 17, the stump to the left of center, and the absence of other stumps or large trees in the immediate vicinity indicates open conditions probably existed when this clone became established.

Although there are no data specific to crown fire in Gambel oak, and mortality is often likely from surface fire effects, there is insufficient data available to determine what surface fire levels are detrimental. Therefore, the effectiveness of treatments to oak was evaluated on the same severity scale as for ponderosa pine, assuming that oak should have less than 10 percent crown fire. Fire modeling shows crown fire in Gambel oak woodlands across the proposed treatment area at 23 percent (Table 7).

Table 7. Modeled fire type for Existing Conditions for oak woodland

Vegetation	Current fire type	Percent
Oak Woodland	Surface	77
	Passive crown	8
	Active crown	15

Grasslands

Desired conditions for grasslands are to restore grassland conditions where there is potential, and to enhance historic grassland inclusions within greater forested areas. Little is known about the pre-settlement condition of grasslands within the project area (Smith and Schusman 2007). Ecological processes were disrupted by domestic grazing years before anyone began to study the flora of the area (Leiberg et al.1904, Allen 1984 in Smith and Schusman 2007).

Frequent fires were the primary disturbance that maintained grasslands, killing young woody encroachment, such as conifer seedlings (Finch, 2004). Fire exclusion permits this encroachment, and grassland acreage has decreased (Arno 1985, Gruell 1985). Most grasslands in the project area are subject to invasion by woody vegetation, (Figure 18) and fire is acknowledged to be the most influential force in checking tree invasion or encroachment (Bond and Keeley, 2005, Kozolwski and Ahlgren 1974, pgs.164 – 168, Archer et al. 2000, Allen 1984 in Smith et al. 2007). It is difficult to reconstruct specific fire regimes in the grasslands themselves because there is no hard evidence left, such as tree rings. However, reasonable extrapolation can be made by observing the rate of encroachment, the response of the grassland to fire, and by extrapolating from fire studies on adjacent lands. Over the years, airborne particles deposited on the leaves are washed to the surface below trees, increasing nutrients. Needle litter also affects soil properties, influencing what can grow there. Droppings from birds and other critters may carry seeds into the area, attracted by trees. Multiple studies have been done on fire return intervals in ponderosa pine sites that are near or immediately adjacent to these montane grasslands (Weaver 1951, Cooper 1960, Swetnam 1990, Swetnam and Baison 1990, Fulé et al.1997a, Fulé et al.1997c, Heinlein et al. 2005, Diggins 2010). These grasslands, have drier microclimates than forested areas and, with an annual accumulation of highly flammable fuels, it can be assumed that they burned as frequently as surrounding forest types. These fires would have killed most young seedlings, and top-killed most shrubs and aspen (Allen 1984 in Smith et al. 2007).

Soil types can be used as a surrogate to estimate what tree densities and dominant vegetation was historically (Abella et al. 2011). Mollisols and mollic intergrade soils indicate grasses and herbaceous vegetation were present for hundreds to thousands of years, although tree cover may have been present as well, generally less than 10 percent on mollisols and 10 – 30 percent on some mollic intergrades (USDA 2007, USDA 2006). Soil surveys indicate that over 50 percent of the treatment area is dominated by soils that would have supported grassland vegetation or very open forests with less than <30 percent tree cover (Stienke 2012).

Figure 18. Woody regeneration in a grassland opening near San Francisco Peaks, Nov, 2011

Soil conditions are likely to shift with woody encroachment. Once established, woody plants alter soils and microclimate in their immediate vicinity to affect both pool sizes and flux rates of nutrients. The result is the formation of 'islands of fertility'. Archer et al. (2001) described three general mechanisms have been proposed to account for this: (1) woody plants act as nutrient pumps, drawing nutrients from deep soil horizons and laterally from areas beyond the canopy, depositing them beneath the canopy via stem flow, litter fall and canopy leaching; (2) tall, aerodynamically-rough woody plant canopies trap nutrient-laden atmospheric dust which rain washes off the leaves and into the soil beneath the canopy; and (3) woody plants may serve as focal points attracting roosting birds, insects and mammals seeking food, shade or cover. These animals may enrich the soil via defecation and burrowing. For these reasons, soil carbon and nitrogen pools should increase subsequent to woody plant colonization in grazed grasslands (Archer et al. 2000).

Fire suppression activities probably became effective in montane grasslands around 1930, judging by the success of tree invasions (Figure 19 and Figure 20) (Allen 1984, Moore and Huffman 2004).

USFS definitions for grasslands suggest that there should be less than 10 percent tree cover. It can be assumed that in a healthy grassland, the trees representing the 10 percent cover would not all burn at once, having withstood multiple fires so that crown fire would not readily initiate. They would have matured only after becoming somewhat fire resistant, by having low intensity fires kill off the lower branches and developing thick bark. However, because there can be some trees in a grassland, there could sometimes be some crown fire in trees. This could occur in areas where there has been no fire for several years and seedlings became established, providing ladder fuels that allowed fire to climb into the crown/s of some of the trees representing the <10 percent tree cover, though it is unlikely that all the trees would burn at once. Therefore, desired conditions include potential crown fire in only a small portion of the 10% tree cover in grasslands. This analysis uses a number of 3 percent as a maximum for crown fire in grassland vegetation for desired conditions. Fire modeling currently shows 9 percent of grassland areas have potential for crown fire (Table 8). Controlling woody species encroachment into grasslands and savanna is most effectively done with fire, as it was historically. However, because fire has been absent so long, there are many trees that are too large to kill with fire and mechanical treatments would be necessary to move the grasslands back to a condition where they could be managed with fire alone.

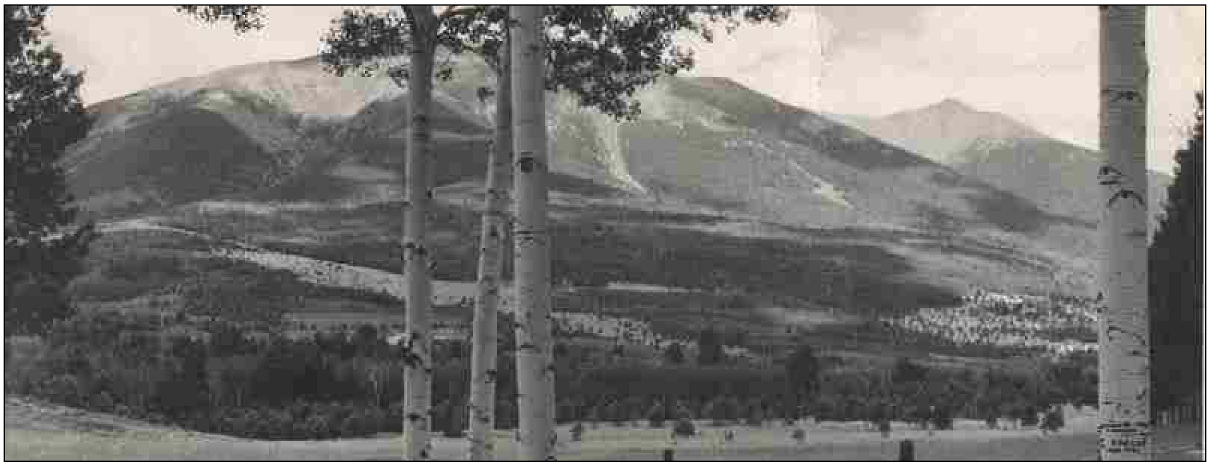

Figure 19. West side of San Francisco Peaks with encroachment in grasslands, circa 1870

Figure 20. West side of San Francisco Peaks with complete closure of openings in right and left background

Table 8. Modeled fire behavior for grasslands (existing condition)

Vegetation	Fire Type (existing condition)	Percent
Grassland	Surface	91
	Passive crown	7
	Active crown	2

Pinyon/Juniper Woodland

Pinyon/Juniper (PJ) ecosystems intergrade with ponderosa pine on an elevational gradient, with PJ becoming the dominant ecosystem as elevation decreases. On the higher elevation, PJ is bounded mostly by ponderosa pine, on the lower elevation, by shrublands and grasslands. The treatment area includes 26,223 acres of PJ, the majority of which are included only to facilitate prescribed fire in adjacent ponderosa pine or grasslands. The one exception is a 535 acre unit in the WUI immediately east of the town of Tusayan for which the objectives are primarily fuel reduction rather than restoration.

Scarred trees and charcoal evidence from research on the Tusayan Ranger District indicated that fire was ubiquitous over the last 500 years. Little evidence has been found, however, to indicate that high severity fires were extensive. This suggested that fires were often small in extent and probably occurred as patchy surface fires to mixed-severity fires that killed groups of trees or small stands (Huffman et al. 2006).

Pinyon/Juniper fires do not carry well unless there is a high wind, though it may creep around and cause occasional torching where there is sufficient litter or surface fuel. The productivity of understory vegetation decreases as stands mature, the canopy closes, and litter becomes the primary contiguous surface fuel. Typically, in a mature PJ stand, canopy base height is low, but surface fuel is usually insufficient to produce surface fire of high intensity, and PJ foliage is often too moist to ignite easily. Pinyon-juniper stands most likely to burn by wildfire have small scattered trees with abundant herbaceous fuel between the trees, or have dense, mature trees capable of carrying crown fire during dry, windy conditions. Such stands are often located just below the ponderosa pine type. Stands of moderate tree density where overstory competition reduces the herbaceous fuel, and the trees themselves are more widely spaced, are very unlikely to burn (Gori et al. 2007). Closed pinyon-juniper stands do not have understory shrubs to carry a surface fire, and do not burn until conditions are met to carry a crown fire.

A study that included part of restoration unit 6 showed juniper (*Juniperus spp.*) was generally confined to upland sites and pinyon pine was found in relatively greater amounts along with ponderosa in the canyons. This suggests that the fire regime in that area is of surface fires burning with relative regularity through ponderosa and pinyon pine communities and less frequently spreading onto upland areas where pinyon and Utah juniper were more important (Huffman et al. 2006). Ponderosa and pinyon pine fire intervals were similar and less than <50 years, whereas juniper intervals tended to be longer than these species with means up to 100 years (Figure 21).

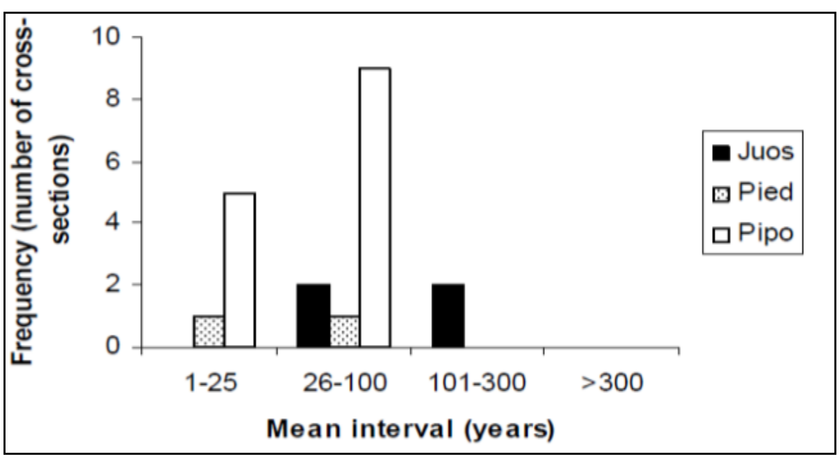

Figure 21. Fire mean intervals by frequency and species (Huffman 2006)

Figure 21 displays fire mean intervals from cross-sections collected at a study site on the Tusayan Ranger District. Means of 1-25, 26-100, 101-300, and >300 represent fire regimes characterized as frequent-low severity, moderate frequency-moderate severity, low frequency-moderate to high severity, and low frequency-high serverity, respectively. Species shown are Utah juniper (Juos), pinyon pine (Pied), and ponderosa pine (Pipo).

On a study site at Tusayan, data collected by Huffman et al. (2006) suggested fires in PJ occurred at a mean frequency of 41.6 years. In that area, there is no evidence of extensive stand replacing fire over the last 400 years and it can be assumed that the historical pattern has been one of frequent surface fires in ponderosa pine communities and small severe fires on pinyon-juniper uplands. The exclusion of these patchy, mixed severity fires at Tusayan has allowed stands to become more dense and homogenous, possibly increasing the site's susceptibility to severe fire of large extent (Huffman et al. 2006). Fire records from the Coconino NF show several large fires (>1,000 acres) in PJ over the last 20 years. It should be noted, however, that pinyon-juniper ecosystems range from PJ savanna/grasslands to dense woodlands, with the fire regimes also varying from frequent to infrequent and low to high severity depending largely on the canopy cover and surface vegetation.

Historically, PJ fires in the treatment area probably carried into upland pinyon-juniper as patchy low severity surface to mixed-severity fires that did not result in large patches of tree mortality (Huffman et al. 2006). Pinyons are poorer recorders of fire than ponderosa pine (e.g. lower post-fire survivorship, more unrecorded fires) and junipers, which appear to scar well, are difficult to age, so fire history reconstructions in some PJ types are difficult. Evidence for low severity surface fires comes from direct observations of fire behavior in pinyon-juniper savanna-woodland settings in central New Mexico, southern and northern Arizona, and western Colorado while evidence for mixed-severity fires come from fire-history and stand reconstruction studies in pinyon-juniper shrub woodlands settings in northern Arizona, northern New Mexico and southwestern Utah (Gori 2007). Pre-settlement high-severity fires that were largely or entirely stand-replacing have been reported in pinyon-juniper shrub and persistent woodlands in northern Arizona, but are rare, with one study suggesting a return interval of 400 years (Huffman et al. 2006).

Post-treatment conditions in the PJ area east of Tusayan to be treated mechanically are likely to be outside the natural range of variability (in terms of structure and fire behavior) in order to adequately decrease potential fire behavior (Huffman et al 2009). However, in that area of PJ proposed for thinning, the desired condition is for fuels reduction rather than restoration, so the resulting stand structure would be moved towards the desired condition. Table 9 shows modeled fire behavior for all PJ in the areas proposed for treatment.

Table 9. Modeled fire behavior for pinyon/juniper under existing conditions

Vegetation	Fire Type (existing condition)	Percent
Pinyon/Juniper	Surface	84
	Passive crown	7
	Active crown	9

Restoration Units

When evaluated at the Restoration Unit scale, none of the RUs meet desired conditions for fire behavior (<10% crown fire), with crown fire potential ranging from 42 percent in RU1 to 19 percent in RU6 (Table 10). ”No fire” includes acres on which there were insufficient fuels to carry fire under the conditions modeled, including water, rock, cinders, areas of sparse vegetation, etc.

Table 10. Modeled fire type for Existing Condition by Restoration Units

Existing Fire Condition by RU (acres/%)	1	3	4	5	6	Total (acres/%)
	156,305	149,718	165,607	76,096	43,529	591,256
Surface fire	88,990/57	90,752/61	111,530/67	111,529/70	35,250/81	380,043/64
Passive crown fire	17,518/11	13,656/9	11,939/7	7,673/10	2,755/6	53,540/9
Active crown fire	48,845/31	44,436/30	41,504/25	9,101/12	5,476/13	149,362/25
No fire*	957/0.6	886/0.5	633/0.4	5,800/7.6	42/0.1	8,319/1.4

Restoration Unit 1

Restoration Unit 1 is currently of the most at risk of all the RUs in regards to crown fire and its effects in its existing condition. Values at risk in or adjacent to RU1 include: Lake Mary, a source watershed for Flagstaff, and a popular recreation site for locals and visitors to the area (Subunit 1-1); Pulliam Airport, the commercial airport that serves Flagstaff and surrounding communities (Subunit 1-1); eastern and southern portions of the city of Flagstaff, the Perkins Telescope (managed by the Lowell Observatory) just north of Lower Lake Mary (Subunit 1-1); more PACs than any other RU, and Walnut Canyon National Monument (Subunit 1-1). With 42 percent of RU1 having potential for crown fire, of which 31 percent would be active crown fire, there is a need to restore the ecosystems in RU1 to a condition where fire, when it occurs, is beneficial and does not support undesirable fire behavior or effects. There are concerns in the area of Mormon Mountain (Figure 22) because of heavy fuel loading in mixed conifer adjacent to the proposed treatment area, as well as the city of Flagstaff to the northwest. Active crown fire would be expected on the steep slopes to the west, south, and east of Mormon Mountain. Wildfires in those locations would move into untreated fuels upslope of the area modeled below. Second order effects from high severity fire on the slopes of Mormon Mountain would include flooding and debris flows downslope of the areas of high severity fire. If 31 percent of the watershed burned with active crown fire (Table 10) and another 11 percent burned with passive crown fire, the ability of Upper and Lower Lake Mary to continue to function as a water source for the city of Flagstaff would be diminished by the sediment coming off those areas with high burn severity being deposited in the lakes.

Ponderosa pine occupies 146,037 acres in RU1, more than any other restoration units. It exceeds the desired condition of less than 10 percent crown fire (Table 11). At least 44 percent of the pine has the potential for high severity effects, with 33 percent of it as active crown fire. When the ponderosa pine is broken down further into habitat types, modeling shows 50 percent or more of Target/Threshold and Restricted habitat types (15,866 acres) would be at risk of crown fire (Table 11).

There are no desired conditions for fire type within these habitat and vegetation types, but the potential for undesirable fire behavior and effects within these areas would have potential to negatively affect adjacent areas (Table 11). Areas downhill from active crown fire would be in the path of runoff and debris flows; areas uphill from those areas would be subjected to crown fire moving into them. It would be expected that some of the ponderosa habitat that burns with high severity would go through a type conversion, becoming non-forested (Savage and Mast 2005).

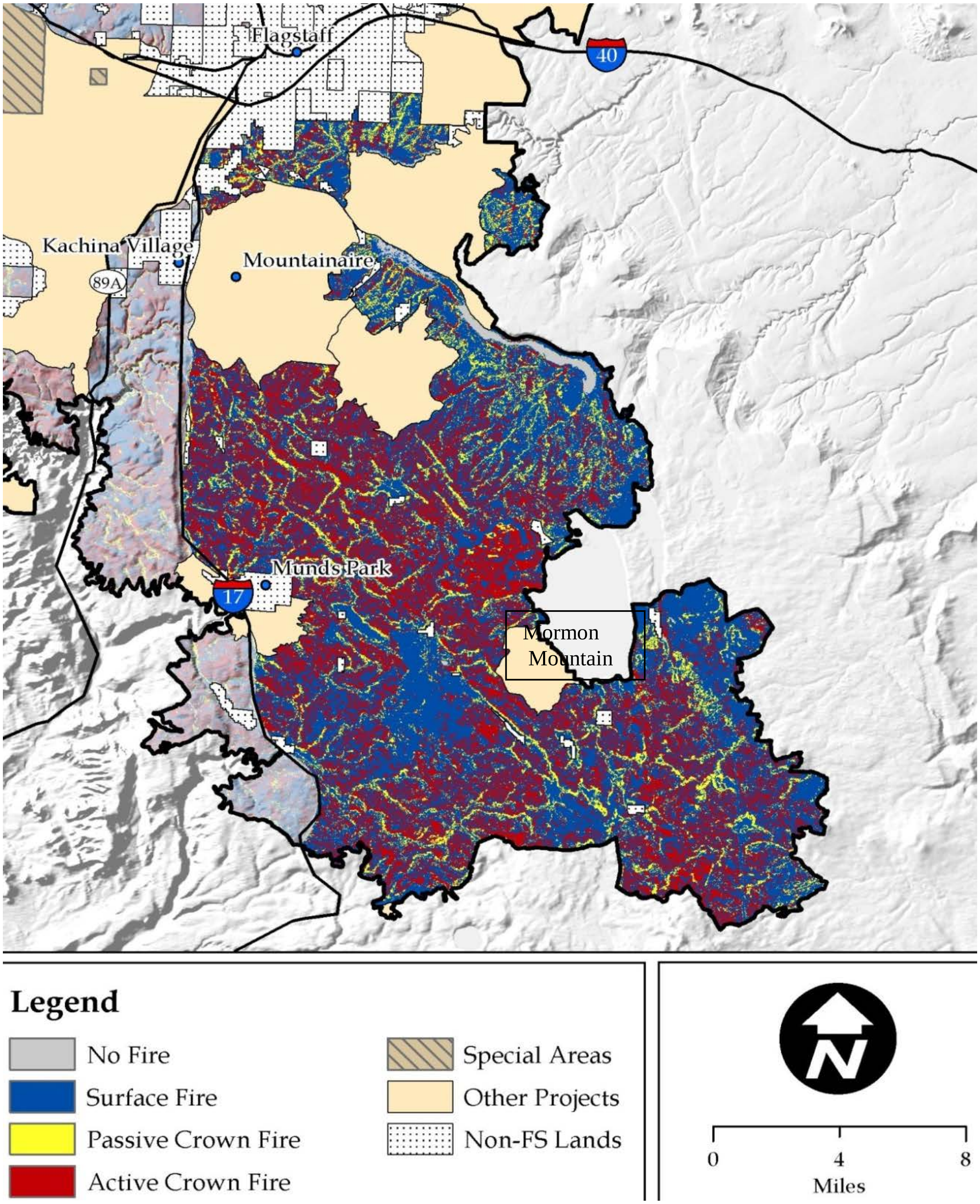

Figure 22. Modeled fire type under existing condition for restoration unit 1

Aspen fire regimes vary somewhat from site to site, so there is no desired condition specifically based on percent crown fire. It is the effects of the fires that do occur that would determine the trajectory of the aspen. Some of the crown fire in aspen stands as modeled above could be attributed to encroaching conifers, which would move the aspen towards the desired condition. Extensive crown fire would topkill the aspen (as well as encroaching conifers) where there is crown fire, but most aspen stands could be expected to sprout vigorously following even high severity fire. Small, and/or highly stressed clones may take longer to recover or, particularly in the presences of browsing ungulates, may disappear. In the absence of browsing, the short term effect would be an exchange of large trees, healthy or decadent, for multiple young sprouts. In the absence of browsing, the longer term effect would be healthier aspen stand in most cases or, in the presence of browsing, much weakened stands.

Grasslands within the treatment areas currently have sufficient encroachment by trees that 19 percent of grassland acres have potential for crown fire. The majority of the crown fire (14 percent) is passive and is likely to be beneficial to the grasslands by killing encroaching trees (grasslands, by definition, should have less than 10 percent tree cover).

Pinyon-juniper fire regimes vary from site to site, so there is no desired condition specifically based on the percent of crown fire, though the effects of fires that do occur will affect the desired condition. Approximately 30 percent (266 acres) of the pinyon/juniper woodland in RU1 has potential for crown fire.

Table 11. Fire type by vegetation/habitat types for existing conditions in restoration unit 1

RU 1 Acres: 156,305			Vegetation Type Acres	Existing Condition	
Vegetation/Habitat Type		Fire Type		Acres	Vegetation Type Percent
Ponderosa Pine	**All Pine**	**Surface**	**146,037**	**81,276**	**56**
		Passive		**15,960**	**11**
		Active		**48,300**	**33**
	MSO Protected	Surface	30,240	15,669	52
		Passive		2,346	8
		Active		12,172	40
	MSO Target/ Threshold	Surface	4,814	2,252	47
		Passive		506	11
		Active		2,045	42
	MSO Restricted	Surface	26,421	13,074	49
		Passive		2,655	10
		Active		10,660	40
	Goshawk PFA/ dPFA/ nest stand	Surface	4,670	2,592	56
		Passive		521	11
		Active		1,556	33
	Landscapes outside PFAs	Surface	79,892	47,689	60
		Passive		9,932	12
		Active		21,867	27
Other Vegetation	Aspen	Surface	420	241	57
		Passive		40	10
		Active		138	33
	Grassland	Surface	8,133	6,151	76
		Passive		1,321	16
		Active		239	3
	Juniper Woodland	Surface	286	232	81

		Passive		14	5
		Active		41	14
	Oak Woodland	Surface	287	194	68
		Passive		62	22
		Active		31	11
	Pinyon/ Juniper	Surface	1,141	896	78
		Passive		115	10
		Active		96	8

Subunits

Values currently at risk in Subunit 1-1are described on page 51 (Figure 7). Subunit 1-3 includes the Lake Mary basin, a source watershed for the town of Flagstaff. Current conditions show 41 percent of Subunit 1-3 to have potential for crown fire, 29 percent of which is active crown fire (Table 12).

Table 12. Modeled fire type in Restoration Unit 1 by subunit and vegetation type

Vegetation Type by Subunit	Acres	Percent of vegetation type in subunit	Fire type					
			Surface (acres)	Passive (acres)	Active (acres)	Surface (percent)	Passive (percent)	Active (percent)
Subunit 1-1	10,169	-	6,379	2,050	1,576	63	20	15
Ponderosa Pine	8,914	88	5,591	1,721	1,485	63	19	17
Grassland	567	6	315	193	46	56	34	8
Oak Woodland	173	2	120	53	0	69	30	0
Pinyon-Juniper	515	5	352	84	44	68	16	9
Subunit 1-2	8,054	-	5,897	830	1,267	73	10	16
Ponderosa Pine	6,517	81	4,508	738	1,248	69	11	19
Grassland	1,537	19	1,389	92	20	90	6	1
Subunit 1-3	41,652	-	23,853	5,200	12,178	57	12	29
Ponderosa Pine	38,324	92	21,467	4,683	12,067	56	12	31
Aspen	88	0	53	14	21	60	15	24
Grassland	3,240	8	2,333	503	89	72	16	3
Subunit 1-4	18,250	-	10,887	1,985	5,363	60	11	29
Ponderosa Pine	17,285	95	10,094	1,868	5,317	58	11	31
Grassland	519	3	409	92	9	79	18	2
Oak Woodland	83	0	53	9	20	64	11	25
Pinyon-	363	2	331	15	17	91	4	5

Vegetation Type by Subunit	Acres	Percent of vegetation type in subunit	Fire type					
			Surface (acres)	Passive (acres)	Active (acres)	Surface (percent)	Passive (percent)	Active (percent)
Juniper								
1-5	78,179	-	41,974	7,448	28,461	54	10	36
Ponderosa Pine	74,996	96	39,615	6,950	28,183	53	9	38
Aspen	332	0	188	27	117	57	8	35
Grassland	2,270	3	1,705	441	76	75	19	3
Juniper Woodland	286	0	232	14	41	81	5	14
Oak Woodland	32	0	21	1	10	66	2	32
Pinyon-Juniper	262	0	212	16	35	81	6	13

Restoration Unit 3

Restoration Unit 3 currently has the second greatest potential for undesirable fire effects and fire behavior based on crown fire potential. There is potential for crown fire across 39 percent of RU3, of which 30 percent would be active crown fire (Figure 23). Winds on the Mogollon Rim are generally out of the southwest, so this RU has a high strategic importance in regards to wildfire potential for Interstate 17 and Interstate 40, as well as the communities of Flagstaff, Munds Park, Williams, Belmont, Kachina Village, and Parks. Sycamore Canyon and Oak Creek Canyon are within or adjacent to this RU as well. The top and right (north and east) borders are Interstates 10 and 17 respectively. Adjacency concerns for fire behavior include Flagstaff at the top right of the RU, and Oak Creek and Sycamore Canyons. Oak Creek Canyon is a popular recreation area, and includes Slide Rock State Park in addition to homes and businesses. Highway 89A runs though RU3 from Flagstaff to Sedona. It is a scenic, heavily used highway which would be at high risk should there be extensive flooding and/or debris flows from a high severity fire upslope from it. While most of the canyon itself is not within the proposed treatment areas, second order effects (indirect) would be unavoidable within much of the canyon and Oak Creek should there be high severity fires along the rim. The degree of second order (indirect) fire effects would depend on the slope and extent of the burn. The same concerns apply to Sycamore Canyon, and, although there are no roads, there are popular trails that would be affected.

None of the ponderosa pine, oak, or grasslands meets desired conditions for fire type (Table 13), and are at risk of undesirably severe fire behavior and effects. High severity fire in ponderosa pine can result in a type change, converting some of what was previously a forested landscape into one dominated by shrubs or other species (Savage and Mast 2005). With 43 percent (55,000+ acres) of the pine habitat at risk of crownfire, it is likely that a wildfire in this area would destroy much of the MSO and goshawk habitat in RU3.

Ponderosa pine within RU3 does not meet desired conditions in any of the subunits (Table 13). Subunit 3-2 includes an area along Interstate 40 from the outskirts of Flagstaff to Williams, and currently has potential for over 9,000 acres of crown fire. Subunit 3-3 encompasses Sycamore Canyon, and includes Rogers Lake. With potential for over 20,000 acres of crown fire, potential effects to the Sycamore Canyon Wilderness area from flooding and/or debris flows following high severity fire could compromise the functioning of the water resources and adjacent riparian areas. Subunit 3-4 is strategically important for the communities of Flagstaff, Kachina Village, and Munds Park, as well as Interstate 17. Unplanned ignitions starting in or near Pumphouse Wash and Munds Canyon would be likely to funnel wildfires towards or even into, Kachina Village and Munds Park. Additionally, water resources and riparian areas in these areas would be compromised by flooding and/or debris flows. Winds are generally out of the southwest, so fires starting in this RU would be pushed toward these communities and Interstate 17.

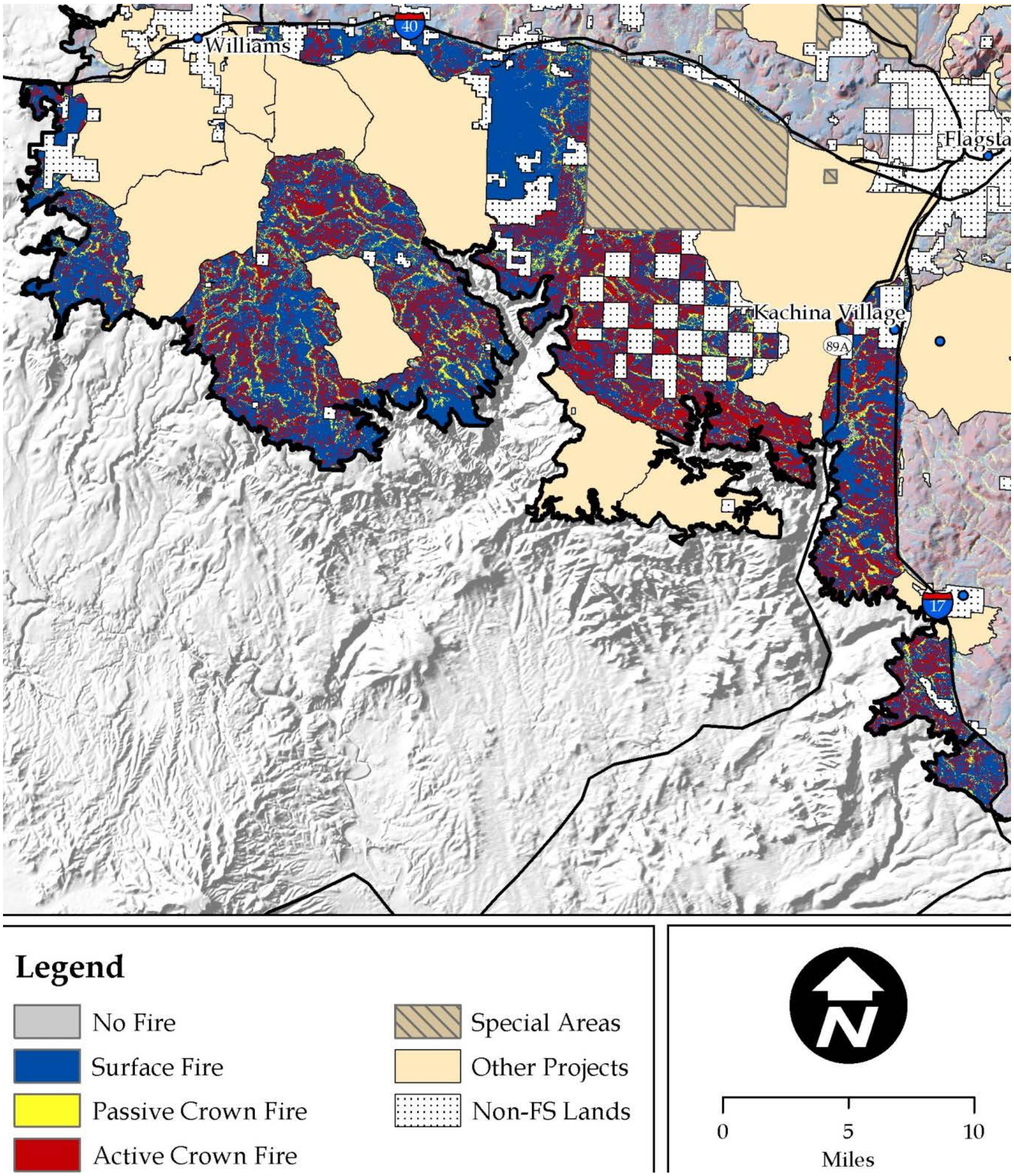

Figure 23. Modeled fire type for restoration unit 3, existing condition.

Aspen in RU3 occupy only a small number of acres (201). The existing fire behavior is not likely to be detrimental because there is only potential for 8 percent active crown fire and 20 percent passive. Some of this crown fire can usually be attributed to encroaching conifers. Aspen adaptation to fire are such that, with its current fire potential, the effects on decadent stands would probably be beneficial, resulting in vigorous post fire sprouting. However, young aspen sprouts would be at risk from browsing ungulates which would result in weakened stands.

Grasslands within RU3 do not currently meet the desired condition for crown fire of less than 3 percent crown fire. Only 5 percent of the area would have potential for passive crown fire, so the fire would be beneficial to the grasslands, removing encroaching trees and other woody encroachment, and rejuvenating the vegetation. The 172 acres with potential active crown fire would have potential to damage surface and soil resources, as well as being a potential control risk.

Table 13. Modeled fire type by vegetation/habitat type for Restoration Unit 3

RU 3 Acres: 149,718			Vegetation Type Acres	Existing Condition	
	Vegetation/Habitat Type	Fire Type		Acres	Vegetation Type Percent
Ponderosa Pine	**All Pine**	Surface	129,225	72,734	56
		Passive		12,618	10
		Active		43,227	33
	MSO Protected	Surface	4,507	1,930	43
		Passive		586	13
		Active		1,907	42
	MSO Target/ Threshold	Surface	3,899	2,040	52
		Passive		420	11
		Active		1,435	37
	MSO Restricted	Surface	38,748	21,183	55
		Passive		3,683	10
		Active		13,804	36
	Goshawk PFA/ dPFA/ nest stand	Surface	5,452	2,891	53
		Passive		588	11
		Active		1,972	36
	Landscapes outside PFAs	Surface	76,619	44,689	58
		Passive		7,342	10
		Active		24,110	31
Other Vegetation	Aspen	Surface	201	145	72
		Passive		40	20
		Active		16	8
	Grassland	Surface	12,775	11,703	92
		Passive		683	5
		Active		172	1
	Juniper Woodland	Surface	1,851	1,552	84

		Passive		50	3
		Active		243	13
	Oak Woodland	Surface	1,633	1,276	78
		Passive		77	5
		Active		271	17
	Pinyon/ Juniper	Surface	4,033	3,343	83
		Passive		176	4
		Active		507	13

Table 14. Modeled fire type in RU3 subunits by vegetation type for existing conditions

Vegetation Type by Subunit	Acres	Percent of subunit in vegetation type	Fire Type Existing Condition					
			Surface (acres)	Passive (acres)	Active (acres)	Surface (percent)	Passive (percent)	Active (percent)
Subunit 3-1	**23,148**	**-**	**15,312**	**2,175**	**5,592**	**66**	**9**	**24**
Ponderosa Pine	18,805	81	11,608	1,944	5,209	62	10	28
Aspen	91	0	65	23	2	72	26	2
Grassland	593	3	511	55	10	86	9	2
Juniper Woodland	907	4	773	33	100	85	4	11
Oak Woodland	845	4	703	40	101	83	5	12
Pinyon-Juniper	1,908	8	1,653	81	170	87	4	9
Subunit 3-2	**32,726**	**-**	**23,091**	**2,790**	**6,569**	**71**	**9**	**20**
Ponderosa Pine	22,885	70	13,754	2,598	6,399	60	11	28
Aspen	59	0	39	8	12	66	14	20
Grassland	9,611	29	9,231	182	55	96	2	1
Oak Woodland	172	1	67	2	102	39	1	60
Subunit 3-3	**48,434**	**-**	**28,912**	**4,512**	**14,916**	**60**	**9**	**31**
Ponderosa Pine	44,426	92	25,593	4,254	14,506	58	10	33
Aspen	50	0	40	8	2	80	17	3
Grassland	1,353	3	1,146	156	46	85	11	3
Juniper Woodland	873	2	713	18	139	82	2	16
Oak Woodland	232	0	206	11	6	89	5	3
Pinyon-Juniper	1,500	3	1,213	66	217	81	4	14
Subunit 3-4		**-**	**5,148**	**841**	**2,815**	**57**	**9**	**31**
Ponderosa Pine	8,920	99	5,101	813	2,805	57	9	31
Grassland	99	1	47	28	10	47	28	10
Oak Woodland	0	0	0	0	0	100	0	0
3-5	**36,392**	**-**	**18,289**	**3,326**	**14,544**	**50**	**9**	**40**
Ponderosa Pine	34,190	94	16,678	3,010	14,308	49	9	42
Aspen	2	0	1	0	0	61	21	18

Vegetation Type by Subunit	Acres	Percent of subunit in vegetation type	Fire Type Existing Condition					
			Surface (acres)	Passive (acres)	Active (acres)	Surface (percent)	Passive (percent)	Active (percent)
Grassland	1,120	3	768	263	51	69	23	5
Juniper Woodland	70	0	66	0	4	94	0	6
Oak Woodland	384	1	299	24	61	78	6	16
Pinyon-Juniper	626	2	477	29	120	76	5	19

Restoration Unit 4

Located west and north of Flagstaff, and north of Williams and Interstate 40, RU4 has potential to affect the communities of Flagstaff, Williams, Parks, and Belmont, though the prevailing winds are fire away from these communities. There is also potential to impact the Fort Valley Experimental Station northwest of Flagstaff. Over the last 20 years, RU4 has been impacted by some large fires, including the Hochderffer (2004, 16,000 acres) and Pumpkin (2000, 8,700 acres) fires. Areas of potential active crown fire currently exist adjacent to heavy fuel loading in mixed conifer on Kendrick and Sitgreaves mountains, and the San Francisco Peaks (Figure 24). Areas of active crown fire show on the slopes of Kendrick and Sitgreaves mountains. In these locations, flooding and debris flows could damage infrastructure and homes scattered downslope. Additionally, potential for high severity fire in areas north and west of Flagstaff could be affected by flooding and debris flows. With 32 percent of RU4 having potential for crown fire, of which 25 percent would be active crown fire, there is a need to restore the ecosystems in RU4 to a condition where fire is beneficial and does not produce undesirable fire behavior and effects.

Ponderosa pine occupies over 134,000 acres in RU4. As described for RUs 1 and 3 above, high severity fire in ponderosa pine can lead to type conversion to a non-forested type. RU4 has potential for over 94,000 acres of crown fire in ponderosa pine (Table 15). Even when broken down to the subunit (Table 15) none of the habitat types in ponderosa pine meet desired conditions. Over half of the restricted habitat is indicated as being at risk of crown fire.

Aspen could benefit from the type of fire that shows up in the modeled fire behavior. With 82 percent surface fire, most of the mortality would come from high surface fuel loads, but post-fire effects in most cases would be likely to include vigorous sprouting (indirect fire effects). There may be a shift, in the short term, to fewer large aspen and more small and sprouted aspen. Young sprouts would be at risk of browsing pressure from ungulates. In the long term, the burned clones could mature and expand, depending on climate conditions and browsing pressure.

Grasslands occupy over 22,000 acres of grasslands in RU4, which include government Prairie. Under existing conditions, 6 percent of these acres (1,366) have the potential for crown fire. There are more acres of grassland in this RU than any of the others so, although there is potential for only 3 percent active crown fire, that represents the potential for over 600 acres of active crown fire in grasslands, with potential to damage surface vegetation and soils. The 753 acres of passive crown fire would be mostly beneficial to the grassland area, decreasing woody encroachment and allowing fire to play its beneficial roles including nutrient recycling, seed scarification, re-invigorating shrubs and decadent grasses, and more.

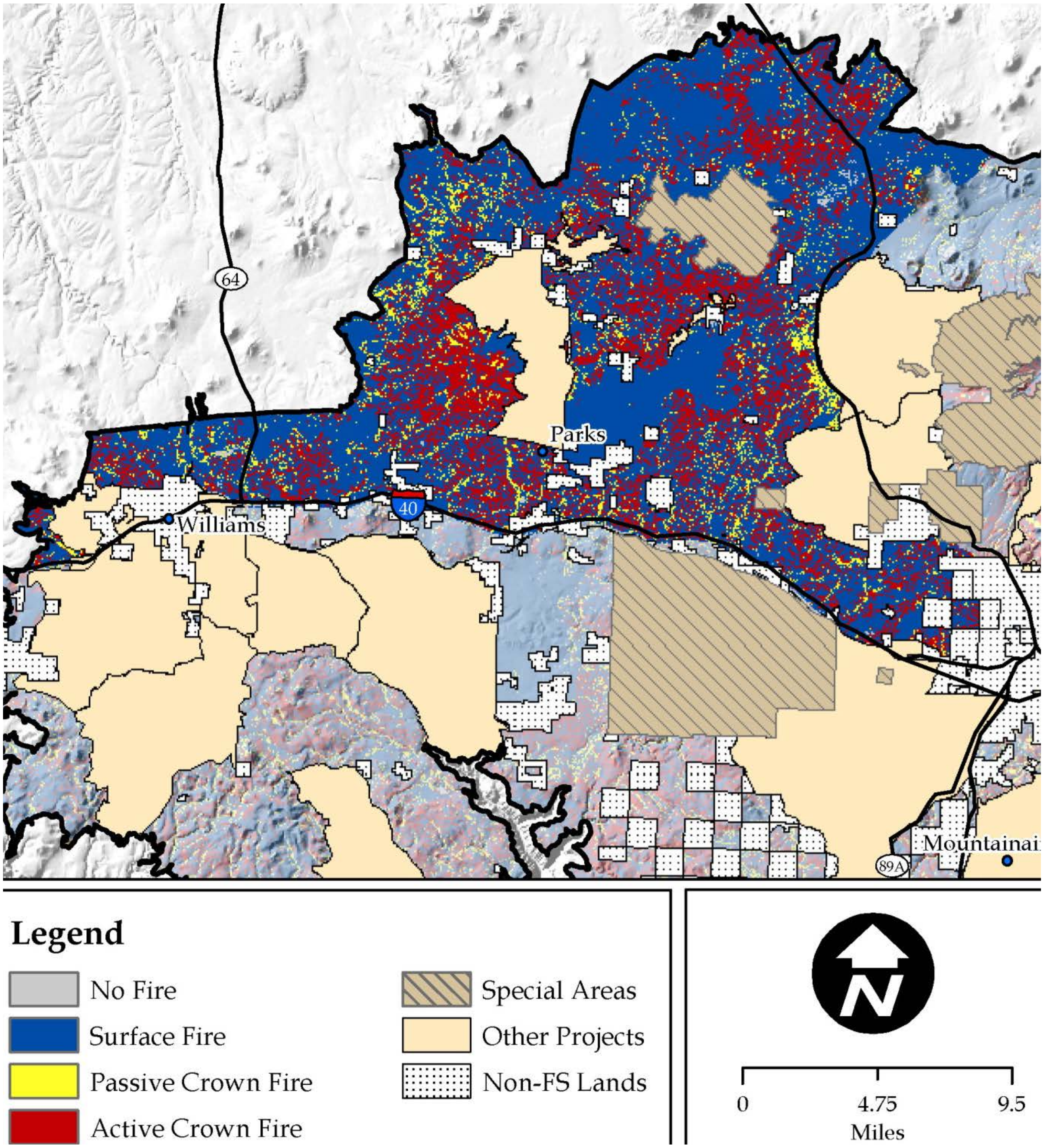

Figure 24. Modeled fire type for Restoration Unit 4, Existing Condition

Table 15. Modeled fire type by vegetation/habitat type for Restoration Unit 4

RU 4 Acres: 165,607			Vegetation Type Acres	Existing Condition	
	Vegetation/Habitat Type	Fire Type		Acres	Vegetation Type Percent
Ponderosa Pine	All Pine	Surface	134,301	83,435	62
		Passive		10,615	8
		Active		39,806	30
	MSO Protected	Surface	558	379	68

RU 4 Acres: 165,607			Vegetation Type Acres	Existing Condition	
	Vegetation/Habitat Type	Fire Type		Acres	Vegetation Type Percent
		Passive		46	8
		Active		133	24
	MSO Restricted	Surface	1,575	749	48
		Passive		197	13
		Active		622	39
	Goshawk PFA/ dPFA/ nest stand	Surface	13,484	8,007	59
		Passive		1,242	9
		Active		4,231	31
	Landscapes outside PFAs	Surface	118,683	74,300	63
		Passive		9,130	8
		Active		34,820	29
Other Vegetation	Aspen	Surface	499	411	82
		Passive		30	6
		Active		55	11
	Grassland	Surface	22,599	21,082	93
		Passive		753	3
		Active		613	3
	Juniper Woodland	Surface	118	68	58
		Passive		4	3
		Active		43	37
	Oak Woodland	Surface	926	669	72
		Passive		85	9
		Active		170	18
	Pinyon/ Juniper	Surface	7,165	5,864	82
		Passive		454	6
		Active		815	11

Subunits

At the subunit level (Table 16) SU 4-5, though the smallest of all the Subunits at 6,943 acres, is adjacent to the city of Flagstaff, and has steep topography, so that indirect fire effects of high severity fires have potential to impact neighborhoods, schools, and infrastructure in west Flagstaff. Currently, 33 percent of SU 4-5 has potential for crown fire, with 28 percent being active crown fire, some of it in Dry Lake Hills, and areas just west of Lowell Observatory. Fires that started southwest of this area would have potential to burn into housing developments on the west side of Flagstaff.

In all subunits except 4-5, grassland areas already meet desired conditions for fire behavior. Fires that did occur in these areas would be beneficial to the grasslands, as described above. In Subunit 4-5, 15 percent of the area has potential for crown fire, of which 11 percent (281 acres) would be active crown fire.

Table 16. Fire type in Restoration Unit 4 subunits by major vegetation type, Existing Condition

Vegetation Type by Subunit	Acres	Percent of subunit in vegetation type	Fire Type Existing Condition					
			Surface (acres)	Passive (acres)	Active (acres)	Surface (percent)	Passive (percent)	Active (percent)
Subunit 4-2	10,231	-	6,991	926	2,214	68	9	22
Ponderosa Pine	7,381	72	4,731	773	1,836	64	10	25
Aspen	1	0	1	0	0	67	0	0
Grassland	332	3	295	8	2	89	2	1
Juniper Woodland	8	0	7	1	0	86	9	5
Oak Woodland	567	6	378	56	131	67	10	23
Pinyon-Juniper	1,941	19	1,579	88	245	81	5	13
Subunit 4-3	67,013	-	48,109	4,402	14,181	72	7	21
Ponderosa Pine	55,311	83	37,849	3,794	13,364	68	7	24
Aspen	232	0	218	5	8	94	2	3
Grassland	6,951	10	6,413	237	289	92	3	4
Juniper Woodland	31	0	31	0	1	98	0	2
Oak Woodland	325	0	272	26	27	84	8	8
Pinyon-Juniper	4,162	6	3,326	340	493	80	8	12
Subunit 4-4	81,421	-	51,782	6,249	23,191	64	8	28
Ponderosa Pine	65,003	80	36,493	5,717	22,705	56	9	35
Aspen	255	0	186	25	43	73	10	17
Grassland	14,988	18	14,094	474	311	94	3	2
Juniper Woodland	78	0	31	3	42	39	4	54
Oak Woodland	35	0	19	3	12	56	8	36
Pinyon-Juniper	1,062	1	959	26	77	90	2	7
Subunit 4-5	6,943	-	4,649	364	1,917	67	5	28
Ponderosa Pine	6,605	95	4,362	331	1,902	66	5	29
Aspen	11	0	6	0	4	57	4	40
Grassland	327	5	281	33	11	86	10	3

Restoration Unit 5

Restoration unit 5 includes parts of the area that was burned in the Schultz Fire (2010, ~17,000 acres) and the Radio Fire (1977, 2,600 acres) mostly on Mount Elden, immediately upslope and adjacent to northern Flagstaff). Adjacency concerns include housing developments, including Doney Park, and the city of Flagstaff, which would be mostly downslope from any fire occurring in this RU. Figure 25 shows areas of passive crown fire in the northwest, much of which is in Gambel oak.

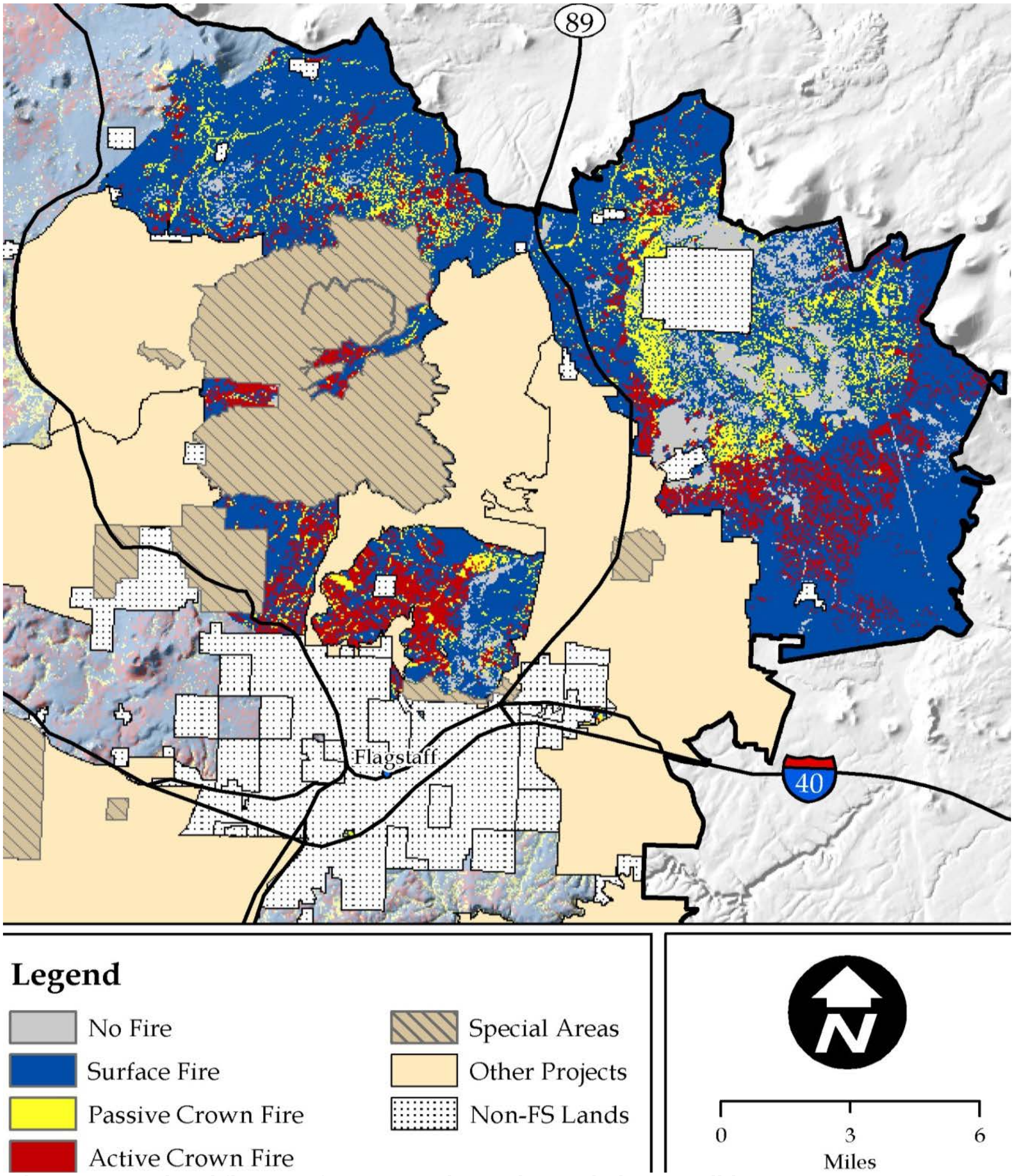

Figure 25. Modeled fire type for Restoration Unit 5, Existing Condition

In the east center are some large contiguous areas of passive crown fire. These would be of particular concern under more extreme conditions than are modeled, because of the potential to become active crown fire. The grey areas represent areas of low to no fuel in the cinder substrate northeast of Flagstaff. These areas, have little fuel, but have been reported to attract lightning, increasing the potential for lightning starts in the vicinity (see Appendix D), though there are areas in the cinder hills of over 500 acres have insufficient vegetation to carry a fire. With 22 percent of RU5 having potential for crown fire, of which 12 percent would be active crown fire, there is a need to restore the ecosystems in RU5 to a condition where the risk of undesirable fire behavior and effects is minimized.

Ponderosa pine in RU5 does not meet desired conditions for fire type (Table 17). The pine vegetation type has potential for 26 percent crown fire, of which 14 percent would be active crown fire. Approximately 3,700 acres are non-burnable (water, cinders, etc.).

Aspen in RU5 is mostly on the west side of Highway 89A. As mentioned earlier, some of the crown fire in aspen can be attributed to encroaching conifers. Where crown fire occurs and/or where there are heavy accumulations of surface fuels, the most likely effects of fire under current conditions would be an increase in sprouts, and a decrease in large stems. It is likely some of the aspen would be topkilled, though the roots would not be killed and would sprout.

Grasslands in RU5 exceed the desired condition for fire behavior, though only 105 acres has potential for active crown fire. On these acres, there is potential for undesirable fire effects to soil and surface vegetation. Passive crown fire (225 acres)in these areas would be beneficial to the grasslands, decreasing woody encroachment (direct effect) and removing immediate seed sources for future encroachment (indirect effect).

Table 17. Fire type by vegetation and habitat type for Restoration Unit 5

RU 5 Acres: 76,096			Vegetation Type Acres	Existing Condition	
	Vegetation/Habitat Type	Fire Type		Acres	Vegetation Type Percent
Ponderosa Pine*	**All Pine**	**Surface**	**61,730**	**42,304**	**69**
		Passive		**7,105**	**12**
		Active		**8,532**	**14**
	MSO Protected	Surface	1,452	631	43
		Passive		164	11
		Active		635	44
	MSO Restricted	Surface	634	460	73
		Passive		72	11
		Active		101	16
	Goshawk PFA/ dPFA/ nest stand	Surface	2,944	1,745	59
		Passive		490	17
		Active		563	19
	Landscapes outside PFAs	Surface	56,700	39,468	70
		Passive		6,380	11
		Active		7,233	13
Other Vegetation**	Aspen	Surface	403	333	83
		Passive		22	5
		Active		42	11
	Grassland	Surface	4,595	2,577	56
		Passive		225	5
		Active		105	2

	Juniper Woodland	Surface	74	66	89
		Passive		8	10
		Active		0	1
	Oak Woodland	Surface	523	443	85
		Passive		35	7
		Active		25	5
	Pinyon/ Juniper	Surface	8,771	7,797	89
		Passive		279	3
		Active		395	5

*Ponderosa pine in RU5 includes approximately 3,788 acres of non-burnable area (cinder substrate)
**"Other vegetation" includes approximately 2,012 acres of non-burnable area

Subunits

Subunit 5-2 includes areas that were burned over by the Schultz Fire. One of the direct effects was to remove the potential for crown fire for much of the area, at least in the short term. Table 18 shows mostly surface fire, with grasslands in Subunit 5-1 meeting desired conditions for fire behavior.

Table 18. Fire type in subunits of Restoration Unit 5 by vegetation type

Vegetation Type by Subunit	Acres	Percent of subunit in vegetation type	Fire Type Existing Condition					
			Surface (acres)	Passive (acres)	Active (acres)	Surface (percent)	Passive (percent)	Active (percent)
			17,914	1,934	3,456	74	8	14
Ponderosa Pine	20,674	86	14,709	1,789	3,359	71	9	16
Aspen	392	2	327	19	42	83	5	11
Grassland	1,299	5	1,174	86	19	90	7	1
Oak Woodland	232	1	180	25	25	77	11	11
Pinyon-Juniper	1,574	7	1,524	15	11	97	1	1
Subunit 5-2	51,924	-	35,607	5,741	5,644	69	11	11
Ponderosa Pine	41,055	79	27,595	5,317	5,173	67	13	13
Aspen	10	0	7	3	1	65	30	6
Grassland	3,297	6	1,403	139	86	43	4	3
Juniper Woodland	74	0	66	8	0	89	10	1
Oak Woodland	291	1	263	10	1	91	3	0
Pinyon-Juniper	7,196	14	6,273	264	384	87	4	5

Ponderosa pine does not meet desired conditions, with 25 percent of the pine still having the potential for crown fire in Subunit 5-1. Effects from the Shultz Fire were beneficial in some cases, where low severity fire dominated. In other areas, flooding and debris flows choked streams and riparian areas downslope from areas with high severity effects (Figure 26). In Figure 27 notice the lack of surface vegetation, litter, or duff to hold the soil in place. Subunit 5-2 includes much of the youngest, most sparsely vegetated cinder cones, as well as areas that were affected by the second order fire effects resulting from the Schultz Fire.

Figure 26. Erosion and deposition from flooding and debris flows downstream resulting from high severity area on the Schultz Fire

Figure 27. Forest Service Road 418 two months after the Schultz Fire

Restoration Unit 6

Restoration unit 6 is the smallest of the RUs, and lies immediately south of, and adjacent to Grand Canyon National Park. Proposed treatments in RU6 are all within the Tusayan Ranger District of the Kaibab National Forest. With 19 percent of RU6 having potential for crown fire, of which 13 percent would be active crown fire, there is a need to restore the ecosystems in RU6 to a condition where fire is beneficial and does not produce undesirable fire behavior or effects. The active crown fire shown in Figure 28 is largely dispersed, with only a few areas of contiguous crown fire.

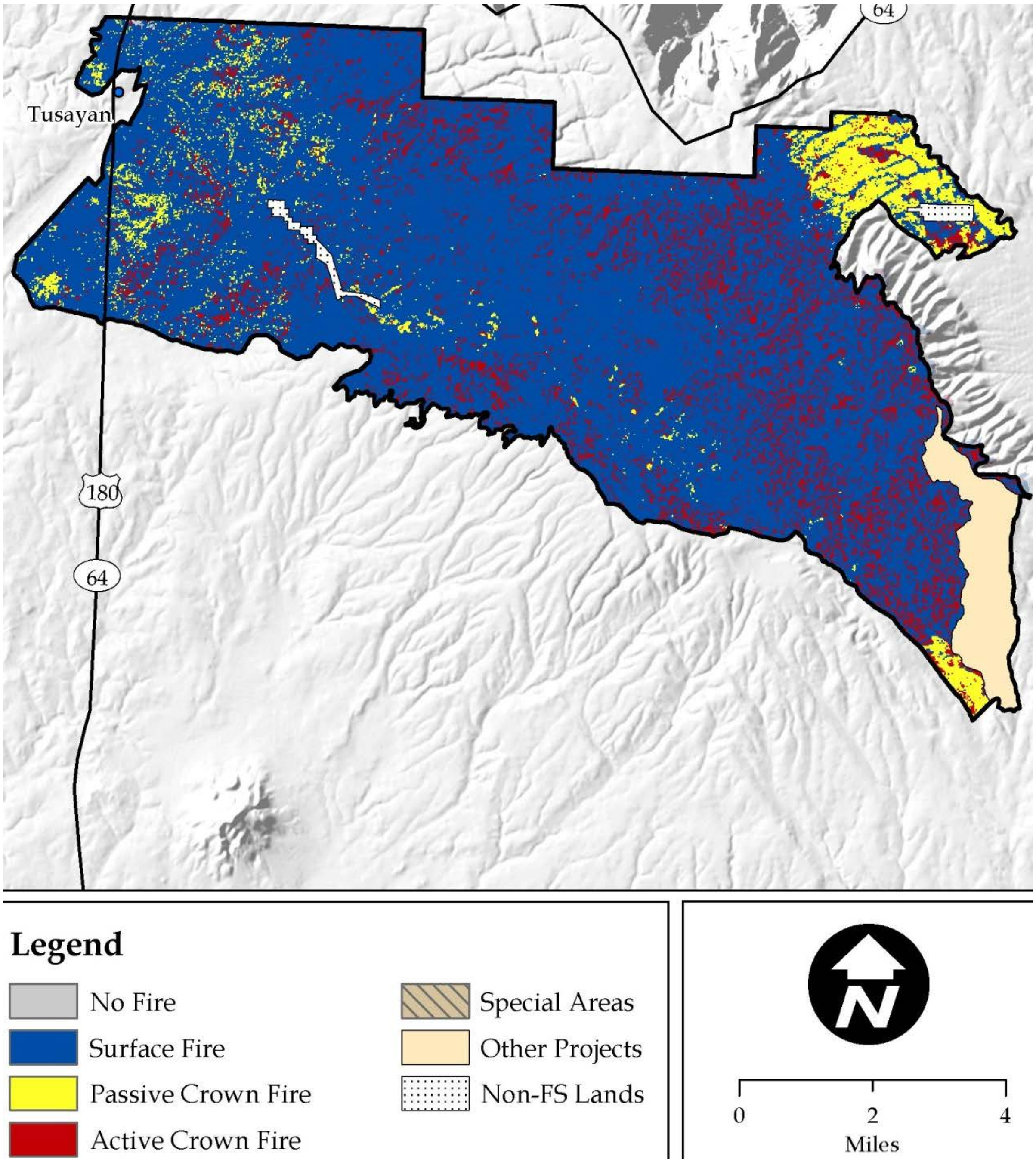

Figure 28. Modeled fire type under existing conditions for restoration unit 6

Continuous areas of passive crow fire show in the northeast and southeast areas where pinyon and juniper are more frequent. In the westernmost area, there is pinyon/juniper for which fire behavior is a concern for the town of Tusayan. It is the driest of all the RUs, and has had more recent fire than most of the rest of the proposed treatment area, with over half of it having had fire in the last 10 years.

The Tusayan Ranger District, which includes all of Restoration Unit 6, has a shorter fire return interval overall, than the rest of the project area (Figure 28). Of the ~55,000 acres of fire documented in Figure 28, less than 2 percent burned with high severity. The majority of the acres burned were within the ponderosa pine, in areas proposed for treatment in 4FRI. In its existing condition, 18 percent of the ponderosa pine has potential to sustain crown fire (Table 19), with 13 percent of it being active crown fire.

Ponderosa pine, in its existing condition, it does not meet desired conditions for fire behavior (Table 19), with a little over 7,400 acres of crown fire potential. However, only 5,247 acres of this is active crown fire, and none if it occurs in contiguous areas of greater than 50 acres. With 82% of the ponderosa pine in RU6 modeled as surface fire, it isn't too far off of desired conditions.

Table 19. Fire type by vegetation/habitat type for Restoration Unit 6, Existing Condition

RU 6 Acres: 43,529			Vegetation Type Acres	Existing Condition	
Vegetation/Habitat Type		Fire Type		Acres	Vegetation Type Percent
Ponderosa Pine	All Pine	Surface	41,188	33,675	82
		Passive		2,224	5
		Active		5,247	13
	Goshawk PFA/ dPFA/ nest stand	Surface	4,050	3,502	86
		Passive		111	3
		Active		433	11
	Landscapes outside PFAs	Surface	37,138	30,173	81
		Passive		2,113	6
		Active		4,814	13
	Grassland	Surface	93	89	96
		Passive		3	3
		Active		1	1
	Juniper Woodland	Surface	13	10	78
		Passive		3	22
		Active		0	0
	Oak Woodland	Surface	30	9	29
		Passive		21	69

RU 6 Acres: 43,529			Vegetation Type Acres	Existing Condition	
Vegetation/Habitat Type		Fire Type		Acres	Vegetation Type Percent
		Active		1	2
	Pinyon/ Juniper	Surface	2,206	1,468	67
		Passive		511	23
		Active		227	10

Grasslands are only slightly departed from desired condition in RU6.

Pinyon/Juniper woodland currently has potential for 1,533 acres of passive crown fire, with an additional 227 of active crown fire. There is no desired condition for those acres included as operational burn only (1,701 acres). For the remaining 535 acres proposed for fuels reduction, the desired condition is for 0% of the area to support crown fire.

Subunits

There are 8,553 acres of ponderosa pine proposed for treatment in Subunits 6-2 and 6-4 combined. There are only a total of 92 acres of grasslands in RU6 and, in its current condition, it meets desired conditions (Table 20). Fires that occur in the grassland area would continue to maintain the grasslands by keeping woody encroachment at bay, recycling nutrients, rejuvenating fire adapted shrubs, and maintaining fuel loads at desirable levels.

Table 20. Fire type in subunits of Restoration Unit 6 by vegetation type, Existing Condition

Restoration Unit	Acres	Percent of subunit in vegetation type	Existing Condition					
			Surface (acres)	Passive (acres)	Active (acres)	Surface (percent)	Passive (percent)	Active (percent)
6-2	5,551	-	4,665	408	471	84	7	8
Ponderosa Pine	5,069	91	4,306	293	463	85	6	9
Pinyon-Juniper	483	9	359	115	8	74	24	2
6-3	34,109	-	28,723	889	4,466	84	3	13
Ponderosa Pine	32,635	96	27,583	722	4,299	85	2	13
Grassland	85	0	82	2	1	96 t	3	1
Juniper Woodland	13	0	10	3	0	78	22	0
Pinyon-Juniper	1,375	4	1,048	162	166	76	12	12
6-4	3,870		1,863	1,464	539	48	38	14
Ponderosa Pine	3,484	90	1,786	1,210	485	51	35	14
Grassland	7	0	7	0	0	99	1	0
Oak Woodland	30	1	9	21	1	29	69	2
Pinyon-Juniper	348	9	61	234	53	17	67	15

Some of the pine within these subunits are on the edge of the core area of ponderosa pine, and have a component of juniper and/or oak (Figure 29). Figure 29 shows an area in the northwestern corner of Subunit 6-4 where oak, ponderosa pine, an juniper co-occur. Although the canopies are not always contiguous, there are copious ladder fuels, illustrating why modeled fire behavior in this area showed up as almost contiguous passive crown fire. Gambel oak is present in most of the pine in all subunits, but is most prevalent in subunit 6-4 where there are areas of pure oak woodland. Oak is being overtopped in many of these areas by ponderosa pine.

Figure 29. Ladder fuels in northeastern 6-4 where oak, ponderosa pine, and juniper co-occur

Surface fuels and canopy characteristics affecting fire behavior and effects

The ability of a forest to maintain its resilience to fire depends, in part, on how close it is to threshold conditions that would support crown fire. Canopy characteristics and surface fuel loading combine to produce combinations of surface fire intensity (flame length is a good proxy for fireline intensity – the higher the intensity, the longer the flame length) and physical structure (the height, density, and horizontal and vertical continuity of canopy fuels) that can produce crown fire under a given set of conditions. For ponderosa pine, the closer conditions are to the threshold, the faster it will deteriorate to a point where crown fire is possible.

Canopy characteristics

Existing conditions for Canopy Base Height (CBH), and Canopy Bulk Density (CBD) are shown in Table 21. The following figures and tables classify canopy characteristics by desired openness which represents the openness of an area, as well as how well it can maintain a trajectory towards the desired condition. The areas with lower desired openness are primarily those associated with MSO habitat, currently have the highest fuel loading (Table 22), as well as the lowest Canopy Base Heights (CBH), the higher Canopy Bulk Density (CBD), and the highest Canopy Cover (CC). Across the landscape, a mosaic at all scales would be well adapted to fire for southwestern ponderosa pine, and would be maintainable by fire alone should that be desired.

Table 21 shows modeled canopy characteristics for Existing Conditions. Shaded cells indicate acres that do not currently meet desired conditions. Desired conditions are for Canopy Base Height (CBH) to average greater than 18 feet (affects the initiation of crown fire) and for Canopy Bulk Density (CBD) to be less than 0.05 (affects the ability of crown fire to be sustained from one tree crown to the next) (Nicolet 2011). It is important to note that the average CBH, in particular, is only an indicator of potential. Fire only needs one access point to the canopy to initiate crown fire so, if there is one tree with a low CBH and sufficient CBD, that could be sufficient to initiate crown fire. However, averages are an indicator that can be a useful part of an assessment when used with other indicators and as baseline data to judge trends. Currently, at the stand level, average canopy bulk density in the ponderosa pine of the treatment area averages around 0.061 kg/m3, with 61 percent of the pine having a canopy bulk density greater than .05 kg/m3. Currently the canopy base height in the treatment area average is approximately 15 feet.

Table 21. Modeled canopy characteristics for Existing Conditions

Desired openness	Existing Conditions			Percent of Ponderosa Pine
	CBH (feet)	CBD (kg/m3)	CC (%)	
High	15.16	0.066	68	34
Moderate	14.74	0.061	66	27
Low (Mechanical)	16.42	0.063	67	7
Low (Burn-Only)	14.01	0.047	58	21
Very Low (Burn-Only)	15.95	0.062	69	4
Very Low (Mechanical)	14.30	0.063	70	2
Very Low (PAC Burn-Only)	14.29	0.067	72	4
Very Low (MSO Core Areas)	14.09	0.071	76	1
Weighted Average[2]	**14.84**	**0.061**	66	

Surface fuels: Litter, Duff, and Coarse Woody Debris greater than 3” diameter

Wildland fuels are composed of various categories of fuels, including live and dead, small and large, and so on. Each play a different roles in fire behavior and effects. Litter, duff, and Coarse Woody Debris greater than 3 inches in diameter (CWD>3 inches) affect fire behavior and effects, including emissions. They contribute more than other fuels to total emissions in prescribed fires because prescribed fires are almost exclusively surface fires, and very little of the canopy fuels are generally consumed. With a crown fire, large amounts of canopy fuels over a relatively short duration. Both wildfire and prescribed fire consume surface fuels. The heat produced by smaller woody debris (<3 inches in diameter), mostly goes upwards, having less of an effect on surface fire effects than litter, duff, or larger woody fuels. Additionally, small woody fuels generally burn quickly, contributing less

[2] Weighted averages for desired openness are based on the number of acres of ponderosa pine proposed for treatment under each alterantive. For Alternative A, the maximum proposed treatment area was used (593, 211 acres).

to troublesome emissions, than litter, duff and CWD. These three fuel components also tend to represent the majority of surface fuels by weight. These surface fuels are far more likely to cause high severity effects to soil because they can smolder in place for long periods, transferring more heat into the soil, cambiums, and other surface and soil components of an ecosystem than aerial fuels (fuels that are not in contact with the surface) and produce troublesome emissions. Mechanical thinning alone can contribute significantly to decreasing the potential for crown fire by breaking up vertical and horizontal canopy fuel continuity, but does little, in the long run, to decrease surface fuel loading. Initial thinning impacts may include temporary fire 'breaks' where there are skid trails, or other surface disturbances, but surface fuels are generally not removed from the treatment area, and remain a potential source of heat and emissions. Post mechanical thinning often increases surface fuel loading by small amounts (Fule et al., 2012). Effects may be spottier but, where fuels have been pushed into piles or furrows (intentionally or otherwise), they may smolder for a long time.

When averaged by desired openness (Table 22), CWD is lower than recommended levels (see shaded areas), in all but the two lowest levels of openness. Duff levels exceed historic levels in all categories.

Table 22. Existing Condition of litter, duff, and CWD > 3" (in tons/acre)

Existing Conditions					Percent of ponderosa pine
Desired openness	CWD	Litter	Duff	Total	
High	3.9	3.5	3.4	10.8	34
Moderate	3.6	3.9	3.1	10.7	27
Low (Mechanical)	3.8	3.2	3.3	10.3	7
Low (Burn Only)	3.2	2.5	2.9	8.6	21
Very Low (Burn Only)	4.7	4.4	3.6	12.7	4
Very Low (Mechanical)	4.6	4.5	4.0	13.0	2
Very Low (PAC Burn Only)	6.0	4.8	5.1	15.9	4
Very Low (Core Areas)	5.9	5.0	4.8	15.7	1
Weighted Average[3]	3.8	3.5	3.3	10.7	

In the existing condition, shown in Figure 31, the majority of the area that currently exceeds recommended levels for surface fuel loading is near, or associated with MSO habitat. Figure 30 shows heavy fuel loading within the project area in a PAC on Mormon Mountain in 2011. In this location, litter was 8-12 inches deep, with several inches of duff beneath it and large logs scattered about. This location probably has around 15 tons of CWD, and another 10 or more tons of litter and duff. While this is one end of the extremes for fuel loading, it is an extremely hazardous condition from the perspective of fire behavior and effects. If a wildfire burned though this area, even under moderate conditions, the effect to the area could be devastating, with high tree mortality, loss of soil productivity, and total loss of habitat. This condition is not a large portion of the project area, less than 50,000 acres, but it is an important component of the landscape, much of which is critical to wildlife.

[3] Weighted averages for desired openness are based on the number of acres of ponderosa pine proposed for treatment under each alterantive.

When heavy fuel loading burns, particularly fuels that smolder in place for extended periods, more heat is transferred to the soil, and can consume or kill soil biota and other organic matter in soil that is critical to soil function and productivity.

Figure 30. Very high surface fuel loading in a PAC on Mormon Mountain in 2011

The likelihood of undesirable fire behavior and effects increases with increased surface fuel loading, but could be expected in areas where fuel loading is >20 tons/acre, though there would be variations from site to site based on the conditions under which a fire burns (aspect, temperature, backing fire, headfire, etc.). Currently, there are ~3,011 acres, mostly in PACs, that have surface fuel loading greater than 20 tons/acre. There are also over 65,000 acres on which surface fuel loading is between 15 and 20 tons/acre. These 65,000 acres do not currently exceed recommended fuel loadings, but are on the high end of recommended fuel loading. However, conditions that would affect the severity of direct and indirect fire effects include environmental factors at the time of the burn such as fuel moisture, wind speed, and those factors that affect fireline intensity (page 27).

Figure 31 displays surface fuel loading of duff, litter, and coarse woody debris (>3 inches diameter) for existing conditions. The darkest blue represents areas where fuel loadings are on the high end of what is recommended from the combined perspectives of soil productivity, historic levels, soil heating, wildlife, and fire hazard (Brown et al. 2003). Yellow though red show where surface fuel loads exceed levels recommended.

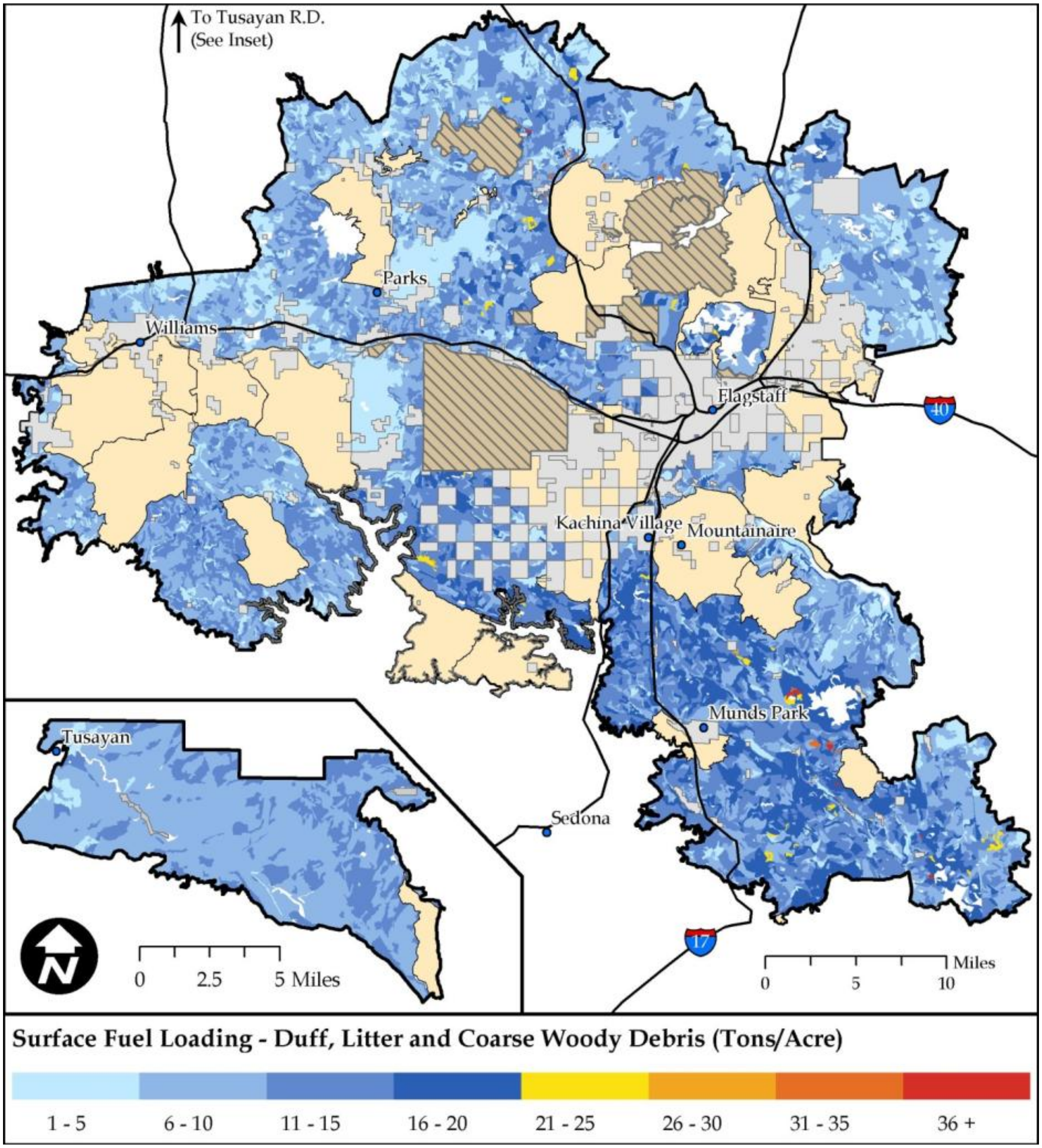

Figure 31. Surface fuel loading of duff + litter + Coarse Woody Debris (>3" diameter)

Fire Regime/Condition Class (FRCC)

Figure 32 shows a landscape within the project area that was mostly in a Condition Class 1 around 1880. The photograph shows evidence of grazing in foreground, but wide open meadows with scattered individual trees in background. Figure 33 shows the same area around 1980 in Condition Class 3. Note heavy invasion and infill by conifers in meadows. Fern Mountain can be seen in the background. The desired condition would be to have the entire treatment area in a Condition Class 1.

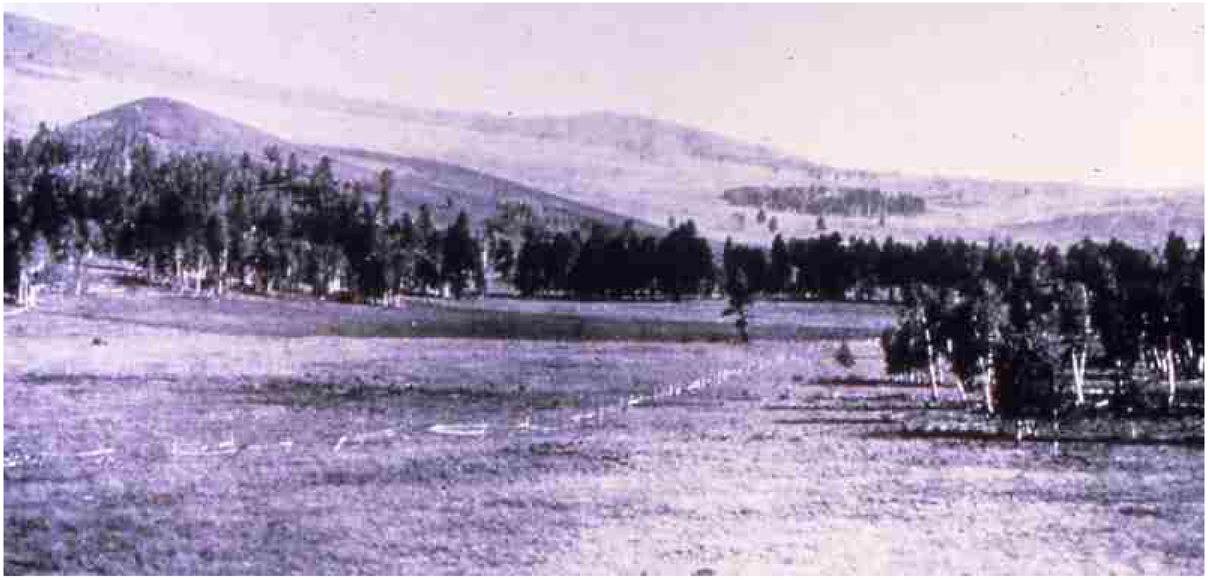

Figure 32. Montane Grasslands on west side of San Francisco Peaks, near Flagstaff, AZ. Circa 1880

Figure 33. Same area as above. Circa 1980

Table 23 shows 59 percent of ponderosa pine and savanna (287,768 acres) is currently classified as FRCC3, indicating the ecosystem is highly departed from its historical range, and an additional 27 percent as FRCC2, indicating the ecosystem is moderately departed from its historical range. In grasslands, the second largest area proposed for treatment (56,093 acres), 10 percent (5,610 acres) is classified as FRCC3, with an additional 75 percent (40,389 acres) in FRCC2. Only 14 percent of the combined area of grasslands and ponderosa pines is in Condition Class 1; the desired condition is to have 100 percent of the treatment area in FRCC1.

Table 23. Fire Regime/Condition Class (FRCC), Existing Condition

	Ponderosa Pine Existing Condition			Grasslands Existing Condition		
FRCC	**FRCC1**	**FRCC2**	**FRCC3**	**FRCC1**	**FRCC2**	**FRCC3**
Acres	70,680	136,311	297,866	10,097	40,389	5,610
Percent	14	27	59	18	72	10

Fire Return Interval

FRI is one factor used to calculate Fire Regime/Condition Class (pg. 21) and can be used as a coarse indicator of the status of an area. As calculated for this analysis, it does not take into account seasonality, severity, average size, spatial complexity, or other important characteristics of a fire regime. The average, however, can be a useful indicator of how close or far an area is from a sustainable fire regime that can create and maintain the temporal and spatial disturbance patterns produced by the ecological functions of fire.

Fire Return Interval is closely related to fire history. The Mogollon Rim has a high density of ignitions, both lightning and human, and a large percent of the area burned with wildfire in the last 10 years (Figure 34). Approximately 30 percent of the area burned by fires greater than 1,000 acres in the last 25 years (not counting WFU) produced high severity effects. Many of these areas have been slow to regenerate and remain open areas with excessive CWD in an area dominated by herbaceous vegetation. Prescribed fire has focused in a ‘donut’ around the Flagstaff area, and near other high risk areas. In Figure 34, the spatial layers are translucent to show areas with multiple burns.

For ponderosa pine in the project area, the historic fire return interval ranged from 2 to 22 years (Weaver 1951, Cooper 1960, Swetnam 1990, Swetnam and Baison 1990, Fulé et al. 1997a, Fulé et al. 2003, Covington et al. 1997, Heinlein et al. 2005). The fire return interval from 2001 through 2010, was calculated to be 43 years for the ponderosa pine and grassland in the EIS analysis area. These calculations included planned and unplanned ignitions, indicates a current fire return interval of ~43 years with ~34,000 acres burning annually from 2001 to 2010. This FRI is an average that includes both areas that have burned much more frequently than every 43 years, and areas that have burned at a much longer frequency. It was only calculated between 2001 to 2010 because the consistency of the data between forests was less dependable before 2010, and the work was done in the fall of 2010. This is double the desired maximum average for ponderosa pine on the Mogollon Rim. This fire return interval of 40 years, has contributed to the degree of departure from historic conditions that puts over 34 percent of the area proposed for treatment area at risk of high severity fire effects based on crown fire alone. From 2001 through September of 2010, average acres burned over the project area, including both wildfire and prescribed fire were approximately 15,000.

Air Quality and Smoke Effects

Wildland fire emissions, can cause adverse health effects and/or become a nuisance, but are fundamental to the disturbance ecology associated with healthy ecosystems in the project area. Because fire is a necessary part of the equation, air quality impacts are part of all action alternatives in one form or another. All action alternatives propose using prescribed fire extensively, and all expected to achieve the desired conditions for air quality. Air quality within the project area currently meets EPA air quality standards.

Desired conditions do not currently exist for Air Quality on both the Kaibab and Coconino National Forests, but the desired conditions in this analysis are:

- Air quality meets all State and Federal ambient air quality standards.
- Visibility in Grand Canyon National Park, and Sycamore Canyon, Class 1 areas, makes reasonable progress towards, or meets national visibility goals established in the Clean Air Act, the Regional haze Rule, and the Arizona State Implementation Plan.

The management action that has the greatest potential effect on air quality is prescribed burning. All prescribed fires are expected to achieve the desired conditions for air quality under all alternatives, and hence, Air Quality is not expected to be a primary driver in selecting one alternative over another.

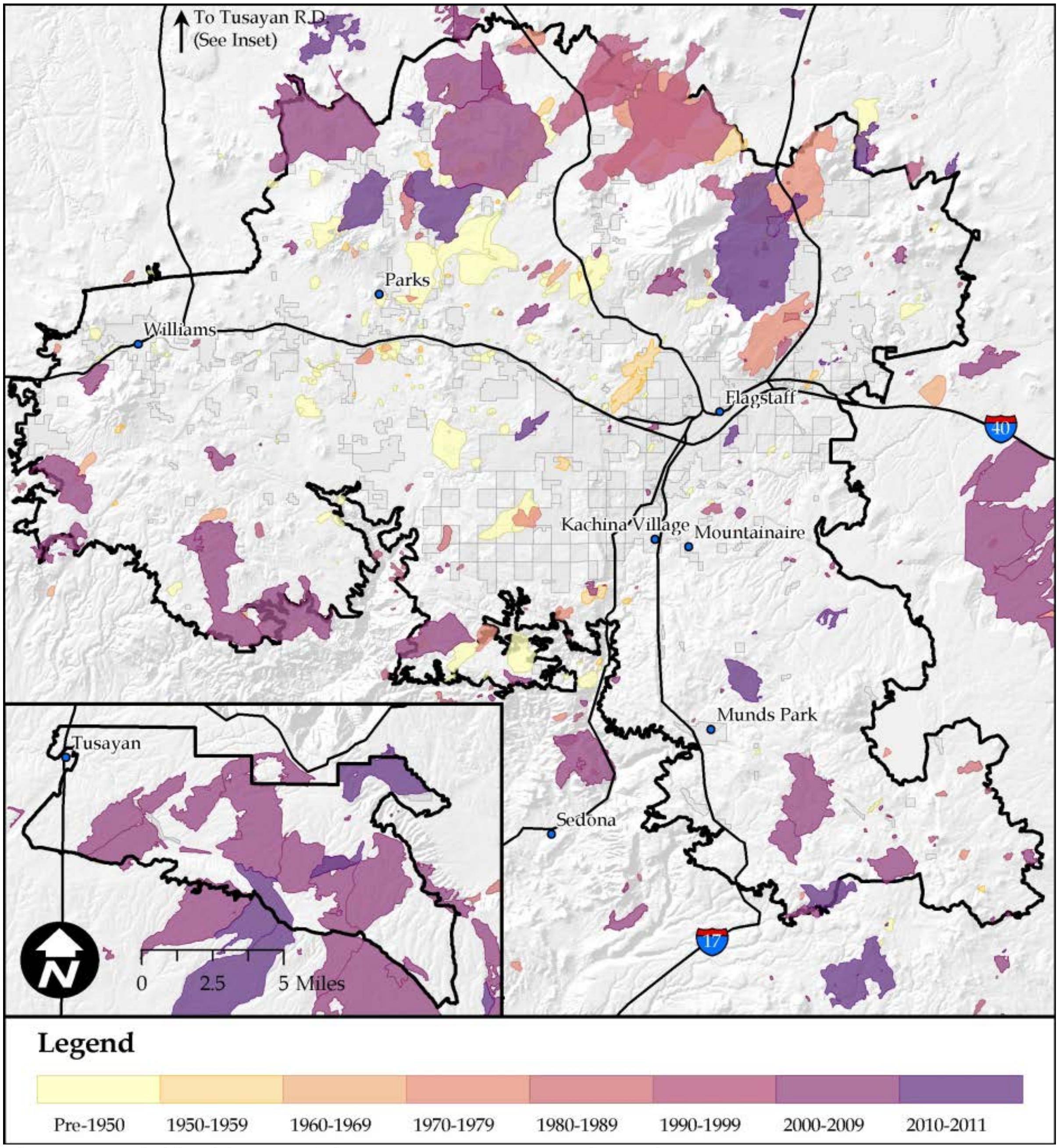

Figure 34. Wildfire history of the 4FRI area pre-1950 through 2011

Some comparison between alternatives can be made by looking at the indirect effects of management activities that reduce the likelihood of high severity fires. High severity active crown fires produce large quantities of emissions that are often heavily concentrated. The alternatives that best alter stand structure to promote surface fire over active crown fire and decrease surface fuel loading would have the least negative environmental consequences to Air Quality, and are the focus of comparison between alternatives regarding Air Quality in this report.

Wildfire vs. Prescribed Fire

National Forests are increasingly using prescribed burns, and wildfires to achieve resource objectives, and to reduce the risk of wildfires that are larger and of higher severity than is desirable (see Appendix A). Federal land managers have conflicting roles when it comes to protecting visibility in Class I areas, or managing nuisance smoke. On the one hand, they are given the responsibility of protecting and meeting visibility standards and being responsive to public tolerances. On the other hand they are tasked to allow fire, as nearly as possible, to function in its natural role in the ecosystem (USDA, USDI 1995). This puts the land manager in the awkward position of contributing to emissions, and needing to explain why smoke from wildland fires may be acceptable, while other types of pollution (i.e. Auto emissions, industrial emissions) are not. So in this context, smoke and visibility impairment from wildland fire that closely mimics what would occur naturally may generally be viewed as acceptable (Peterson 2001).

Wildfires contribute to air quality impacts, and their emissions are monitored in the same manner as emissions sources that can be controlled (such as dust, vehicle emissions, smoke from wood-burning stoves, industrial emissions, prescribed fire, etc.), and included in air quality assessments used to approve burn plans. Smoke impacts from wildfire are less easily mitigated than prescribed fire, whether the expected effects of the fire are desirable or not. Among the many factors fire managers and line officers must carefully weigh when deciding whether to suppress a wildfire, manage it to perform its natural role as in the ecosystem, or to ignite a prescribed fire is whether the potential benefits of the wildfire outweigh the smoke impacts to the airshed, affected communities, and rural residents. Prescribed fires and wildfires both create smoke, but differ in the amount, timing, and predictability of these events (Table 24). Most wildfires occur during the summer months.

Table 24. Generalized comparison of options for managing fire on federal land

Emission characteristics	Planned ignitions	Unplanned ignitions
Predictability of **when** smoke events occur	Predictable	Somewhat predictable to unpredictable
Predictability of the **severity** (concentration) of smoke impacts	Predictable	Somewhat predictable to unpredictable
Predictability of **where** there will be smoke impacts	Mostly predictable	Somewhat predictable to unpredictable (knowing where a fire will start)
Controllability of smoke	Mostly controllable	Mostly controllable to uncontrollable
Duration of smoke events	Days or weeks	Days, weeks, or months
Frequency of smoke events	Intermittent to frequent and increasing	Intermittent to frequent during the fire season, likely to increase
Severity/desirability of the effects of the fire	Mostly desirable	Mostly desirable to mostly undesirable
Longevity of negative effects	Short to moderate	Short to permanent
Extent of negative effects	Small, unlikely to be more than a few contiguous acres if it occurs	Variable, ranging from less than an acre to hundreds of thousands of acres
Potential for significant negative effects	Low, but present	Low to very high

(other than smoke), such as downstream flooding or damage to infrastructure outside the fire perimeter		
Threat to human life and property	Low, but present	Low to very high

Fire managers are able to manage smoke impacts to some degree by timing prescribed fire and, to some degree burn out operations on wildfires, to occur when ventilation conditions are favorable. It may be possible to check a fire's edge on days when reduced emissions are needed, or blackline burn units days or even weeks in advance of burning the main units of a prescribed fire in order to best take advantage of burn windows with good ventilation. Various Emissions Reductions Techniques are utilized and documented as a standard part of implementing prescribed fires. (ERTs are listed in Appendix E). A 'Daily Burn Accomplishment Form' is completed and submitted for each day a burn is being implemented (see Appendix E). Activities on prescribed fires and wildfires in an airshed are coordinated between fire managers, in conjunction with ADEQ, to either spread high emission producing events from multiple wildfires over several days to reduce the concentration of pollutants, or facilitate these events to occur simultaneously on days with favorable ventilation to move the pollutants up and out of the airshed all at once to reduce the duration of smoke impacts.

In the last ten years, acres of prescribed fire have increased across both forests, though the actual amount fluctuates from year to year (Figure 35). Actual smoke impacts are dependent on numerous unforeseeable factors such as ventilation parameters, live and dead fuel moisture, wind direction and speed, firing techniques, timing and duration of ignition, fuel arrangements and loading, atmospheric stability, and more. Air quality impacts are related much more closely to these factors than the 4FRI Alternatives.

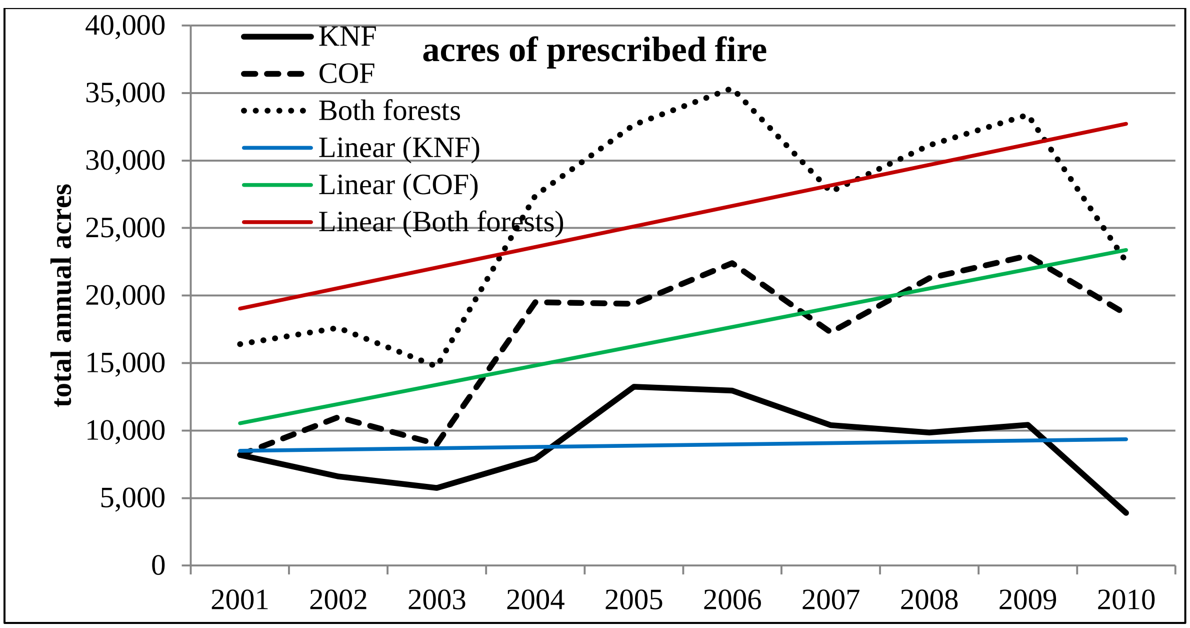

Figure 35. Acres of prescribed fire and trends for both forests from 2001 through 2010

Smoke is inevitable in the airsheds of northern Arizona, whether from wildfire, or prescribed fire. Smoke can travel great distances and affect communities far away from the burn unit, often persisting for a time after the burn has been completed. Fires burning under historic conditions (wildfire or prescribed fire) produce behavior and effects that are low to moderate. Fires that burn under more extreme conditions (most/all fires in this category are wildfires) produce behavior and effects that are moderate to severe. Air quality effects from large, high severity fires usually creates more emissions over a longer time than prescribed burning, because of differences in the size and duration of the fires (Hardy et al. 2001b pg. 93) and the amount of fuel consumed.

Prescribed burning is implemented only with approved site specific burn plans and with smoke management mitigation and approvals. All burning is conducted according to Arizona Department of Environmental Quality standards and regulations, including the legal limits to smoke emissions from prescribed burns as imposed by Federal and State Law. The Arizona Department of Environmental Quality ADEQ) enforces these laws by regulating acres that are treated based on expected air impacts. These regulations ensure that effects from all burning within the area are mitigated and that Clean Air Act requirements are met. Prescribed fires are initiated under conditions that allow managers to meet both control objectives (fire behavior), and resource objectives (fire effects, including air quality impacts). Figure 35 charts acres of prescribed fire in the last 10 years and the trends for both forests. The red line is the average for both forests; green is average for the Coconino National Forest (COF); and the blue line is the average for the Kaibab National Forest (KNF).

Meteorological, Climatological and Topographical effects on Air Quality

Climatological limits are set by weather and fuel moisture, which profoundly affect fire behavior, fire effects, and the behavior and effects of emissions. As weather varies from year to year, so does the risk of high severity fires and the ability to use prescribed burns and wildfires to achieve resource objectives. Large fluctuations in the number of days of opportunity vary widely from year to year, creating large fluctuations in the number of acres treated with wildland fire. Running averages over many years must be used in order to view trends in fire use or fire effects (Kleindienst 2012).

Topography and weather patterns determine the extent to which airborne particulate matter accumulates within local airsheds. Diurnal temperature changes affect how pollutants in the region are dispersed. Meteorological conditions also limit how much smoke the airshed can absorb at any point in time without violating NAAQS (details on page 11) or visibility thresholds. During the warmest days and seasons of the year, air is heated at the surface, and rises, lifting smoke up to heights where transport winds carry it away and disperse it during the daily burn periods. Winds in the project area are predominantly from the south, southwest, and west (figure 36) and, as such, during daytime hours, fire activities within the 4FRI treatment area are most likely to affect smoke sensitive receptors to the north, northeast, and east of fire locations. The best ‘windows’ for smoke dispersal are when the atmosphere is unstable, allowing smoke to rise up high and disperse. These conditions, when combined with low fuel moistures and high fuel loading, can also lead to undesirable fire behavior and effects. The best dispersal days are often too extreme for prescribed fire. Overnight, winds often become calm, allowing topographic effects to dominate smoke movement. As the temperature decreases, air flows downhill, carrying smoke from smoldering fuels (duff, needles, dead/down wood), which will often ‘pool’ in low lying areas until the air warms again the next day. Nighttime settling of residual smoke from fires generates as many concerns and complaints of nuisance smoke as daytime smoke. “Nuisance Smoke” is defined in the State Implementation Plan (pg 12) as “Amounts of smoke in the ambient air which interfere with a right or privilege common to members of the public, including the use or enjoyment of public or private resources” (Arizona State Implementation Plan Appendix A-10 page 35)

Figure 35 shows the prevailing wind direction for each of three Remote Automated Weather Stations (RAWS) that are used to determine overall weather patterns in the area. Flagstaff (left), Mormon Lake (middle), and Tusayan (right). For each RAWS, a wind rose shows the average wind speed and direction for a year; from November through April, and from April through October. Prevailing winds are from the west, southwest, and south during the day. Night-time winds are calm most of the time, allowing topography to be the main control on the movement of emissions so, for multiple consecutive burn days, there are likely to be smoke impacts in low area and, for most prescribed burns during the day, there is some potential for smoke impacts to locations north, northeast, and/or east of the burn unit.

During the winter, weather conditions can trap emissions in a layer of cold surface air (inversion). Under winter conditions and inversions particulates can be trapped close the surface in local airsheds, including Flagstaff, Williams, and the Verde Valley. Visibility is also an air quality consideration. Visibility tends to be lowest in the summer due to regional haze and smoke from fires.

Emissions and Public Health

Air pollutants called particulate matter include dust, dirt, soot, smoke and liquid droplets directly emitted into the air by sources such as factories, power plants, cars, construction activity, fires and natural windblown dust. The Clean Air Act establishes National Ambient Air Quality Standards (NAAQS) for six principal pollutants that pose health hazards: carbon monoxide (CO), lead, nitrogen dioxide, particulate matter less than 10 microns in size (PM 10), particulate matter less than 2.5 microns in size (PM 2.5), ozone, and sulfur dioxide.

Particulate Matter (PM)

The pollutant form of greatest concern from wildland fire, including both prescribed fires and wildfires is particulate matter (PM), (Ottmar 2001, Graham 2012), although fire also creates other criteria pollutants and visibility impacts. Particulate matter is defined as tiny particles of solid or semi-solid material suspended in the air. Particles may range in size from less than 0.1 microns to 50 microns. Particles larger than 10 microns tend to settle out of the air quickly and are not likely to affect public health; smaller particles remain airborne, are considered inhalable, and have the greatest health effects.

Total suspended particulate (TSP) was the first indicator used to represent suspended particles in the ambient air. EPA used the indicator PM-10 starting in 1987, which included only those PM-10 particles in the ambient air. In July of 1997, however, EPA adopted the indicator PM-2.5, which includes only those particles with aerodynamic diameter smaller than 2.5 micrometers.

Fine particulate matter is the major pollutant of concern in smoke from wildland fire, including prescribed burns and wildfires (Ottmar 2001). Studies indicate that 90 percent of smoke particles emitted during wildland fires are PM 10, and about 90 percent of PM 10 is PM 2.5 (Ward and Hardy 1991). Human health studies on the effects of particulate matter indicate that it is PM 2.5 that is largely responsible for health effects (Dockery et al. 1993). Because of its small size PM 2.5 has an especially long residence time in the atmosphere and penetrates deeply into the lungs (Ottmar 2001).

The Clean Air Act defines the NAAQS for PM 2.5 as an annual mean of 15µg/m^3, and a 24 hour average of 35µg/m^3. At this concentration or above, PM 2.5 is considered to have a detrimental effect on public health. It is important to note that it is not the total amount of emissions from a fire that have effects on human health, but rather how concentrated pollutants in ambient air are for a period of time.

Atmospheric conditions during a fire have a considerable influence on how particulate matter is distributed though the ambient air, and its potential to affect public health. Wind speed and direction, mixing layer height, atmospheric temperature profile upward in the atmosphere, and atmospheric stability all impact where and how well smoke will disperse. Particles from 2.5 microns to 10 microns in diameter come from many sources. In many cases windblown dust and dust kicked up on unpaved roads by vehicle traffic account for much of this fine particulate matter (Kleindienst 2012).

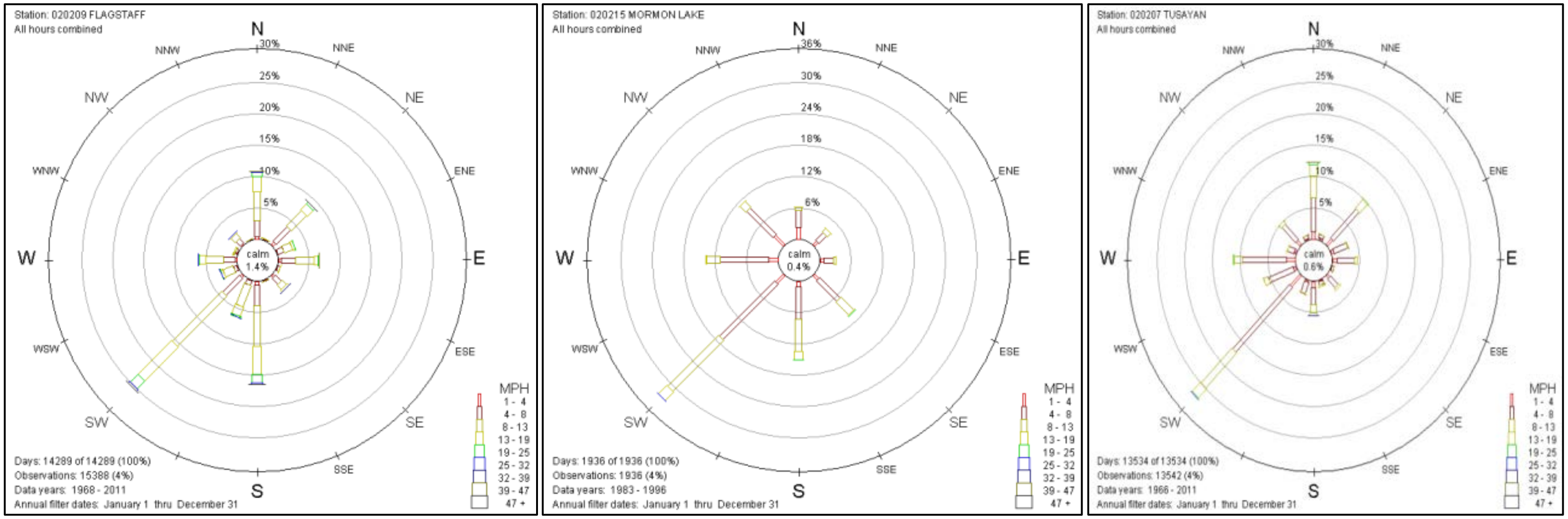

Figure 37. Wind roses from the three Remote Automated Weather Stations (RAWS) showing average winds in the project area

Studies of human populations exposed to high concentrations of particles (sometimes in the presence of SO2) and laboratory studies of animals and humans, indicate there is potential for detrimental effects on human health. These include effects on respiratory symptoms, aggravation of existing respiratory and cardiovascular disease, alterations in the body's defense systems against foreign materials, damage to lung tissue, carcinogenesis, and premature death. The major subgroups of the population that appear to be most sensitive to the effect of particulate matter include individuals with chronic obstructive pulmonary or cardiovascular disease of influenza, asthmatics, the elderly and children. Particulate matter also soils and damages materials and is a major cause of visibility impairment. The same particulate matter that poses health risks is also largely responsible for these impairments to visibility. "The combination of light absorption by elemental carbon and light scattering caused by the very small particles that make up wildland fire smoke explains why emissions from wildland fire play such an important role in visibility impairment (Core 2001a)."

Management activities with the largest direct impact on Air Quality are prescribed burns. Road dust has not been demonstrated to be a measurable contributor on a regional level to visibility in the 16 Class I areas located on the Colorado Plateau (ADEQ 2003). The Kaibab National Forest has burned approximately 8,000 acres/ year with prescribed fire in ponderosa pine since 2000. When wildfire acres are added, the Kaibab averaged about 17,000 acres a year (in ponderosa pine) from 2001 through fall of 2010. From 2001 through fall of 2010, the Coconino NF averaged a little over 13,000 acres of prescribed fire in ponderosa pine. When wildfire acres are added, the Coconino averaged approximately 20,000 acres in ponderosa pine for that same period. No notice of violation of NAAQS standards has ever been issued to the Kaibab NF. Over the same period of time, one exceedence occurred on the Coconino National Forest. It occurred on one monitor for one day for an exceedence in $PM_{2.5}$ in Flagstaff in 2007 (Figure 36 and Figure 37). Figure 36 charts PM 2.5 levels from January 2001 through November of 2011. The dotted line indicates the NAAQS for PM 2.5, which is 35 ug/m3*). NAAQS for PM 10 (Figure 37) is 150.

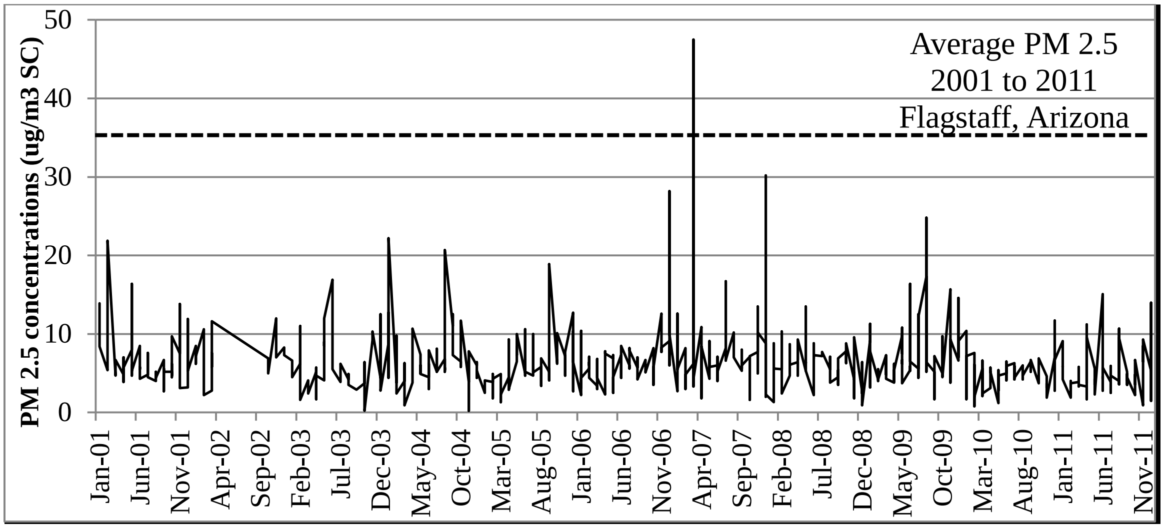

Figure 36. PM 2.5 levels from January 2001 through November 2011 in Flagstaff, AZ. (*ug/m^3 = micrograms per square meter)

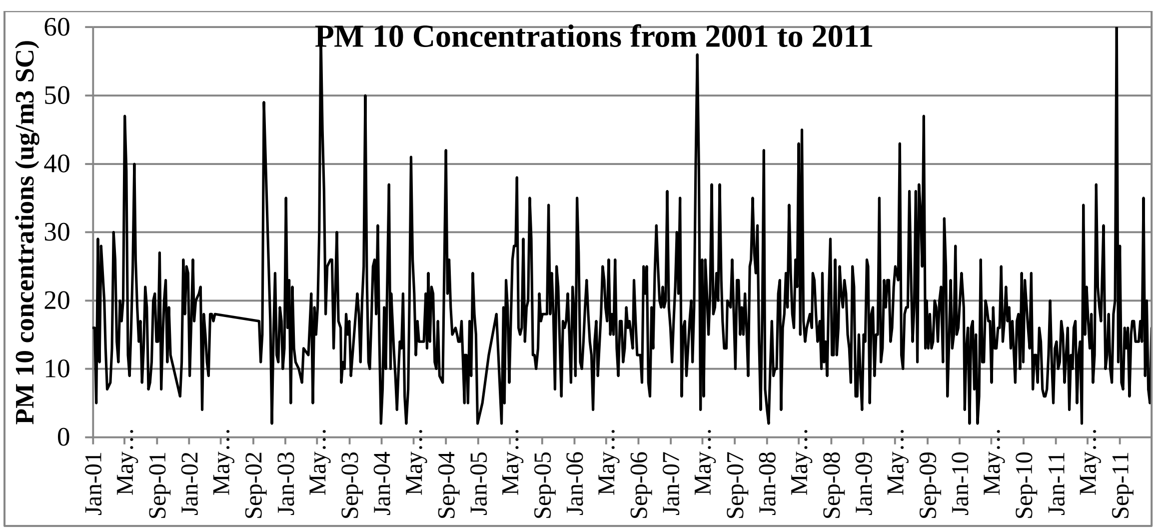

Figure 37. PM 10 levels from January 2001 through November 2011

Fugitive dust

Heavy equipment used on paved and unpaved roads during the implementation of projects has the potential to create localized impacts from fugitive dust. With high wind events, this fugitive dust has the potential to be carried for several kilometers. Control measures developed for site specific projects can reduce these localized particulate matter emissions, such as reducing travel speeds on unpaved surfaces, ceasing work activities during periods of high winds, applying gravel or soil stabilizers on dust problem areas, covering loads, and covering ground surfaces with water during earth moving activities (BLM 2011). There will be dust abatement measures on about 7 miles of roads in areas of concern.

Radioactive emissions

Concerns have been raised about the potential for smoke from prescribed fire treatments proposed in 4FRI to contain radioactive substances. During the Cerro Grand fire of 2000, there was also considerable public concern regarding the potential release of radionuclides from the Los Alamos National Laboratory (LANL). The following risk summary is from "2002 Fact Sheet: Cerro Grand Fire Releases to Air" which may be viewed at: ftp://ftp.nmenv.state.nm.us/www/doe/publications/lanl/2002FireAirFactSheet.pdf

"The primary health risks during the Cerro Grande fire were associated with breathing materials released into the air. It was estimated the risk of cancer from breathing any LANL-derived chemical or radioactive material that may have been carried in the smoke plume to be less than 1 chance in 10 million. Potential exposures in the surrounding communities to LANL-derived chemicals that are not carcinogenic were about 10 times lower than acceptable intakes established by the U.S. Environmental Protection Agency (EPA). The risk of cancer from breathing chemicals and radioactive materials in and on the natural vegetation that burned in the Cerro Grande Fire was greater than that from LANL derived materials, but still less than 1 chance in 1 million. The vegetation that burned contained naturally occurring chemicals and radioactive materials and radioactive fallout produced during atmospheric tests of nuclear weapons. These materials and the risks they posed are present during any forest fire. The evidence suggests that some adverse health effects did result from breathing high concentrations of particulate matter in the smoke. Such exposures are associated with any forest fire. Deposition of LANL-derived chemicals and radioactive materials from the smoke plume to the soil was minimal."

Following the Cerro Grande fire that burned the city of Los Alamos and the Los Alamos National Laboratory (LANL) in New Mexico in 2000, the US Environmental Protection Agency (EPA), New Mexico Environment Department (NMED), and LANL partnered with Department of Energy to operate radiological monitoring systems as well as to initiate several studies to assess the impacts of the fire. The results of these efforts with regard to air quality and human health impact indicated that radionuclides originating from the LANL site during the Cerro Grande Fire were restricted to naturally occurring radionuclides.

LANL, the Department of Energy, and NMED monitored radionuclide concentrations in smoke from the Las Conchas fire that burned through the Los Alamos area in the summer of 2011 and reported no significant detection levels (http://www.nmenv.state.nm.us/aqb/WildfireSmokeResources).

A study that included Lockett Meadow, within the EIS analysis area, found levels of radioactive materials in the soil were no different than background levels, and would provide no added human health risk (Ketterer et al 2004, Graham 2012a).

Communication with the EPA (Gerdes 2012, Graham 2012a), and studies that addressed these emissions (Schollnberger et al. 2002) indicate that radioactive isotopes and other undesirable chemicals are present in wildfire emissions. Some are naturally occurring chemicals that have always been present at some level in wildfire smoke and some have resulted from the weapons testing that occurred in the mid-20th century. At the level of exposure the public is subjected to, radionuclides do not pose as great a risk as wildfire. Radioactive material that may be carried in the smoke plume carries a risk of human health concerns of less than 1 chance in 10 million (NMED 2002, Graham 2012a) and the greatest health risk is from breathing high concentrations of particulate matter in the smoke.

Smoke Sensitive Areas and Sensitive Receptors

The Regional Haze State Implementation Plan for Arizona defines ‘sensitive receptors’ as “population centers such as towns and villages, camp grounds and trails, hospitals, nursing homes, schools, roads, airports, mandatory Class I Federal areas, etc. where smoke and air pollutants can adversely affect public health, safety, and welfare” (State Implementation Plan, Appendix A-10 page 36). Several smoke sensitive areas lay within the airsheds of the areas proposed for treatment (Table 25). The list is not inclusive, and we recognize that there are a number of communities within, adjacent, or sometimes downwind of the project that are likely to have some impacts of smoke from 4FRI activities and are not listed. While these areas do not necessarily meet the official definition of smoke sensitive, we are aware of smoke-sensitive populations in airsheds that could be impacted by prescribed fire, and experience has shown that these areas need to be considered when planning and executing prescribed fires.

Table 25. Smoke sensitive areas and sensitive receptors

Area	Proximity to implementation area	Concerns
Flagstaff	Within boundaries or directly adjacent in all directions	Hospital, schools, human habitation, visibility, young children, Interstate visibility
Williams	Within boundaries or directly adjacent in all directions	Hospital, schools, human habitation, visibility, young children, Interstate visibility
Verde Valley	Less than 10 miles downslope south and southwest.	Hospital, schools, human habitation, visibility, young children.
Grand Canyon National Park	Adjacent to the northern boundary of EIS analysis area	Class I airshed, school, human habitation, campgrounds
Havasupai Reservation	Approximately 50 miles Northwest of the EIS analysis area	Hospital, schools, human habitation, visibility, young children, elders.
Navajo Reservation	Northeast and east of the EIS analysis area	Hospital, schools, human habitation, visibility, young children, elders.
Hualapai Reservation	Approximately 50 miles west of the EIS analysis area	Hospital, schools, human habitation, visibility, young children, elders.
Hopi Reservation	Northeast of the EIS analysis area	Hospital, schools, human habitation, visibility, young children, elders.

A Class I area is an area classification that requires the highest level of protection under the Clean Air Act of 1963. Projects which may potentially impact Class I areas must address efforts to minimize smoke impacts on visibility. Class I areas most likely to be impacted by activities in the

4FRI project area are the Grand Canyon National Park and Sycamore Canyon Wilderness Area. The national visibility goal of the Clean Air Act is, "the prevention of any future, and the remedying of any existing, impairment of visibility in mandatory Class I areas in which impairment results from manmade air pollution." Wildfires are considered to be natural sources of visibility impairment, and generally outside state control or prevention.

Coconino County enjoys good air quality most of the time. Less than 1 percent of days per year rated in the Unhealthy for Sensitive Groups category, and no days were rated Unhealthy, Very Unhealthy or Hazardous (US EPA 2010).

Non-attainment areas are where air quality has violated one or more of the National Ambient Air Quality Standards (pg 11). If a project area is within attainment, no additional requirements of the Regional Haze Rule State Implementation Plan administered by the ADEQ apply. The State Implementation Plan (40 CFR 51.309(d) (7)) for Arizona from December 23, 2003 states that "road dust is not a measurable contributor on a regional level to visibility impairment in the 16 Class I areas. There are no non-attainment zones that are expected to be affected by any of the alternatives in this project.

No NAAQS are in non-attainment over the project area. On rare occasions, pollution from distant large population centers in California affects the air quality in the area. Huge dust storms that occur in the Phoenix valley can produce large amounts fugitive dust that have also been known to affect air quality in Northern Arizona, but these events are generally limited to a few days a year. Ozone is also a NAAQS pollutant. Levels are increasing, and are trending up in northern Arizona (Kleindienst, 2012). Natural background ozone concentrations are naturally high in the West; transport from industry and large urban areas in California and other non-local sources also contributes significantly (Koo and others 2010, Tong and Mauzerall 2008). Under current regulations, ozone levels in northern Arizona are largely outside of the regulatory control of the State of Arizona. Spikes seen in ozone levels do not correlate with fire activity although, under certain weather conditions, smoke from fires has the potential to create ozone. As yet, data on how much ozone is created from wildland fire, or prescriptive criteria to deter ozone creation are not available. The airsheds 1, 3, and 5 (Figure 38) can be expected to experience the majority of the smoke impacts originating from the proposed treatment area, with rare instances of mild impacts in airshed 6.

Permits are issued by the Arizona Department of Environmental Quality (ADEQ), who help to monitor/manage potential smoke impacts by tracking what is burning at any given time. The ADEQ currently has air quality monitors in Campe Verde, Sedona, Flagstaff, Prescott, Show Low, and Springerville, with additional monitors that can be set up if when there are specific concerns. Outputs of these monitors are available online at:

http://www. phoenixvis.net/PPMmain.aspx.

Cumulative effects from prescribed burns and from wildfires that are not being actively suppressed on Federal, State, and Tribal lands, are largely mitigated through implementation of the Enhanced Smoke Management Program, in the Arizona Smoke Implementation Plan (SIP), by the Smoke Management Group. When the Federal land managers actively began prescribed burn programs in the 1970s, they became rapidly aware that a pro-active program for the coordination of prescribed burns would be vital to obtain and continue support of prescribed burning programs by ADEQ and the public. An interagency Smoke Management Group was developed in

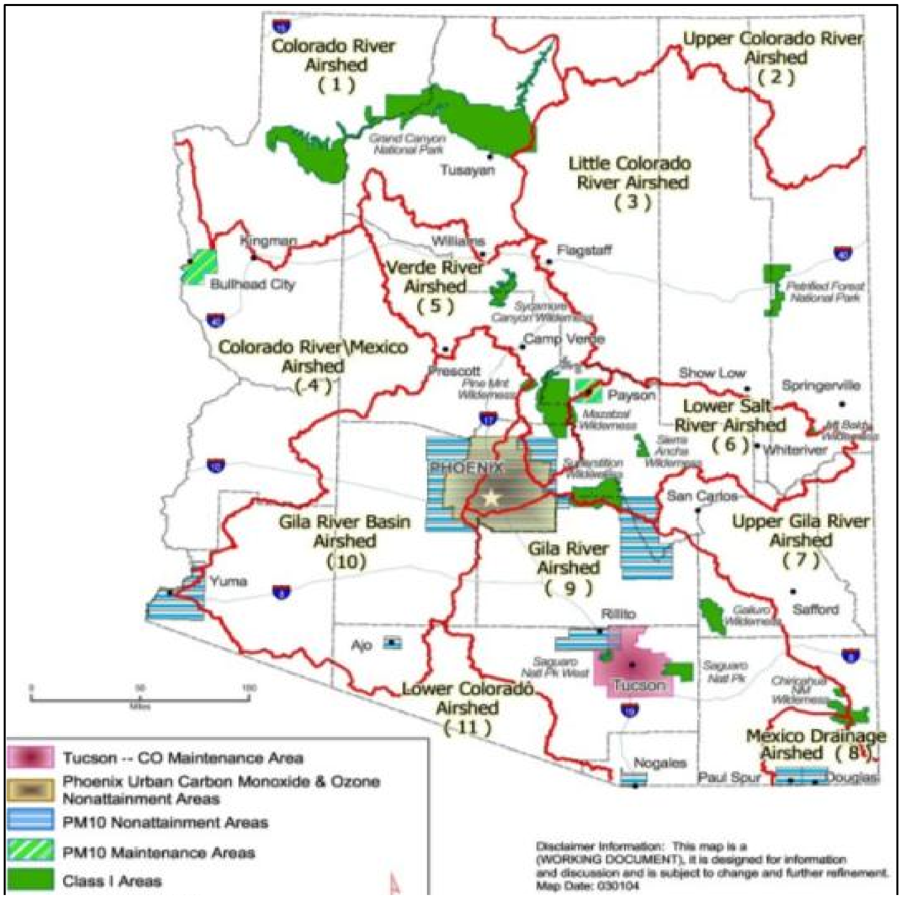

Figure 38. Airsheds defined by the Arizona Department of Environmental Quality

partnership with the State, and housed in the ADEQ offices in Phoenix. The personnel in the group are funded largely by the Federal agencies, demonstrating the initiative of the agencies to, in some degree, self-regulate emissions production from prescribed burns, across Federal and State boundaries. This group assists land managers in not exceeding NAAQS or visibility thresholds through the following services:

- Serves as a central collection point for all burn requests from the numerous Federal, State, and Tribal land managers who are all competing to produce smoke that will impact the same airsheds during limited windows of opportunity.
- Evaluates potential emissions from individual and multiple, and determines how meteorological forecasts will affect smoke concentrations both during the burn, and during diurnal settling. The Group considers cross-boundary impacts; and weighs burning decisions against possible health, visibility, and nuisance effects.
- Assists in coordinating activities within and between agencies when potential emissions would likely exceed desired conditions.
- Makes recommendations on the approval or disapproval of each burn request to ADEQ officials.
- Tracks the use of Best Management Practices and Emission Reduction Techniques used by land managers, to document efforts by land managers to minimize impacts to Air

Quality. This information is used promote support from both ADEQ and the public.

- Monitors data gathered from the IMPROVE network to assess visibility impacts in Class I areas, and track progress towards Arizona SIP goals.

While emissions from wildfires are not regulated, Federal, State, and Tribal land managers understand their responsibility to balance the ecological benefits of wildfires with the social impacts of the smoke they produce. The Smoke Management Group also assists land managers in this area through:

- Limiting prescribed burn approvals during periods when wildfires are already impacting an airshed.
- Making recommendations on the timing, or assisting in the coordination between units, of tactical operations such as burn outs, that will produce large amounts of emissions, so that they are done, when possible, when ventilation conditions are most favorable, or spread out over several burning periods to reduce total emissions when ventilation is not as good.
- Assisting land managers in determining the strategy to take on new wildfires. There may be enough fires burning that suppression on a new start is recommended to reduce cumulative smoke impacts even though all other fire effects would be desirable, and move the fire area towards desired conditions in the Land Management Plan.
- Acting as a sounding board for public complaints. In keeping tabs on the type and number of complaints, the Group is able to provide land managers feedback from beyond their local publics on the state of public smoke tolerance. This is vital in maintaining general public support of allowing wildfires to perform their natural role in the ecosystem under the right circumstances in future windows of opportunity.

Through the services of the Smoke Management Group, cumulative effects from wildland fire that are within the control of Federal and State Land Managers, are thus managed to keep Air Quality across Arizona within desired conditions, including not exceeding NAAQS, protecting visibility in Class I Areas, and additionally promoting general public support of prescribed burn and wildfire management programs.

Over 280 million people visit our nation’s national parks and wildernesses areas every year. Visitors expect to view the scenery through clean fresh air. To protect visibility in these areas of high scenic value, Congress designated all wilderness areas over 5,000 acres and all national parks over 6,000 acres as mandatory federal Class I areas in 1977, subject to the visibility protection requirements in the Clean Air Act.

Baseline visibility conditions have been established for the Grand Canyon National Park and Sycamore Canyon Wilderness which are the two Class I areas potentially affected by activities and wildfires in the 4FRI implementation area (Table 26). The Forest Service will continue to adhere to requirements in the Arizona State Implementation Plan to meet natural condition visibility goals. Data from Table 28 is from Fitch and Truman 2007.

The most sensitive smoke receptor in the State of Arizona is the Verde Valley, which is easily impacted with nuisance smoke from the cumulative burning on the southern part of the KNF, the eastern side of the COF, and the Western side of the Prescott National Forest, as diurnal drainage of smoke from fires settles into this valley. Considerable coordination between Forests takes place when burns and wildfires that can affect the Verde Valley take place, facilitated by the interagency Smoke Management Group housed at ADEQ. Smoke monitors in the Verde Valley (Sedona, and Camp Verde) track emissions concentrations, as well as equipment that captures images of visibility conditions. Spikes are found in particulate matter concentrations as smoke from fire activity on the surrounding forests settles into the valley at night, although levels have not, as yet, exceeded NAAQS thresholds in the Verde Valley. Many complaints of nuisance smoke in the Sedona area are primarily concerned with the reduced quality of highly valued scenic views of the Red Rocks. Visibility in the Class I area of Sycamore Canyon Wilderness can also be affected by smoke from fires in the southeast portion of the KNF. Table 26 lists most of the areas that are expected to be impacted to some degree by implementation of prescribed fires in the 4FRI treatment area.

Table 26. Baseline and 2064 goal in 2003 Arizona State Implementation Plan for Natural Conditions

Class I Area	Baseline Data Years	Baseline Conditions	2064 Goal in 2003 AZ SIP
Grand Canyon NP	1999-2000, 2002-2004	11.6 dv	6.95 dv
Sycamore Canyon Wilderness	2001-2004	15.2 dv	6.96 dv

Table 27. Areas expected to be impacted by proposed prescribed fire treatments

Camp Verde	Highway 180	Interstate 17
Cornville	Wupatki/Sunset Crater National	Co. Rd. 65
Cottonwood	Lake Mary Road (Co. Rd. 209)	Highway 89A
Flagstaff	Grand Canyon National Park	Interstate 40
Flagstaff Airport	Walnut Canyon National Monument	Hopi Reservation
Mormon Lake	Highway89	Williams
Parks and Bellmont	Grand Canyon Airport	Navajo Reservation
Sedona	Highway 64	Town of Tusayan
Strawberry and Pine	Village of Oak Creek	

Visibility is measured in deciviews (dv). Deciviews is a metric of visibility proportional to the logarithm of the atmospheric condition. The deciview haze index corresponds to incremental changes in visual perception from pristine to highly impaired conditions. Visibility conditions are monitored and tracked through the Interagency Monitoring of Protected Visual Environments (IMPROVE) network. The data can be accessed at http://vista.cira.colostate.edu/tss, and includes data for all of the Class I areas that have monitors, including the Grand Canyon National Park.

The number of days (duration) of smoke impacts is of concern to the public as well as concentrations. While the variability from year to year will be great, the average number of acres proposed for treatment in the 4FRI differs somewhat between alternatives. The desired Fire Return Interval is between 2 and 20, with different FRIs being appropriate for different areas of the proposed treatment area at different stages of restoration. Overall, however, to produce a 10 year fire return interval, the following number of acres would need to be burned annually on average (this assumes no wildfire). Table 28 displays the average number of acres by alternative that need to burn annually (prescribed fire or wildfire) for a 10 year fire return interval on those acres proposed for prescribed fire.

Table 28. Average annual acres needed to produce a 10 year fire return interval

	Alt. A	Alt. B	Alt. C	Alt. D
Average annual acres	0	58,792	59,321	17,875
Current average acres burned	37,000	37,000	37,000	37,000
Additional acres needed to implement alternative	0	21,792	22,321	0

All acres are not equal when it comes to emissions. Open stands support surface fire over crown fire under most conditions, and surface fire produces fewer particulates than crown fire. Stands that have burned more recently and more frequently also produce lower emissions. Figure 41 shows differences in emissions from wildfire or prescribed fires that burn at different stages in burn only and mechanical plus burn treatment cycles.

Modeling results show very little difference in wildfire emissions between no treatment and a mechanical only treatment. While this excludes emissions from canopy fuels, it is a good indicator of surface fire intensity, is worth noting when considering the potential fire effects of a wildfire burning in those acres proposed for mechanical treatment only in Alternative D.

The initial difference in fuel loading was 11 tons/acre, and the difference in emissions between the treatments stays roughly the same, with no statistical difference and can be attributed the initial difference in fuel loading with one exception. The first prescribed fire following a mechanical treatment produced a little over 30,000 pounds/acre of emissions. The first prescribed fire without thinning produced a little over 40,000 pounds/acre of emissions. Since the mechanical plus fire stands started out with more fuel, this shows a difference that can be produced by removing some fuels prior to burning.

Public Influence

Public tolerance for smoke, rather than law, regulation, or policy, effectively sets a social limit to how many acres are treated with wildland fire. ADEQ and other agencies respond to public inputs by trying to minimize impacts, even when they're well within legal limits. Community public relations and education coupled with pre-burn notification greatly improve public acceptance of fire management programs. The general public will tolerate several days in a row, and several weeks a year, but even the most supportive and educated have tolerance limits (Kleindiest 2012). In order to maintain public support for prescribed burns and the beneficial use of wildfires, land managers must be responsive to the public's tolerance thresholds.

Public acceptance of smoke varies greatly from year to year. Acceptance of smoke from prescribed burns and beneficial wildfires is high following seasons with high profile, high severity events, and during extremely dry years when the threat of large, high severity incidents is elevated. Conversely, acceptance wanes during wetter years when the threat of uncharacteristic fires is low, despite climatology in milder years being more favorable for achieving desired fire effects, especially in areas highly departed from reference conditions (Kleindiest 2012).

Ecological effects of smoke

From an ecological perspective, smoke effects are important to the germination of many native plants, and in some cases appears to be more important than heat (Abella 2006, Abella et al. 2007, Abella 2009, Keeley and Fotheringham 2002, Schwilk and Zavala, 2012), many of which occur in the treatment area, including *Nama dichotomum, Heliomersis longifolia, Penstemon spp. Artemisia ludoviciana, Erigeron speciosus, and Symphyotrichum falcatum.* Smoke may also be a natural control for mistletoe and other tree infections (Parmeter and Uhrenholdt 1975, Alexander and Hawksworth 1976, Zimmerman et al. 1987).

The composition of surface vegetative communities has shifted with fire suppression and changes to forest structure (Laughlin et al. 2011), and some of the changes could be attributed to the lack of effects from smoke, as smoke has been shown to affect the richness of seedbanks, and germination of many local species (Abella 2009). Pine needles, specifically, may reduce or prevent the growth of fungi (Parmeter and Uhrenholdt 1974).

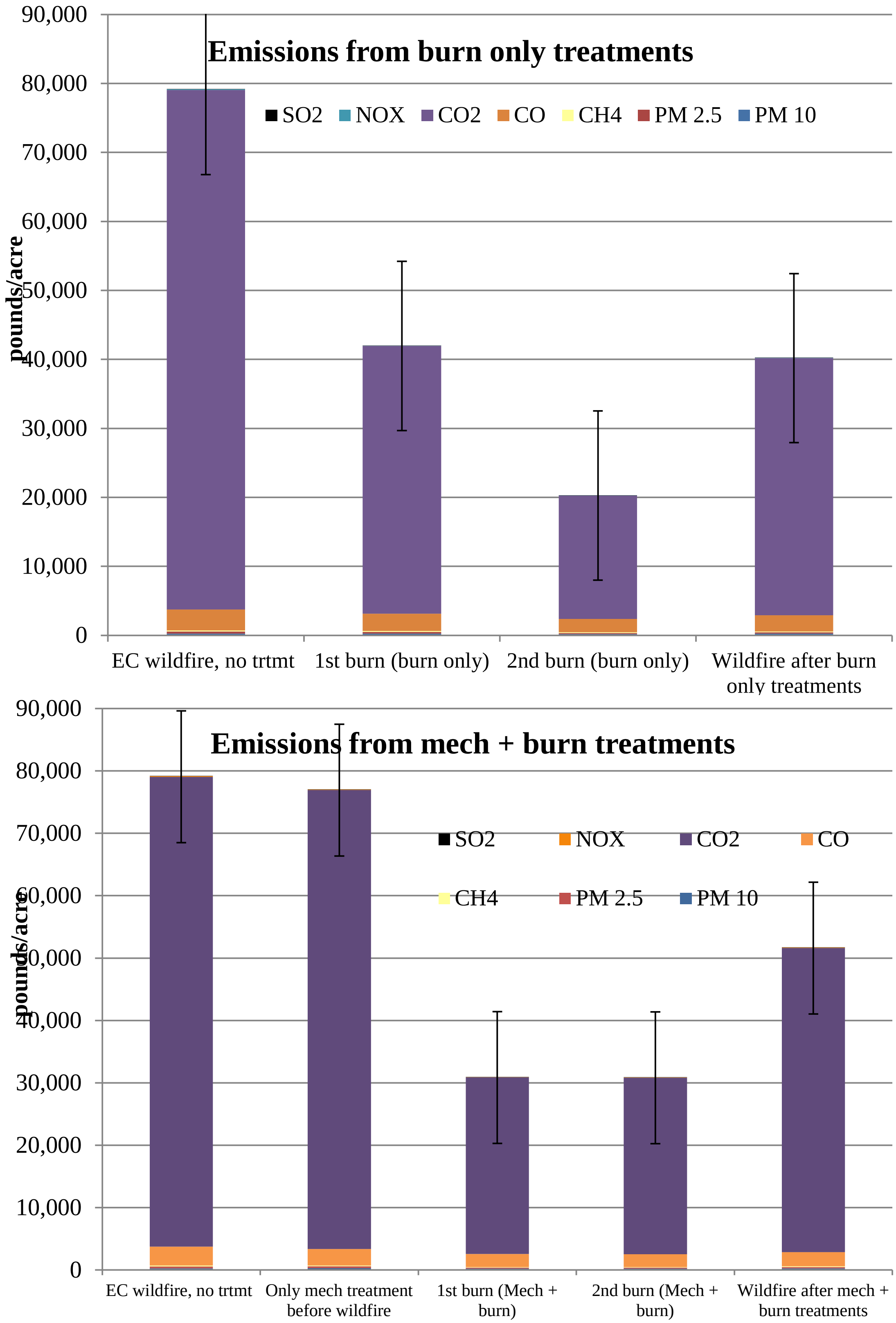

Figure 39. Emissions from surface fuels under various treatment scenarios

Environmental Consequences

Throughout this section, changes directly attributable to proposed actions, such as thinning or prescribed fire, are direct effects. These include changes to canopy bulk density, canopy base height, consumption of surface fuel, etc. Changes to the potential behavior and effects of wildfires that result from the direct effects are considered indirect effects.

Alternative A No Action

Under Alternative A, there would be no changes to current management. Alternative A would not meet the purpose and need of this project because the ecosystems and natural resources within the treatment area would continue to degrade. The treatment area would not move towards desired conditions. This alternative would not reduce the risk to human lives nor would it result in safe, cost-effective fire management that would protect, maintain, and enhance National Forest System lands, adjacent lands, and lands protected by the Forest Service under cooperative agreements. As required by FSM 5100 (pg 9).

This Alternative would not meet direction in Forest Service Manual 5100 (page 9), which includes direction on USFS use of prescribed fire to meet land and resource management goals and objectives. The objectives of fire management on lands managed by the USFS are:

1. Forest Service fire management activities shall always put human life as the single, overriding priority. This Alternative would not fully support incorporation of the highest standards for firefighter and public safety and would not be expected to improve and enhance the safety of the public as it relates to wildland fire.

2. Forest Service fire management activities should result in safe, cost-effective fire management programs that protect, maintain, and enhance National Forest System lands, adjacent lands, and lands protected by the Forest Service under cooperative agreement. This Alternative would not achieve restoration in project area. Under this Alternative fire, when it occurs, would be detrimental to the ecosystems in which it burns as well as areas outside of the burned area. Wildfire in untreated areas is more costly and less efficient to manage in untreated areas than prescribed fire, or wildfire that is managed in areas that have had restoration treatments.

Direct and Indirect Effects

Effects resulting from alternative A are indirect because there would be no management actions. The effects of implementing Alternative A are discussed in the following order.

1. Fire behavior at the treatment area scale

2. Potential fire behavior by vegetation type

3. Within Restoration Units/Subunits, fire behavior is broken out by vegetation/habitat types

4. Canopy characteristics and fuel loading and how they affect fire behavior, fire effects and air quality are presented by desired openness

5. Fire Return interval/FRCC by treatment area

6. Air Quality

This alternative would not meet the purpose and need of 4FRI. Under alternative A, there would be no effective decrease in crown fire potential (as modeled under Schultz Fire Conditions), and Fire Regime/Condition Class would continue to move away from desired conditions. The direct and indirect effects of Alternative A relate to the effects of the continued degradation of surface and canopy fuel conditions, and the effects of the lack of low severity fire. These include the potential for the direct effects of wildfires of increasing size and severity occurring within the project area. Increasing loads of surface fuels would burn with high severity effects, consuming and killing roots, seeds, biota, and other organic matter in the top layer/s of soil, and decreasing soil productivity. Trees would be damaged or killed as increasing canopy fuels and ladder fuels would allow crown fire to initiate more readily. Mortality rates would increase for large/old trees because of decades of built up fuel around their boles and over their roots, and ladder fuels within or close to their driplines. The indirect effects of such burns could compromise water resources (such as Oak Creek, Mormon Lake, or Lake Mary) from indirect fire effects such as flooding and debris flows. Indirect effects could also include impacts to air quality downwind and downslope of fires. The most likely impacts to air quality being locations northeast of the project area, and in low areas, such as the Verde Valley, Williams, or Flagstaff.

In the short term (<20 years) effects of alternative A would include an increased risk of undesirable behavior and effects. Wildfire behavior would threaten lives, resources, and infrastructure. It would be expected that 65 – 80 percent of the area burned in wildfires larger than 1,000 acres would burn with low severity effects that would beneficial. In the absence of wildfire, air quality would remain at current levels. In the short term, there would be no impacts on air quality from prescribed fires. Average annual acres burned with high severity wildfire would increase, along the associated air quality impacts. This alternative would not move the areas proposed for treatment towards the desired condition of less than 10 percent crown fire potential under conditions that produced the Schultz Fire (Table 29, **Figure 40**).

Table 29. Modeled fire type in 2020 under Alternative A by Restoration Unit

	RU	Surface Fire	Passive Crown Fire	Active Crown Fire	No Fire	Surface Fire	Passive Crown Fire	Active Crown Fire	No Fire
		Acres by RU				Percent of RU			
Alt A (2020)	RU 1	90,633	18,251	46,463	957	58	12	30	0.6
	RU 3	92,532	14,219	42,082	866	62	9	28	0.6
	RU 4	111,840	11,850	41,285	633	68	7	25	0.4
	RU 5	52,931	7,265	10,100	3,788	70	10	13	6.1
	RU 6	37,121	2,766	3,600	42	85	6	8	0.1
	Total	**385,056**	**54,351**	**143,530**	**8,319**	**65**	**9**	**24**	**1.4**

”No fire” includes acres on which there were insufficient fuels to carry fire, including water, rock, cinders, areas of sparse vegetation, etc.

In the long term (>20 years), tens of thousands of acres (the amount would be a subset of the 200,000+ acres in the treatment area that would likely burn with high severity effects) would be potentially converted to non-forested systems as a result of high severity fire, while other acres of non-ponderosa pine would be increasingly encroached upon by pine, including aspen, grasslands, and oak. Aspen stands would continue to decline, and some stands would be likely to disappear. In the short term, there would be no impacts on air quality from prescribed fire. If the current average annual acres burned by wildfire remained the same, it is likely that the entire treatment area would burn with wildfire by 2050, along with the associated air quality impacts.

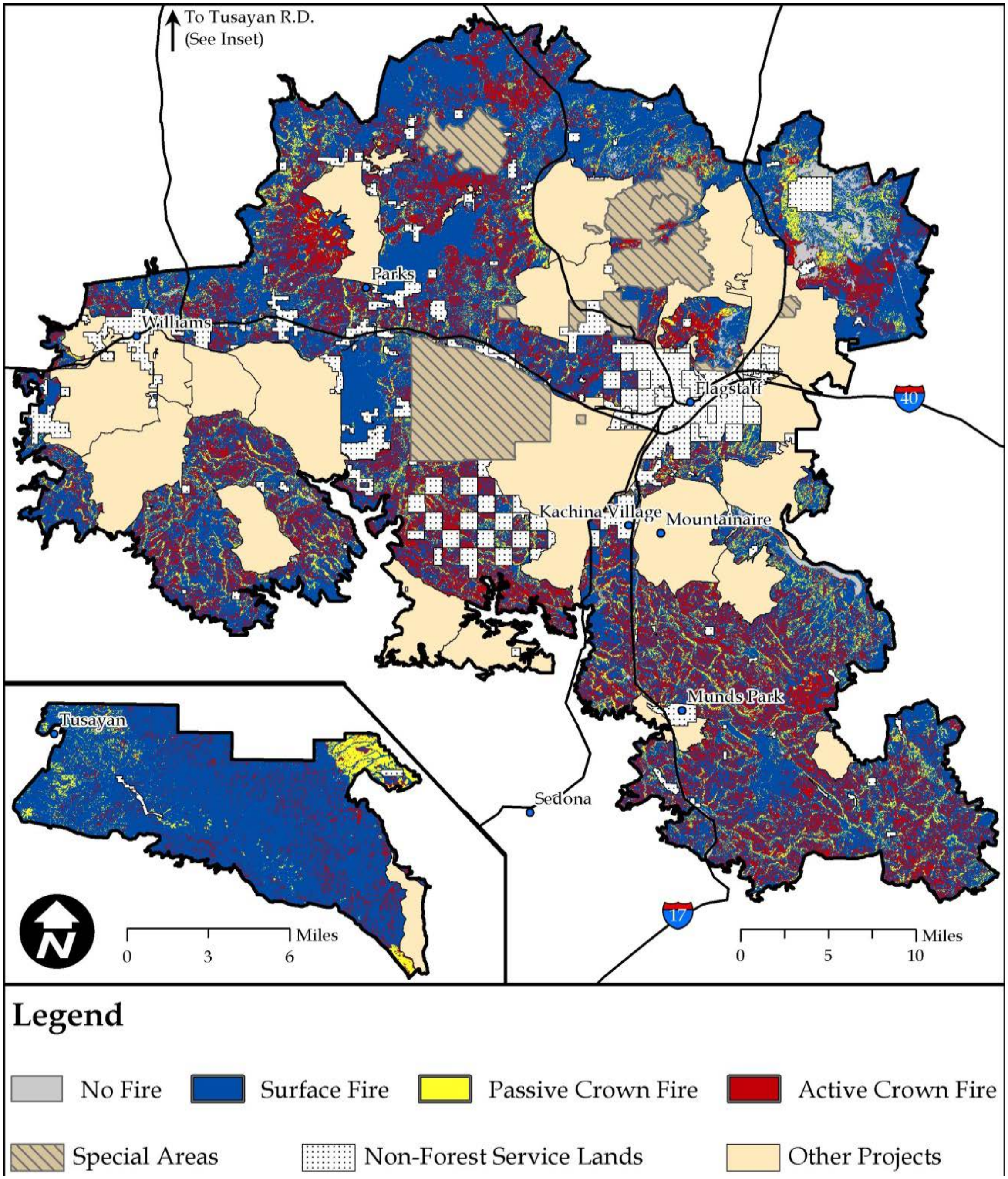

Figure 40. Modeled fire type for Alternative A, 2020

Data from the COF and KNF indicates that, without additional fires (prescribed or wildfire), the average fire return interval across the treatment area would increase to 80 years by 2020, and 160 by 2050. In addition to allowing surface fuels to buildup, this would allow ladder fuels to grow up in areas on the edges of denser forested areas, and woody species continue to encroach into grasslands and aspen.

Any fire that does occur in the treatment area would be wildfire, which can be beneficial or detrimental, depending on environmental conditions at the time of the fire, and the condition of the forests in which they burn. Figure 40 shows modeled fire behavior for 2020 if no treatments were implemented with 33 percent of the treatment area having potential for crown fire.

Ponderosa pine

Fire is a keystone process for all ponderosa pine in the 4FRI area. Eliminating it as a restoration tool would not meet the purpose and need of 4FRI. Over time, indirect effects include a shift in species composition towards more species that are less fire tolerant (Fulé and Laughlin 2007, Laughlin et al. 2011). When wildfires did occur, approximately a third of the acres burned would have undesirable effects such as severely burned soil, erosion, flooding, debris flows, vulnerability to invasive weeds, decreased soil productivity affecting species composition and vegetative patterns (Moir 1988, Laughlin et al. 2011, Abella et al. 2007).

Under current management, 512,178 acres of ponderosa pine forests in the treatment area would continue to grow denser, surface fuel loads would continue to build up and canopies would continue to close up. The only acres on which fire would reduce the potential for undesirable fire effects and behavior would be those parts of wildfires which burn at a low severity. Annual wildfire acreage increased from 2001 – 2010, and wildfires burned an average of ~15,000/year in the project area. Of these acres, approximately 2/3 (10,000 acres) could produce desirable fire effects (RAVG data). Even if all 15,000 annual acres wildfire are counted as low severity, this alternative would lead to exceptionally dense stands over most of the project area (Covington et al. 2001). It is unlikely that the resultant dense stands would be sustainable over time, and large areas would be expected to burn with high severity fire, or killed by beetles and pathogens (McCusker 2012). Even without pathogens, the potential is for over 200,000 acres of crown fire (34 percent of the area proposed for treatment under the action alternatives) under conditions similar to those under which the Schultz Fire burned in 2010. Those modeled conditions were not extraordinary, and more extreme conditions occur every year. High severity fires in ponderosa pine may cause changes to vegetative type/species composition are likely to persist for decades or longer (Savage and Mast 2005).

None of the ponderosa pine habitat types listed below would meet desired conditions for fire type (Table 30). Under this alternative, there would be potential for crown fire in 37% of the ponderosa pine (188,553 acres), of which 27% (137,736 acres) would be active crown fire. LOPFAs would not meet desired conditions for fire behavior in ponderosa pine, with 35 percent of it having potential for crown fire, 25 percent of which would be active crown fire. There would be a risk of undesirable fire behavior and effects in the other pine habitats, with almost half of protected and target/threshold at risk of crown fire.

Table 30. Potential fire type in ponderosa pine habitat under Alternative A

Vegetation Type	Fire Type	Existing Condition		Alt. A 2020	
		acres	percent	Acres	percent

Ponderosa Pine	**All Pine**	**Surface**	**313,423**	**62**	**318,506**	**63**
		Passive crown	**48,523**	**10**	**49,817**	**10**
		Active crown	**145,113**	**29**	**138,736**	**27**
	MSO Protected	Surface	18,610	51	19,072	52
		Passive crown	3,141	9	3,069	8
		Active crown	14,847	41	14,456	39
	MSO Target/ Threshold	Surface	4,292	49	4,527	52
		Passive crown	926	11	1,228	14
		Active crown	3,479	40	2,943	34
	MSO Restricted	Surface	35,465	53	37,014	55
		Passive crown	6,608	10	7,658	11
		Active crown	25,187	37	22,587	34
	Goshawk PFA/ dPFA/ Nest Stand	Surface	18,737	62	18,702	61
		Passive crown	2,952	10	2,945	10
		Active crown	8,756	29	8,798	29
	Landscapes outside PFAs	Surface	236,320	65	239,192	66
		Passive crown	34,896	10	34,917	10
		Active	92,844	26	89,951	25

It is unlikely that many dense stands of ponderosa pine could be sustained for long, so the true "no-action" alternative is extensive mortality through fire or pathogens. Post-mortality biomass may be a different type of ecosystem, such as a persistent shrub type, grass-dominated system, or unnaturally dense ponderosa pine (Savage and Mast 2005).

Pine/Sage

With no treatment, the ~16,000 acres of potential pine/sage community in RU6 would continue to decline. Currently, sage dominates in some areas, and completely absent in others where prescribed fire was implemented with the objective of eliminating the sage. As ponderosa continues to increase in density, there would be increasing risk of sage being shaded out, as well as increasing risk to pine, sage, and other vegetative components of this vegetative community from high severity fires which could eliminate sage and other shrubs locally, in addition to changing the site potential because of high severity effects to the soil (chemical and physical changes resulting from the heat of the fires). Where there is an existing mosaic of sage and other shrubs, sage would continue to dominate some areas, except as affected by wildfires or when it becomes shaded out by pine.

Large/old trees

Under this alternative, approximately 194,804 acres meeting old growth conditions (see Silviculture Report for attributes required for old growth) , and scattered large and old trees across the treatment area would be increasingly threatened by the increasing size and severity of wildfires (Swetnam 1990, Covington and Moore 1994, Swetnam and Betancourt 1998, Westerling et al. 2006). Old ponderosa pines are often more susceptible to mortality after fire (even low intensity fires) than younger mature trees (Kolb et al. 2007). The increasing size and severity of wildfires and the ensuing death of large/old ponderosa pines has been linked to fuel accumulation resulting from a century of fire exclusion (Covington et al. 2001, Hood 2010, Kolb et al. 2007). In this alternative, fires that do burn would be likely to occur during hotter, drier times of year (during the fire season), when potential fire behavior is more extreme. Generally, old or large trees are not prepped prior to wildfire (there may be a rare opportunities to prep large or old trees in the path of a wildfire being managed primarily for resource benefit). In areas where wildfire would be a first entry burn, there would be a much greater potential for high severity fire than where there had been thinning and/or a low severity fire before a wildfire occurred. In this alternative, many old trees are killed or damaged by wildfire. Effects would include trees that are killed or severely damaged in a fire, and those trees that die or decline slowly as a result of fire effects that add to other stressors.

Aspen

There are 1,516 acres of aspen within the treatment area. With no treatments or disturbance, it would be expected that the aspen would continue to decline. If wildfire burns though aspen, the larger clones (>300 stems/acre) could likely respond well, with prolific sprouting. Recent trends, however, show that browsing pressure would probably prevent the sprouts from reaching maturity so, without some sort of protection or change to ungulate browsing, clones would be weakened as the roots use up carbohydrates trying to keep suckering. Smaller clines that are already declining may be killed, or pushed closer to dying from ungulate browsing, particularly when combined with fire at the wrong time of year, particularly a hot fire in the spring or early summer. If they did respond by sprouting (likely), browsing of those sprouts would further weaken the stands, and some could disappear (DeLuca 2008, Amacher et al. 2001, Fairweather et al. 2007).

Gambel oak

Mature Gambel oak would increasingly be shaded out by the increase in ponderosa pine density. Up to a third of the area burned by wildfires that do occur are likely to be high severity, which would decrease densities of larger oak, and is likely to produce copious sprouting, further increasing the density of sprouts and small stems which are already over-represented on the landscape (Abella 2008a, Fulé et al. 1997a). Where high severity fire occurs in pine/oak, the result in some areas may be persistent oak brush fields where oak and other shrubs are likely to sprout (Ffolliott and Gottfried 1991, Savage and Mast 2005).

Table 31 shows an insignificant change in crown fire potential over time for oak woodland. Where oak is dominant, this could be where oak stems are maturing and there is less ladder fuel available in the oak, or they would be shaded out by maturing pine in the vicinity. Regardless of the cause, active crown fire remains at unnaturally high levels and, when combined with passive crown fire, these oak woodlands are at risk from unnaturally high severity fire.

Table 31. Fire behavior modeled for existing conditions and Alternative A in 2020.

Vegetation Type	Fire Type	Existing Condition		Alt. A 2020	
				Acres	Percent
Oak Woodland	Surface	2,591	77	2,620	78
	Passive crown	280	8	262	8

	Active crown	497	15	486	14

Grasslands

There are approximately 45,774 acres of grasslands within the treatment area that would continue to shrink as woody encroachment continued at increasing rates. Tree seedlings would continue to become established, leading to more acres of grassland being replaced by young forests. In encroached areas, crown fire potential would increase (Table 32). The increase in active crown fire indicates greater continuity in the acres of encroachment.

Table 32. Alternative A fire behavior modeled for Existing Conditions and 2020

Vegetation Type	Fire Type	Existing Condition		Alt. A 2020	
		Acres	Percent	Acres	Percent
Grassland	Surface	41,602	91	41,705	91
	Passive crown	2,984	7	2,366	5
	Active crown	1,131	2	1,646	4

Piñon/Juniper (PJ)

535 acres of PJ east of the town of Tusayan would continue to pose an increasing threat to the town of Tusayan based on potential fire behavior. Across the treatment area, there is an increase of 209 acres of modeled crown fire by 2020 (Table 33). PJ grows slowly, but the trajectory would continue until there was treatment of some kind, or wildfire.

Table 33. Fire type modeled for alternative A and 10 years post-treatment

Vegetation Type	Fire Type	Existing Condition		Alt. A 2020	
		Acres	Percent	Acres	Percent
Pinyon/Juniper	Surface	19,367	84	19,157	84
	Passive crown	1,535	7	1,691	7
	Active crown	2,041	9	2,094	9

Restoration Units

Under Alternative A (Table 34), none of the Restoration Units would meet desired conditions for fire behavior, ranging from 14 percent (RU6) to 42 percent (RU1). "No fire" includes acres on which there were insufficient fuels to carry fire under the conditions modeled, including water, rock, cinders, areas of sparse vegetation, etc.

Table 34. Modeled fire type for Alternative A by Restoration Unit

Alt. A (2020)	RU	Acres				Percent of treatment area			
		Surface	Passive	Active	No	Surface	Passive	Active	No fire

					fire				
	RU 1	90,633	18,251	46,463	957	58	12	30	0.6
	RU 3	92,532	14,219	42,082	886	62	9	28	0.6
	RU 4	111,840	11,850	41,285	633	68	7	25	0.4
	RU 5	52,931	7,265	10,100	5,800	70	10	13	6.1
	RU 6	37,121	2,766	3,600	42	85	6	8	0.1
	Total	**385,056**	**54,351**	**143,530**	**8,319**	**65**	**9**	**24**	**1.4**

Restoration Unit 1

Restoration Unit 1 is currently of the most at risk of all the RUs in regards to fire type and current condition. It is of particular concern because the Lake Mary watershed is a source for the city of Flagstaff. The Lake Mary watershed would continue to be at a high risk of undesirable fire effects as the likelihood of high severity fire increased, with 42 percent of it being crown fire (Table 34).

Ponderosa Pine comprises 46,037 acres of Restoration Unit 1, more than the other restoration units. There is potential for over 146,000 acres of crown fire (44% of the pine), with 33 percent active crown fire. There are adjacency concerns in the area of Mormon Mountain because of heavy fuel loading in mixed conifer upslope from the 4FRI treatment area, and the potential for flooding and debris flows downslope. Should a fire ignite on a slope below the mixed conifer, it would quickly move upslope and would be difficult to control, as well as burning at high severity for much of its extent. Additionally, portions of the city of Flagstaff occupy the northwestern corner of this RU, and the community of Elk Park is at risk.

When fire behavior is considered by vegetation and habitat type (Table 35), ponderosa pine would not meet desired conditions for fire behavior, with 44 percent of it having potential for crown fire, of which 32 percent would be active crown fire. Landscapes outside of PFAs would also not meet desired conditions, with 39 percent having potential for crown fire, 26 percent of it active crown fire. Over half of the acres of Target/Threshold habitat would be at risk of crown fire, and 45 percent of the PFA/dPFA/ nest stand. While these areas do not all have desired conditions relating to fire behavior, there is good potential that around 60,000 acres could burn with high severity, a subset of which would convert to a non-forested vegetation type.

Table 35. Fire type by vegetation and habitat types for Restoration Unit 1, Alternative A

RU 1: 156,305 acres) Vegetation/Habitat Type		Vegetation Type Acres	Fire Type	Alternative A (2020)	
				Acres	Percent
Ponderosa Pine	All Pine	146,037	Surface	82,913	57
			Passive crown	18,251	12
			Active crown	46,463	32
	Protected	30,240	Surface	16,061	53
			Passive crown	2,318	8
			Active crown	11,808	39
	Target/ Threshold	4,814	Surface	2,374	49

RU 1: 156,305 acres) Vegetation/Habitat Type		Vegetation Type Acres	Fire Type	Alternative A (2020)	
				Acres	Percent
			Passive crown	709	15
			Active crown	1,719	36
	Restricted	26,421	Surface	13,778	52
			Passive crown	3,241	12
			Active crown	9,370	35
	PFA/ dPFA/ nest stand	4,670	Surface	2,561	55
			Passive crown	522	11
			Active crown	1,586	34
	Landscapes outside of PFAs	79,892	Surface	48,137	60
			Passive crown	10,228	13
			Active crown	21,122	26
	Aspen	420	Surface	240	57
			Passive crown	42	10
			Active crown	138	33
	Grassland	8,133	Surface	6,169	76
			Passive crown	1,043	13
			Active crown	499	6
	Juniper Woodland	286	Surface	234	82
			Passive crown	16	6
			Active crown	37	13
	Oak Woodland	287	Surface	197	69
			Passive crown	62	22
			Active crown	28	10
	Pinyon/ Juniper	1,141	Surface	880	77
			Passive crown	70	6
			Active crown	157	14

Aspen occupies approximately 420 acres in Restoration Unit 1, 43 percent would have potential for crown fire. While high severity fire in aspen may serve to regenerate some stands, those that are stressed already, particularly small ones, may have a hard time recovering, particularly in the presence of browsing.

Grasslands occupy a little over 8,000 acres of grassland in RU1, and 19 percent of it has potential for crown fire. Grasslands are, by definition, supposed to have less than 10 percent canopy cover, so most crown fire would be beneficial, decreasing encroachment. The 6 percent that is active crown fire could create some areas of undesirable fire effects on 499 acres, such as high burn severity (detrimental soil effects), including killing the existing seed bank and potentially giving invasive plant species a foothold.

Oak/woodlands occupy approximately 287 acres scattered throughout RU1. When these acres are combined, they exceed desired conditions for fire behavior though, like aspen, it is likely to sprout following most fire. The larger oaks would be topkilled. With 33 percent of the oak woodlands likely to burn with a crown fire, the short term effects of a wildfire burning though this area would be a shift from few larger stems, to multiple smaller stems, which are already over represented on the landscape (Abella 2008a, Fulé et al. 1997a).

Pinyon/Juniper woodlands have potential for ~280 acres of crown fire, the majority of which would be active crown fire. This may not be out of the natural fire regime, but it is adjacent to ponderosa pine and could serve as ladder fuel if pushed into the pine by wind or terrain. Most of the PJ is in Subunit 1-1 and/or on the easternmost area of RU1.

Subunits

Subunit 1-3 includes the Lake Mary basin, a source watershed for the town of Flagstaff. Current conditions show 41 percent of it to have potential for crown fire, 29 percent of which is active crown fire. Additionally, Upper and Lower Lake Mary are popular recreation sites. Should wildfire burn though this watershed, the second order fire effects could jeopardize the water supply (from the lakes) as well as, at least temporarily, require the closure of the recreation sites. Subunit 1-1 includes Walnut Canyon National Monument, and is adjacent to Flagstaff and the Pulliam Airport. Subunits 1-3, 1-4 and 1-5 contain over 130,000 acres of ponderosa pine, most of which is habitat for the Mexican Spotted Owl and the goshawk. With no treatment, if a wildfire burned though these subunits, there is potential for over 57,000 acres of ponderosa pine habitat to burn with high severity. Some of this area could be expected to be converted to a non-forested type, effectively removing most of its value to MSO and goshawks (Table 36).

Table 36. Fire type in subunits of RU1 by vegetation type for 2020

Vegetation Type by Subunit	Acres	Percent of subunit in vegetation type	Fire Type (2020)					
			Surface crown (acres)	Passive crown (acres)	Active (acres)	Surface (percent)	Passive crown (percent)	Active crown (percent)
Subunit 1-1	10,169		6,381	1,880	1,744	63	18	17
Ponderosa Pine	8,914	88	5,595	1,689	1,513	63	19	17
Grassland	567	6	313	90	150	55	16	26
Oak Woodland	173	2	120	53	0	69	30	0
Pinyon-Juniper	515	5	352	48	81	68	9	16
Subunit 1-2	8,054		5,888	862	1,245	73	11	15
Ponderosa Pine	6,517	81	4,496	779	1,219	69	12	19
Grassland	1,537	19	1,392	83	26	91	5	2
Subunit 1-3	41,652		24,101	5,392	11,737	58	13	28
Ponderosa Pine	38,324	92	21,705	4,976	11,536	57	13	30
Aspen	88	0	53	14	22	60	15	24

Grassland	3,240	8	2,343	403	179	72	12	6
Subunit1-4	18,250		10,989	2,028	5,217	60	11	29
Ponderosa Pine	17,285	95	10,197	1,915	5,167	59	11	30
Grassland	519	3	407	90	13	78	17	3
Oak Woodland	83	0	56	9	18	68	11	22
Pinyon-Juniper	363	2	330	15	19	91	4	5
Subunit 1-5	78,179		43,273	8,089	26,520	55	10	34
Ponderosa Pine	74,996	96	40,920	7,660	26,169	55	10	35
Aspen	332	0	187	29	116	56	9	35
Grassland	2,270	3	1,713	377	132	75	17	6
Juniper Woodland	286	0	234	16	37	82	6	13
Oak Woodland	32	0	21	1	9	68	2	30
Pinyon-Juniper	262	0	198	7	57	75	3	22

Restoration Unit 3

Restoration Unit 3 currently has the second greatest potential for undesirable fire effects and behavior. Winds on the Mogollon Rim are generally out of the southwest, so this RU has a high strategic importance in regards to fire movement. The north and east borders are Interstates 10 and 17 respectively, so fires burning in the vicinity of the interstates could affect the Interstates and/or Highway 89, the main route between Flagstaff and Oak Creek Canyon/Sedona. Multiple drainages in RU3 line up with the prevailing winds, and have the potential to draw fire towards communities, such as Pumphouse Wash (Kachina Village), and Munds Canyon (Munds Park). Adjacency concerns for fire behavior include a number of communities (Figure 7) as well as Oak Creek and Sycamore Canyons. Second order fire effects (such as flooding, debris flows, deposition, erosion, etc.) would have potential to impact Oak Creek and Sycamore Canyons, with the specific locations depending on the slope, proximity, and size of high severity fire. Overall, with no treatment, there is potential for over 56,000 acres of crown fire (38 percent of the RU), of which over 42,000 (28 percent of the RU) would be active crown fire.

When RU3 is considered by vegetation and habitat types, ponderosa pine does not meet desired conditions for fire behavior, with 42 percent that would have crown fire potential, of which 32 percent would be active crown fire. MSO and Goshawk habitat are at risk as well, with almost 50 percent of the PFA/DPFA/ Nest Stand habitat and 54 percent of protected habitat at risk of crown fire. In the long run, it could be assumed that a subset of the 74,463 of pine that would burn with high severity would be permanently converted to non-forested habitat (Table 37).

<u>Aspen</u> occupies 207 acres of aspen in RU3, and 27 percent of it (54 acres) has potential for crown fire, all of which are in the northeast area of RU3. See description under RU1 for effects (pg. 53).

Table 37. Fire type by vegetation type and habitat for Restoration Unit 3, Alternative A

RU 3: 149,718 acres		Vegetation type acres	Alternative A 2020	
Vegetation/Habitat Type	Fire Type		Acres	Percent

RU 3: 149,718 acres			Vegetation type acres	Alternative A 2020	
Vegetation/Habitat Type		Fire Type		Acres	Percent
Ponderosa Pine	All Pine	Surface	129,225	74,463	58
		Passive crown		13,312	10
		Active crown		40,805	32
	MSO Protected	Surface	4,507	1,993	44
		Passive crown		573	13
		Active crown		1,857	41
	MSO Target/ Threshold	Surface	3,899	2,152	55
		Passive crown		518	13
		Active crown		1,224	31
	MSO Restricted	Surface	38,748	21,956	57
		Passive crown		4,126	11
		Active crown		12,589	32
	Goshawk PFA/ dPFA/ Nest Stand	Surface	5,452	2,808	52
		Passive crown		574	11
		Active crown		2,068	38
	Landscapes outside PFAs	Surface	76,619	45,554	59
		Passive crown		7,521	10
		Active crown		23,066	30
Other Vegetation	Aspen	Surface	201	147	73
		Passive crown		39	20
		Active crown		15	7
	Grassland	Surface	12,775	11,736	92
		Passive crown		566	4
		Active crown		255	2
	Juniper Woodland	Surface	1,851	1,553	84
		Passive crown		61	3
		Active crown		232	13
	Oak Woodland	Surface	1,633	1,284	79
		Passive crown		73	4
		Active crown		267	16
	Pinyon/ Juniper	Surface	4,033	3,349	83
		Passive crown		168	4
		Active crown		509	13

Grasslands occupy 12,775 acres in RU3, most of which are in Garland Prairie. Under this alternative, grasslands in RU3 would support ~ 800 acres (6 percent) of crown fire. Only 255 of those acres would be active crown fire and have potential to produce undesirable fire effects. Surface fire and passive crown fire would decrease woody encroachment, and begin to restore the natural role of fire to the grasslands.

Oak woodlands occupy 1,633 acres in RU3, more than any other RU. These acres are scattered throughout the RU from the southern-most part of the treatment area in Subunit 1-5 to the westernmost. Twenty percent of these acres would have the potential to produce crown fire, double what would be desired. Oak can be topkilled by fire, but is unlikely to be killed outright. As described earlier, the short term effects would be a decrease in larger diameter oak, and a proliferation of sprouts. Since small diameter oak is already over-represented on the landscape, this would move these acres away from the desired condition.

Pinyon/Juniper Woodlands in RU3 compose 6,699 acres. Most are close to the rim, or in the west/southwest part of the RU, primarily in Subunit 3-1 (Table 38). The majority of the crown fire potential in the PJ in RU3 would be active crown fire which would pose a control issue, as well as having the potential to initiate crown fire in ponderosa pine if wind and terrain were to push it that way.

Subunits

Within RU3, ponderosa pine does not meet desired conditions in any of the subunits (Table 38). Subunit 3-2 includes an area along Interstate 40 from the outskirts of Flagstaff to Williams, and would have the potential for over 9,000 acres of crown fire. Subunit 3-3 encompasses Sycamore Canyon, and has the potential for almost 20,000 acre of high severity fire from crown fire. There would be potential for second order effects to the Sycamore Canyon Wilderness area from flooding and/or debris flows following high severity fire which could compromise the functioning of the water resources and adjacent riparian areas. Subunit 3-4 has potential for over 6,000 acres of high severity effects from crown fire, and is strategically important for the communities of Flagstaff, Kachina Village, and Munds Park, as well as Interstate 17. Ignitions starting in or near Pumphouse Wash and the canyon southwest of Munds Park would be likely to funnel Kachina Village and Munds Park. Additionally, water resources and riparian areas in these areas would be compromised by flooding and/or debris flows. Winds are generally out of the southwest, so fires starting in this RU would be pushed toward these communities and Interstate 17.

Table 38. Modeled fire type in subunits of RU3 by vegetation type for 2020.

Vegetation Type by Subunit	Acres	Percent of subunit in vegetation type	Alternative A Fire Type (2020)					
			Surface (acres)	Passive crown (acres)	Active crown (acres)	Surface (percent)	Passive crown (percent)	Active crown (percent)
3-1	23,148	-	15,426	2,174	5,480	67	9	24
Ponderosa Pine	18,805	81	11,701	1,949	5,111	62	10	27
Aspen	91	0	66	23	2	73	25	2
Grassland	593	3	519	48	8	88	8	1
Juniper Woodland	907	4	774	35	96	85	4	11
Oak Woodland	845	4	708	36	99	84	4	12

Vegetation Type by Subunit	Acres	Percent of subunit in vegetation type	Alternative A Fire Type (2020)					
			Surface (acres)	Passive crown (acres)	Active crown (acres)	Surface (percent)	Passive crown (percent)	Active crown (percent)
Pinyon-Juniper	1,908	8	1,658	83	164	87	4	9
3-2	32,726	-	23,231	2,702	6,516	71	8	20
Ponderosa Pine	22,885	70	13,874	2,518	6,360	61	11	28
Aspen	59	0	39	8	11	66	14	20
Grassland	9,611	29	9,252	174	42	96	2	0
Oak Woodland	172	1	67	2	103	39	1	60
3-3	48,434	-	29,239	4,726	14,374	60	10	30
Ponderosa Pine	44,426	92	25,915	4,497	13,942	58	10	31
Aspen	50	0	41	8	1	81	16	3
Grassland	1,353	3	1,145	122	80	85	9	6
Juniper Woodland	873	2	711	26	133	81	3	15
Oak Woodland	232	0	207	11	6	89	5	3
Pinyon-Juniper	1,500	3	1,220	64	211	81	4	14
3-4	9,019	-	5,300	932	2,572	59	10	29
Ponderosa Pine	8,920	99	5,254	919	2,546	59	10	29
Grassland	99	1	46	13	26	47	13	27
Oak Woodland	0	0	0	0	0	100	0	0
3-5	36,392	-	19,334	3,684	13,141	53	10	36
Ponderosa Pine	34,190	94	17,720	3,429	12,847	52	10	38
Aspen	2	0	1	0	0	61	21	18
Grassland	1,120	3	774	210	98	69	19	9
Juniper Woodland	70	0	67	0	3	95	0	4
Oak Woodland	384	1	301	24	59	78	6	15
Pinyon-Juniper	626	2	471	21	134	75	3	21

Restoration Unit 4

RU4 is located west and north of Flagstaff, and north of Williams and Interstate 10, and has potential to affect the communities of Flagstaff, Williams, Parks, and Belmont, though the prevailing winds would tend to blow fire away from most of the populations in Williams, Parks and Belmont. There is also potential to impact the Fort Valley Experimental Station northwest of Flagstaff. Over the last 20 years, RU4 has been impacted by some large fires, including the Hockderffer (2004, 16,000 acres) and Pumpkin (2000, 8,700 acres) fires. Areas of potential active crown fire would be adjacent to heavy fuel loading in mixed conifer on Kendrick and Sitgreaves mountains, and the San Francisco Peaks. Overall, with no treatment, there is potential for over

53,000 acres of crown fire (32 percent of the RU), of which over 41,000 (25 percent of the RU) would be active crown fire.

Ponderosa pine comprises 134,301 acres within RU4 and, when considered by vegetation and habitat type, it would not meet desired conditions, with 29 percent (>38,000 acres) having potential for crown fire (Table 39). Within the ponderosa pine, MSO and Goshawk habitat are at risk of high severity fire effects from crown fire. The areas of the most contiguous crown fire in RU4 are downslope from mixed conifer on Kendrick, Sitgreaves, and the San Francisco Peaks. In these areas, crown fire would move upslope with at a rapid rate of spread, producing large areas of high severity fire on steep slopes. In these areas, second order fire effects could be extreme, such as occurred on the east side of the Peaks following the Schultz Fire, with sediment laden flood waters scouring out channels, and debris flows damming culverts and washing out and/or blocking roads.

Table 39. Modeled fire type by vegetation and habitat type for Restoration Unit 4

RU 4 Acres: 165,607			Vegetation Type Acres	Alternative A (2020)	
Vegetation/Habitat Type		Fire Type		Acres	Vegetation Type Percent
Ponderosa Pine	All Pine	Surface	134,301	83,645	62
		Passive crown		10,694	8
		Active crown		27,566	21
	MSO Protected	Surface	558	343	6
		Passive crown		33	6
		Active crown		89	16
	MSO Restricted	Surface	1,575	809	51
		Passive crown		221	14
		Active crown		403	26
	Goshawk PFA/ dPFA/ nest stand	Surface	13,484	7,922	59
		Passive crown		1,294	10
		Active crown		3,098	23
	Landscapes outside PFAs	Surface	118,683	74,571	63
		Passive crown		9,145	8
		Active crown		23,976	20
Other Vegetation	Aspen	Surface	499	415	83
		Passive crown		25	5
		Active crown		22	4
	Grassland	Surface	22,599	21,117	93
		Passive crown		590	3
		Active crown		371	2
	Juniper Woodland	Surface	118	65	55
		Passive crown		3	3

RU 4 Acres: 165,607			Vegetation Type Acres	Alternative A (2020)	
Vegetation/Habitat Type		Fire Type		Acres	Vegetation Type Percent
		Active crown		37	32
	Oak Woodland	Surface	926	687	74
		Passive crown		71	8
		Active crown		147	16
	Pinyon/ Juniper	Surface	7,165	5,910	82
		Passive crown		466	7
		Active crown		733	10

Aspen occupies ~500 acres within RU4 which are widely scattered. As with the other RUs, the effects of a wildfire would be both beneficial and detrimental, depending on the initial condition of the stand. Large and small stems could be topkilled, and replaced by vigorous, profuse sprouting. The survival of the sprouts would depend, in large part, on browsing pressure. If aspen stands were small and stressed, and the fire was high severity, recovery would be less certain and, if browsing is excessive, some stands could disappear (DeByle 1985, Amacher et al. 2001, Fairweather et al. 2007).

Grassland acres total over 22,000 acres in RU4, including Government Prairie. There would be potential for 961 acres of crown fire, with 371 acres of active crown fire. These 371 acres have the potential for undesirable fire effects, while fire effects on the rest of the grassland area could reduce woody encroachment, moving 21,707 acres of grasslands towards the desired condition. With no proposed treatments, this would only occur if a wildfire burned across the entire area.

Oak woodlands comprise 926 acres of RU4 and would support over 200 acres of crown fire. In RU4, these acres are widely scattered, and mostly in mostly stands <100 acres. As with aspen, and as described in the previous sections, the long term effects of wildfire under this alternative would be a decrease in large oak stems, and an increase in small as topkilled oaks sprouted. Since small diameter oaks are already over-represented on the landscape, this alternative would not move these acres towards the desired condition.

Pinyon/Juniper woodlands in RU4 are mostly on the west, northwest, and northern portions, occurring in stands, or groups of stands ranging from less than 10 acres to over 700. RU4 has more pinyon/juniper woodland than any other RU. With no treatment, wildfire occurring under modeled conditions would be expected to burn over 1,000 acres with high severity effects by 2020, over 850 of which would be active crown fire.

Subunits

At the subunit level (Table 40) SU 4-5, the smallest SU in the project (6,943 acres), is adjacent to northwest Flagstaff, and has steep topography, so that the second order fire effects of any high severity fires have good potential to impact neighborhoods and schools. Currently, 33 percent of SU 4-5 has potential for crown fire, with 28 percent being active crown fire. Most of Government Prairie is in Subunit 4-4 and, with no treatment, wildfire could produce undesirable effects on 284 acres, with effects on the rest (~14,500 acres) moving those acres towards desired conditions.

Table 40. Modeled fire type in subunits of RU4 by vegetation type for 2020

Vegetation Type by Subunit	Acres	Percent of subunit in vegetation type	Alternative A Fire Type (2020)					
			Surface (acres)	Passive crown (acres)	Active crown (acres)	Surface (percent)	Passive crown (percent)	Active crown (percent)
4-2	10,231	-	6,985	935	2,211	68	9	22
Ponderosa Pine	7,381	72	4,707	785	1,849	64	11	25
Aspen	1	0	1	0	0	67	0	0
Grassland	332	3	295	8	2	89	2	0
Juniper Woodland	8	0	7	1	0	86	12	2
Oak Woodland	567	6	391	48	125	69	8	22
Pinyon-Juniper	1,941	19	1,584	93	235	82	5	12
4-3	67,013	-	48,136	4,429	14,127	72	7	21
Ponderosa Pine	55,311	83	37,895	3,905	13,207	69	7	24
Aspen	232	0	218	4	8	94	2	3
Grassland	6,951	10	6,353	153	434	91	2	6
Juniper Woodland	31	0	31	0	1	98	0	2
Oak Woodland	325	0	277	21	27	85	6	8
Pinyon-Juniper	4,162	6	3,362	348	450	81	8	11
4-4	81,421	-	52,062	6,168	22,992	64	8	28
Ponderosa Pine	65,003	80	36,672	5,711	22,532	56	9	35
Aspen	255	0	190	21	43	75	8	17
Grassland	14,988	18	14,190	405	284	95	3	2
Juniper Woodland	78	0	27	2	46	35	3	59
Oak Woodland	35	0	19	2	14	54	6	40
Pinyon-Juniper	1,062	1	964	25	73	91	2	7
4-5	6,943	-	4,656	318	1,956	67	5	28
Ponderosa Pine	6,605	95	4,371	293	1,929	66	4	29
Aspen	11	0	5	0	5	50	4	47
Grassland	327	5	279	25	21	85	8	6

Restoration Unit 5

Restoration Unit 5 includes parts of the area that was burned in the Schultz fire (2010, ~17,000 acres) and the Radio Fire (1977, 2,600 mostly on Mount Eldon, immediately upslope and adjacent to northern Flagstaff) (Table 41). Adjacency concerns include housing developments, including Doney Park, and the city of Flagstaff, which would be mostly downslope from any fire occurring in this RU. The northeastern area of this RU has scattered cinder cones, and cinder areas which support only sparse vegetation. In these areas, active crown fire is less likely because of decreased potential for high intensity surface fire and decreased canopy fuel continuity. These areas, though they have little fuel, have been reported to attract lightning, increasing the potential for lightning starts in the vicinity (see map, Appendix D). Overall, with no treatment, there is potential for over 17,000 acres of crown fire (23 percent of the RU), of which over 10,000 (13 percent of the RU) would be active crown fire.

Aspen comprises 403 acres of RU4. Eight percent would have potential for crown fire, of which 4 percent (15 acres) would be active crown fire (Table 41). In clones that are stressed out and/or becoming crowded and overtopped by conifers, high severity fire could be either detrimental or beneficial, depending on the conditions under which it occurs, and the condition of the stand in which it burns, and the intensity of browsing pressure on sprouts.

Grasslands in RU5 would have potential for 262 acres (6 percent) of crown fire, of which 99 acres would be active crown fire. Active crown fire in an area classified as grassland has potential to both reduce woody encroachment, and produce undesirably fire effects in those areas which burn with high severity. No action would result in continued encroachment of woody species and increasing cover of species not adapted to fire.

Pinyon/Juniper woodlands would have potential for 881 acres of crown fire, by 2020, an increase of ~200 acres of mostly passive crown fire.

Table 41. Fire type by vegetation type and habitat for Restoration Unit 5

RU 5 Acres: 76,096			Vegetation Type Acres	Alternative A (2020)	
Vegetation/Habitat Type		Fire Type		Acres	Percent
Ponderosa Pine	All Pine	Surface	61,730	41,969	68
		Passive crown		6,564	11
		Active crown		6,887	11
	MSO Protected	Surface	1,452	675	46
		Passive crown		145	10
		Active crown		472	32
	MSO Restricted	Surface	634	471	74
		Passive crown		70	11
		Active crown		83	13
	Goshawk PFA/ dPFA/ nest stand	Surface	2,944	1,753	60
		Passive crown		444	15
		Active crown		400	14
	Landscapes outside PFAs	Surface	56,700	39,070	69
		Passive crown		5,905	10
		Active crown		5,932	10
Other Vegetation	Aspen	Surface	403	338	84
		Passive crown		17	4
		Active crown		15	4
	Grassland	Surface	4,595	2,593	56

RU 5 Acres: 76,096			Vegetation Type Acres	Alternative A (2020)	
Vegetation/Habitat Type		Fire Type		Acres	Percent
		Passive crown		163	4
		Active crown		99	2
	Juniper Woodland	Surface	74	66	89
		Passive crown		8	10
		Active crown		0	1
	Oak Woodland	Surface	523	443	85
		Passive crown		36	7
		Active crown		25	5
	Pinyon/ Juniper	Surface	8,771	7,522	86
		Passive crown		477	5
		Active crown		396	5

Subunits

Oak woodlands comprise 523 acres of RU5. Under this alternative, by 2020, there would be potential for 31 acres of crown fire in oak woodlands. Table 42 shows mostly surface fire in SU5-2, the area most severely affected by the Schultz Fire. Subunit 5-2 includes many acres of cinder cones that are too sparsely vegetated to carry fire, as well as areas that were affected by flooding and debris flows resulting from the Schultz Fire. Upslope from north flagstaff there would be potential for high severity fire effects on steep slopes (>30 percent) in RU 5-1. Effects would include flooding and debris flows resulting from high severity fire in these areas would be likely to affect those areas downslope, including infrastructure, with the effects depending on the location, severity, timing, and extent of the area burned with high severity effects.

Table 42. Modeled fire type for Restoration Unit 5 subunits by vegetation type

Vegetation Type by Subunit	Acres	Percent of subunit in vegetation type	Alternative A Fire Type (2020)					
			Surface (acres)	Passive crown (acres)	Active crown (acres)	Surface (percent)	Passive crown (percent)	Active crown (percent)
5-1	24,172	-	18,037	1,678	3,589	75	8	15
Ponderosa Pine	20,674	86	14,851	1,527	3,478	72	9	17
Aspen	392	2	331	14	42	84	5	11
Grassland	1,299	5	1,179	71	30	91	7	2
Oak Woodland	232	1	180	26	24	77	11	10
Pinyon-Juniper	1,574	7	1,496	39	15	95	1	1
5-2	51,924	-	34,894	5,587	6,511	67	11	13
Ponderosa Pine	41,055	79	27,118	5,037	5,930	66	13	14

Vegetation Type by Subunit	Acres	Percent of subunit in vegetation type	Alternative A Fire Type (2020)					
			Surface (acres)	Passive crown (acres)	Active crown (acres)	Surface (percent)	Passive crown (percent)	Active crown (percent)
Aspen	10	0	7	3	1	65	30	6
Grassland	3,297	6	1,415	92	121	43	4	4
Juniper Woodland	74	0	66	8	0	89	10	1
Oak Woodland	291	1	263	10	1	91	3	0
Pinyon-Juniper	7,196	14	6,026	438	457	84	4	6

Restoration Unit 6

Restoration Unit 6 (Table 43) is the smallest of the RUs, and lies immediately south of, and adjacent to Grand Canyon National Park. It is the driest of all the RUs, and has had more recent fire than most of the rest of the proposed treatment area (Table 43). Active crown fire in RU6 would mostly be dispersed, with only a few areas of contiguous crown fire. Overall, with no treatment, there would be potential for over 6,000 acres of crown fire (15 percent of the RU), of which over 3,000 (13 percent of the RU) would be active crown fire.

When fire behavior is considered by vegetation and habitat, ponderosa pine would not meet desired conditions. When ponderosa pine is considered by habitat type, PFA/ dPFA/nest stand habitat is at lower risk than any other RU, with only 9 percent potential for crown fire.

Table 43. Fire type by vegetation type and habitat for Restoration Unit 6

RU 6 Acres: 43,529			Vegetation Type Acres	Alternative A 2020	
Vegetation/Habitat Type		Fire Type		Acres	Percent
Ponderosa Pine	All Pine	Surface	41,188	35,516	86
		Passive crown		2,229	5
		Active crown		3,156	8
	Goshawk PFA/ dPFA/ nest stand	Surface	4,050	3,657	90
		Passive crown		111	3
		Active crown		262	6
	Landscapes outside PFAs	Surface	37,138	31,859	86
		Passive crown		2,118	6
		Active crown		2,894	8
	Grassland	Surface	93	90	97
		Passive crown		3	3
		Active crown		0	0
	Juniper Woodland	Surface	13	10	78
		Passive crown		3	22

RU 6 Acres: 43,529			Vegetation Type Acres	Alternative A 2020	
	Vegetation/Habitat Type	Fire Type		Acres	Percent
		Active crown		0	0
	Oak Woodland	Surface	30	9	30
		Passive crown		21	69
		Active crown		0	1
	Pinyon/ Juniper	Surface	2,206	1,496	68
		Passive crown		511	23
		Active crown		188	9

Grasslands occupy just 93 acres of grassland in RU6. The 3 acres of crown fire (passive) modeled would be beneficial, decreasing woody encroachment, reinvigorating shrubs and moving these acres towards the desired condition.

Oak woodlands comprise just 30 acres, and would support mostly passive crown fire (21 acres). As with the other RUs, crown fire in the oak would be likely to kill larger stems, and produce multiple smaller stems.

Subunits

The majority of the treatment area in RU6 is in Subunit 6-3 (Table 44). Just east of the town of Tusayan are 535 acres for which potential fire behavior would be a growing concern. In Subunit 6-3, 22 percent of the Pinyon/Juniper has potential for crown fire, 145 acres of which would be active crown fire. Although the severity of the potential fire behavior in this area may be within the historic fire regime, fire exclusion of the patchy, mixed severity fires that were probably typical of the fire regime in RU6 have homogenized the PJ somewhat, so there could be the possibility of fires occurring that would be of larger extent than historic records indicate were typical (Huffman et al. 2006).

Table 44. Modeled fire type in subunits of RU6 by vegetation type for 2020

Vegetation Type by Subunit	Acres	Vegetation type acres	Alternative A Fire Type (2020)					
			Surface (acres)	Passive crown (acres)	Active crown (acres)	Surface (percent)	Passive crown (percent)	Active crown (percent)
6-2	5,551	-	4,835	409	300	87	7	5
Ponderosa Pine	5,069	91	4,475	293	293	88	6	6
Pinyon-Juniper	483	9	360	115	7	75	24	2
6-3	34,109	-	30,272	894	2,912	89	3	9
Ponderosa Pine	32,635	96	29,110	727	2,767	89	2	8
Grassland	85	0	83	3	0	97	3	0
Juniper Woodland	13	0	10	3	0	78	22	0

Vegetation Type by Subunit	Acres	Vegetation type acres	Alternative A Fire Type (2020)					
			Surface (acres)	Passive crown (acres)	Active crown (acres)	Surface (percent)	Passive crown (percent)	Active crown (percent)
Pinyon-Juniper	1,375	4	1,069	162	145	78	12	11
6-4	3,870	-	2,014	1,464	388	52	38	10
Ponderosa Pine	3,484	90	1,931	1,209	341	55	35	10
Grassland	7	0	7	0	0	99	1	0
Oak Woodland	30	1	9	21	0	30	69	1
Pinyon-Juniper	348	9	68	234	47	19	67	13

Surface fuels and canopy characteristics affecting fire behavior and effects

Canopy characteristics and surface fuel loading are discussed in this section by desired openness desired openness. As described on page 9, the desired openness is an indication of the relative desired post-treatment interspace/tree group condition. Relationships between surface fuels and canopy characteristics affecting fire behavior and effects are discussed on page 155. Regarding fire effects, surface fuel loading can produce desirable or undesirable effects, depending on the initial loading and the conditions under which it burns (see page 71 for more details).

Canopy characteristics

As described in the Methodology section on page 18, canopy characteristics are used in modeling potential fire behavior and can be used to show trends that affect fire behavior and effects for conditions not modeled. For example, increasing horizontal continuity in canopy fuels indicates increasing likelihood of active crown fire and the associated effects. Modeled changes to canopy base height (CBH) and canopy bulk density (CBD) are shown in Table 45 and display changes and effects that may not be apparent in fire behavior data. Desired conditions are for CBH to be 18 feet or higher and for CBD to be 0.05 kg/m^3 or lower. This alternative would not meet desired conditions for CBH by 2020 for CBH or CBD. Table 45 displays modeled changes in canopy characteristics from 2010 through 2050 with no mechanical treatments or fire (wildfire or prescribed fire) after 2020. Shaded cells indicate a condition that does not meet desired conditions. Note: desired conditions for CBH and CBD do not apply to PACs or Core Areas.

Table 45. Canopy characteristics under Alternative A 2020 and Existing Condition

Alt A	CBH (feet)			CBD (kg/m3)			CC (%)			Percent ponderosa pine
Desired Openness	2010	2020	2050	2010	2020	2050	2010	2020	2050	
High	15.16	16.89	22.35	0.066	0.067	0.064	68	70	74	34
Moderate	14.74	16.53	22.24	0.061	0.061	0.060	66	68	73	27
Low (Mechanical)	16.42	18.45	24.75	0.063	0.063	0.058	69	69	73	7
Low (Burn	14.01	15.74	20.89	0.047	0.048	0.049	61	61	67	21

Only)										
Very Low (Burn Only)	15.95	18.08	24.26	0.062	0.061	0.060	71	71	74	4
Very Low (Mechanical)	14.30	15.69	21.73	0.063	0.063	0.062	71	71	74	2
Very Low (PAC Burn Only)	14.29	15.99	21.78	0.067	0.067	0.066	73	73	76	4
Very Low (Core Areas)	14.09	15.88	22.24	0.071	0.071	0.070	74	74	76	1
Weighted Average	**14.86**[4]	**16.63**	**22.22**	**0.061**	**0.061**	**0.059**	66	68	72	

As can be seen in figure 43, CBD and Canopy Cover (CC) would increase, while CBH would decrease. This relationship sets up areas with potential for conditional crown fire where active crown fire could be supported in a stand if it moved in from an adjacent stand, but could not initiate within a stand. Stands likely to support conditional crown fire would have little herbaceous surface fuel, and the primary carrier of the fire at the surface would be needle litter. In the absence of fire, CBD, CC and surface fuel loading increase.

Table 45 shows those areas proposed for the lowest intensity treatments (Very Low (PAC Burn Only) and Very Low (Core Areas)) would have the highest CC and CBD, and some of the lowest CBHs of all treatments, indicating a high potential for crown fire initiation. While CBD begins to decrease by 2050, it is still high enough to present a risk from crown fire, particularly when combined with a high CBDs and CCs.

Surface fuels: Litter, Duff, and Coarse Woody Debris greater than 3” diameter

Litter, duff, and Coarse Woody Debris greater than 3” diameter (CWD>3”) contributing to flammability, surface fire intensity, surface fire effects, soil effects, and emissions. They contribute to emissions more than other fuels because they can and do smolder for long periods of time at temperatures that don’t always allow for complete combustion. The initial flame front in a crown fire consumes large amounts of fuel in a relatively short time. Litter, duff, and CWD can smolder for hours, days, or longer. Mechanical thinning alone can decrease the potential for crown fire by breaking up vertical and horizontal canopy fuel continuity, but initially may increase surface fuel loadings until activity fuels are removed or burned. Initial thinning impacts may create temporary fire ‘breaks’ where there are skid trails, or other surface disturbance have moved surface fuels around, but surface fuels are generally not removed from a treatment area, and remain a potential source of heat and emissions. Surface fuels may be patchier following thinning but, are still available fuels.

Twenty tons/acre was used as a the upper end for recommended surface fuel loading. All treated areas would remain below 20. Historical values were around 5 tons per acre on the high end for CWD, and less than 2.5 tons/acre for duff (Brown et al, 2003) so, assuming ~2.5 tons/acre of litter, by 2020, none of the areas would be within the historical range of surface fuel loading in 2020, and would exceed it by 2050.

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[4] Weighted averages for desired openness are based on the number of acres of ponderosa pine proposed for treatment under each alterantive.

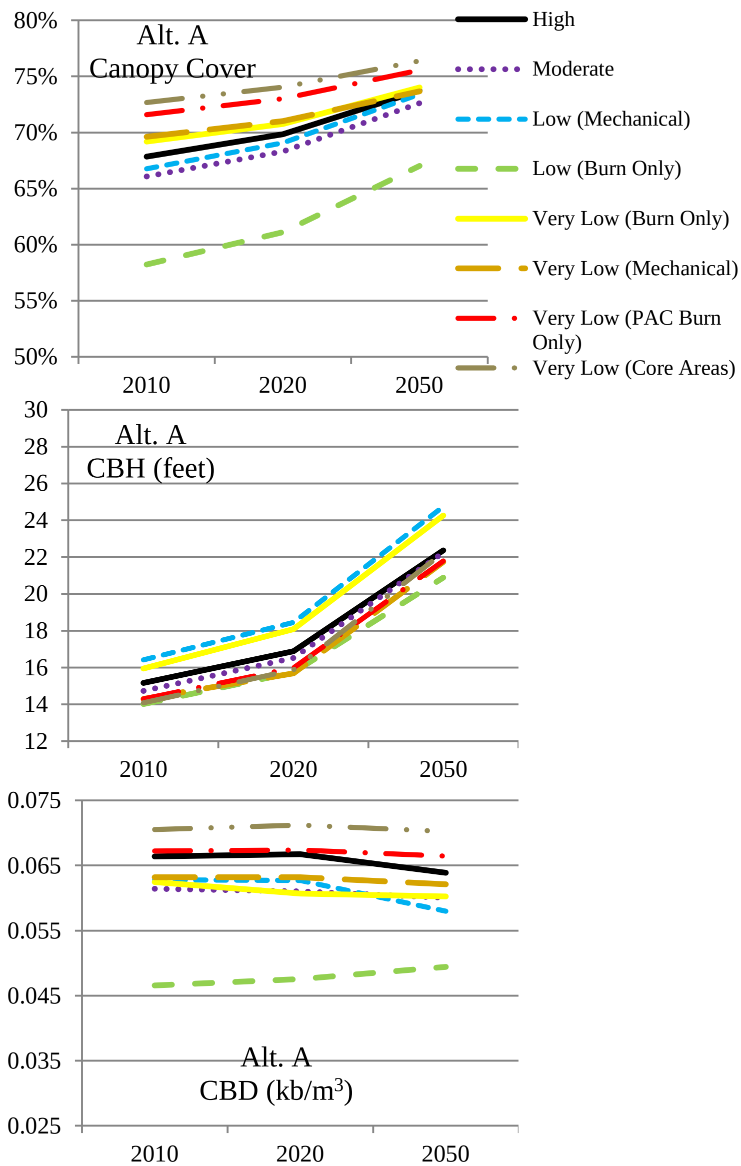


Figure 41. Modeled changes to canopy characteristics

Figure 41 shows modeled changes in surface fuel loading of the combined tons/acre for duff, litter, and CWD over 40 years, assuming no treatment and no wildfire. The increasing trend for all levels of openness would result in increasing amounts of nutrients locked up in dead biomass, and increasing effects on surface vegetation, and increased potential for precipitation to be intercepted by litter and duff before it can reach the ground.

Table 46 shows changes in litter, duff, and CWD>3” as modeled over 40 years with no treatment of any kind or wildfire. The modeling shows a steady increase of litter, duff, and CWD>3”. Under this alternative, duff loads continue to increase, with a maximum of over 6 tons/acre. When this is combined with litter and CWD>3”, total surface fuel loading of these three components ranges from around 16 to 22 tons/acre. These types of fuel loadings could produce undesirable fire effects, including large quantities of emissions.

Table 46. Modeled changes in litter, duff, and CWD>3", Alternative A

Alt A	CWD>3"			Litter			Duff			CWD>3” + Litter + Duff			Percent ponderosa pine
	2010	2020	2050	2010	2020	2050	2010	2020	2050	2010	2020	2050	
High	3.9	4.8	7.6	3.5	4.2	4.7	3.4	3.6	4.2	10.8	12.5	16.5	34
Moderate	3.6	4.6	7.4	3.9	4.6	5.2	3.1	3.3	4.1	10.7	12.5	16.6	27
Low (Mechanical)	3.8	4.7	7.7	3.2	3.9	4.4	3.3	3.5	4.1	10.3	12.1	16.3	7
Low (Burn Only)	3.2	3.8	6.0	2.5	3.2	3.7	2.9	3.1	3.6	8.6	10	13.3	21

Very Low (Burn Only)	4. 7	5.9	9.7	4.4	5.1	5.6	3.6	3.8	4.6	12.7	14.8	19.9	4
Very Low (Mechanical)	4.6	6.1	10.1	4.5	5.0	5.5	4.0	4.2	5.0	13	15.3	20.6	2
Very Low (PAC Burn Only)	6.0	7.7	12.5	4.8	5.6	6.1	5.1	5.3	6.2	15.9	18.6	24.8	4
Very Low (Core Areas)	5.9	7.7	12.4	5.0	5.7	6.2	4.8	5.1	6.0	15.7	18.4	24.6	1
Weighted Average	**3.8**[5]	**4.7**	**7.6**	**3.5**	**4.2**	**4.7**	**3.3**	**3.5**	**4.2**	10.7	12.4	16.5	

Areas that would have the highest surface fuel loading are shown in Figure 43, and are often associated with PACs and Core Areas. RUs 1 and 3 would have the highest surface fuel loading. Under Alternative A, there would be approximately 18,000 acres with surface fuel loading greater than 20 tons/acre, and over 146,000 acres with fuel loading between 15 and 20 tons/acre. By 2040, almost 20 percent of the treatment area would have fuel loads exceeding 20 tons/acre, and an additional 18 percent would be in the 15 – 20 tons/acre range. Figure 43 shows tan areas excluded from potential treatment because of special designation, (Wilderness, etc.), implementation of other projects, or other NEPA planning.

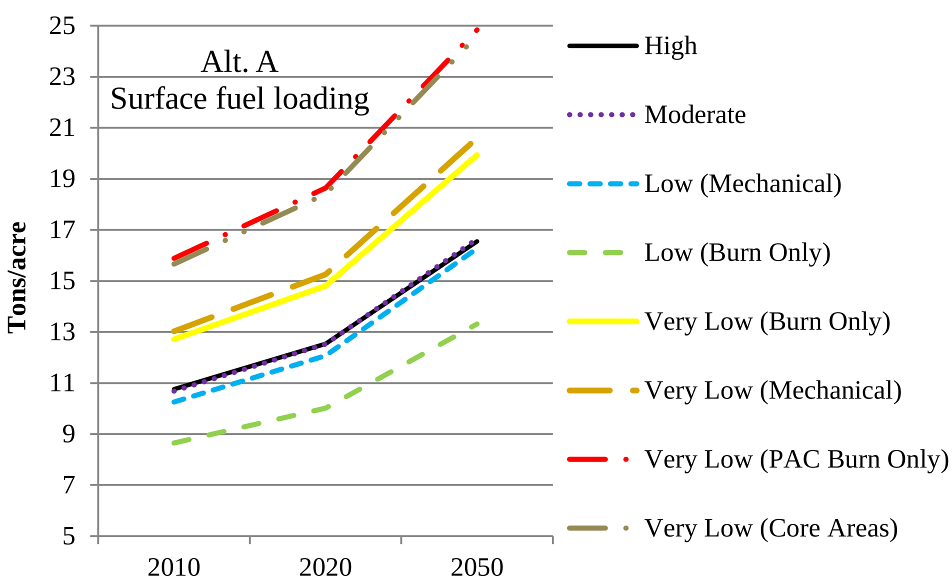


Figure 42. Modeled changes in surface fuel loading with no treatments or fire

[5] Weighted averages for desired openness are based on the number of acres of ponderosa pine proposed for treatment under each alterantive.

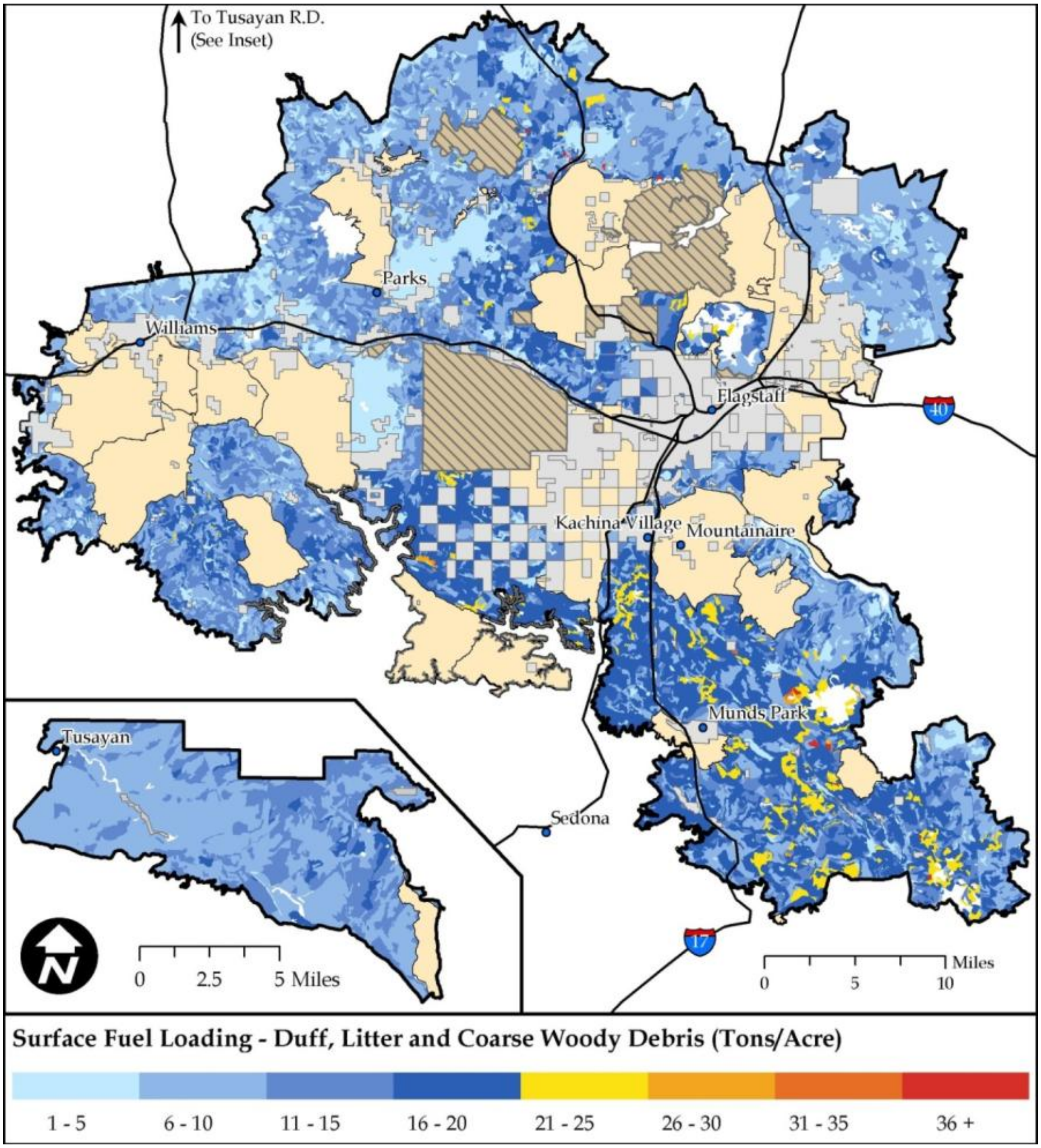


Figure 43. Modeled surface fuel loading for Alternative A, 2020

Fire Regime/Condition Class

Fire Regime/Condition Class is another coarse measure of the health of an ecosystem, particularly in regards to fire. If this alternative was implemented, grasslands and ponderosa pine ecosystems would increasingly become departed from desired conditions, increasing the risk to key ecosystem components. Table 47 shows FRCC as modeled for 40 years of ponderosa pine and grasslands.

Acres of ponderosa pine in Fire Regime/Condition Classes 2 and 3 would continue to increase, leaving just 1 percent in FRCC1. Acres of grasslands in Fire Regime/Condition Class 1 would decrease in the absence of any type of treatment. With nothing to retard encroachment by woody species in grasslands, ponderosa pine and grasslands in the project area would be at moderate to high risk of losing key ecosystem components, should there be a disturbance event, such as fire or extended drought.

Table 47. Alternative A changes to Fire Regime/Condition Class

Vegetation Type	Condition Class	2010		2020		2050	
		Acres	Percent	Acres	Percent	Acres	Percent
Ponderosa Pine	1	70,680	14	55,534	11	5,049	1
	2	136,311	27	95,923	19	136,311	27
	3	297,866	59	353,400	70	363,497	72
Grasslands	1	10,097	18	6,731	12	1,683	3
	2	40,389	72	42,632	76	45,998	82
	3	5,610	10	6,731	12	8,414	15

Fire Return Interval

Fire return intervals (FRI), (page 26), are a characteristic of a fire regime, and a coarse measure of the health of a system. The fire return interval from 2001 through 2010, was calculated to be 43 years for the 1.4 million acres of ponderosa pine and grassland areas in the EIS analysis area. The estimated fire return interval for the treatment area is currently about 40 years. This is double the desired maximum average for ponderosa pine on the Mogollon Rim. From 2001 to 2010, the average number of acres that burned within the treatment area was around 15,000 (dividing the acreage burned by the total number of acres, so 593,000/15,000 = ~40). With no additional fire the average annual acreage burned decreases, increasing the average FRI (Table 48) so by 2050, the average FRI for the treatment area would be 160 years.

Table 48. Average fire return intervals for Alternative A

	# of years averaged (years)	Average annual acres burned	Fire Return Interval
Existing conditions	10 (2001 -2010)	15,000 (2001 -2010)	40
Alt. A 2020	20 (2001- 2020)	7,500 (2001- 2020)	80
Alt A 2050	40 (2001- 2050)	3,750 (2001- 2050)	160

Air Quality and smoke effects

The timing and type of smoke effects would change little initially but, as the likelihood of large fires would increase along with, the potential for air quality levels that exceed National Ambient Air Quality Standards (NAAQS), and nuisance smoke. Restoration Units 1 and 3 have the greatest potential to produce emissions outside of those produced by the flaming front of a crown fire because of surface fuel loading. This alternative would not increase potential smoke impacts during certain times of the year when smoke impacts are largely from prescribed fire (pile burning, broadcast burns, and jackpot burning), generally, mid/late fall, winter, and early spring. The likelihood and degree of potential impacts from wildfire smoke would continue to increase as fuel loading increased. Wildfire smoke is less predictable, less frequent, and more concentrated than emissions from prescribed fires.

Emissions from surface fuels burning in a wildfire in stands that have been thinned, but not burned are not statistically different than those from stands in their existing condition (figure 46). Figure 46 displays emissions from surface fuels burning in wildfires after various treatments including: Left: no treatment; second from left, after two prescribed fires; third from the left, after only mechanical treatment and furthest right, after mechanical treatment and two prescribed fires. Wildfire would be the only source of emissions from the treatment area under this alternative. Figure 46 shows differences in emissions from surface fuels under different treatment scenarios and identical fire conditions. This does not show the effects of the canopy fuels which, in the initial flame front, are a significant producer of emissions from fuels that do not burn in prescribed fires either because they have been removed from the forest, or because prescribed fires are mostly low severity, and rarely consume significant canopy fuels. Emissions from canopy fuels in a crown fire are generally of shorter duration since they are produced as the flaming front passes by. Much of the lingering smoke comes from duff, CWD, litter, stumps, and other fuels that can smolder.

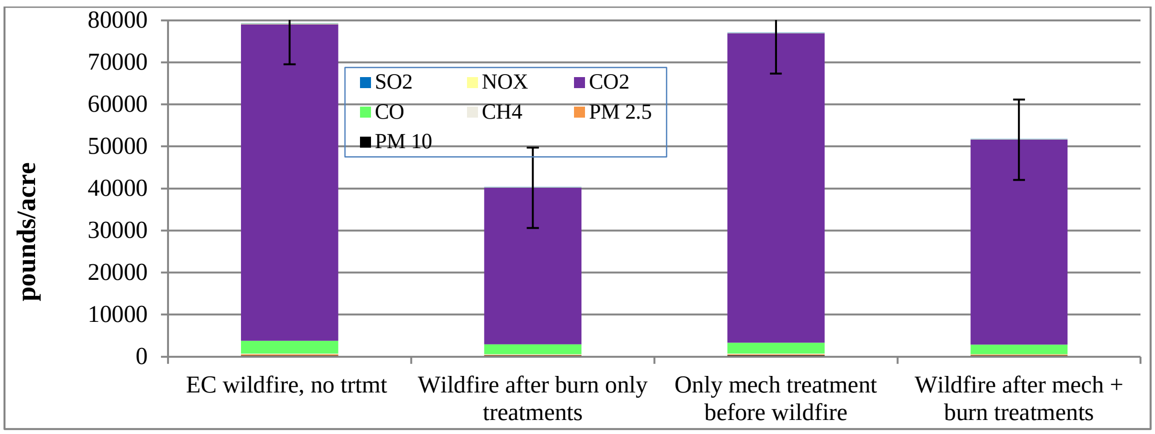


Figure 44. Emissions from surface fuels burning in wildfires after various treatments

In this alternative, smoke impacts generated from the proposed treatment area would only come from wildfires. The impacts would be infrequent (a few times a year); more severe when they occur; and the duration, location, and extent of area/s affected would be largely unpredictable.

Ecological effects of Smoke

Smoke has been shown to be a factor in the germination of many native plants (Abella et al., 2007, Abella 2009), and may be a natural control for mistletoe and other tree infections (Parmeter and Uhrenholdt 1975, Zimmerman et al.1987). With no prescribed fire, the only smoke would come from wildfires. Population dynamics for species that depend on smoke for germination would depend on the chance of a wildfire burning though the area at a beneficial severity. The effects of smoke on tree health is less certain, but there would be no mitigating effects to mistletoe and other tree diseases.

Roads

There would be no change to the existing road condition under this Alternative except for natural changes that occur to roads that were closed under the 2012 Travel Management Rule.

Unavoidable Adverse Effects, Irreversible and Irretrievable Commitment of Resources

As described above, with no treatment, there would be more larger, higher severity fires than occurred historically, or than are sustainable on the landscape. In recent years, fires on the Mogollon Rim that have taken human lives, destroyed homes/property/infrastructure, and produced high severity effects across large areas not adapted to high severity fire include Rodeo/Chediski 2002 (469,000 acres), Wallow 2011 (538,000 acres), and Whitewater 2012 (~297,000 acres). Such fires permanently change tens of thousands of acres of forests when they burn with high severity in areas which are not adapted to high severity fire. There is broad consensus that such fires will continue to burn in this area if no action taken, though the specific extent and location of the negative effects could not be known until an incident occurs. First order effects would include (but are not limited to): chemical and physical changes to soil, high levels of mortality across ~30% or more of the burned area (assuming ~30% high severity), consumption and/or killing of the seed bank, consumption of organic material in soil, including flora and fauna, conversion of forested habitat to non-forested habitat. Second order fire effects would include (but are not limited to) erosion, flooding, debris flows, destroyed infrastructure, changes in visitation to the forest and the economies of local businesses that depend on visitors and degradation of water resources for wildlife and humans. Some of these effects would last just a few days or weeks (infrastructure would be rebuilt), some would take years to recover, some changes would be permanent. For example, topsoil is critical to healthy surface vegetation and would take centuries to recover though, with climate change, it is unknown exactly what the ecological trajectory would be. The loss of old growth and old trees would require decades and centuries to recover.

Effects common to all proposed prescribed fire treatments in all action alternatives

Fire is a natural process with which the ponderosa pine and associated ecosystems within the 4FRI project evolved. It will occur eventually as high or low severity fire, depending on the condition of the forest, and the environmental conditions at the time of the fire. Up to 80% of the area burned in wildfires may be low-severity, producing multiple benefits to the ecosystem, producing less smoke than high severity fire in forested ecosystems. Such fires could be replicated with prescribed fire, with more control over where and when they occur. Most of the effects of the natural role of fire could not be effectively replicated by other means, including nutrient recycling; seed scarification (by both heat and smoke); promotion of a mosaic of seedlings, shrubs, forbs, and grasses; regulating surface fuel loads. Within the treatment areas, fire would contain the dominance of some species, while enhancing that of others (Pyke et al. 2010, Laughlin and Fulé 2011), such as *Ceanothus fendelerii*, *Robinia neomexicana*, legumes, aspen, *Penstemon* spp.C3/C4 grass distribution, and the mosaic of ponderosa pine. Benefits from prescribed fire are numerous and include a controlled reduction in both surface fuels and canopy fuels which is needed across the treatment area. Over time, prudent use of prescribed burning would reduce the damage caused by wildfires, as well as the costs associated with fire suppression (Moody et al. 1992). Fire increases structural heterogeneity and diversity, creating mosaics within stands and over larger areas. Burning promotes natural regeneration of ponderosa pine, providing favorable seedbeds and enhancing the growing environment for survival (Harrington and Sackett 1990).

The effectiveness of using prescribed fire as a tool, alone or combined with mechanical means to restore ponderosa pine to a healthier, more sustainable and resilient conditions is well documented (Fulé et al. 2001, Roccaforte et al. 2008, Strom and Fulé 2007, Fulé et al. 2012). In a systematic review of 54 studies with quantitative data, Fulé et al. (2012) found that:

- Canopy fuels and both fine and coarse surface fuels were significantly reduced relative to controls in burn-only treatments, though the conditions under which a burn is conducted affect the efficiency of a prescribed burn.
- Fine and coarse surface fuels significantly increased in thin-only treatments
- Surface fuels changed little in thin + burn treatments, but had a greater effect than either thinning alone or burning alone on reducing tree density, basal area, and canopy cover.

The proposed treatments would create a mosaic of interspaces and groups (of ponderosa pine) of various sizes that would be maintained with fire. This mosaic is also a mosaic of crown fire potential, with some groups having potential for crown fire under some circumstances, with the surrounding interspaces causing crown fire to transition back to surface fire.

Post-treatment conditions for the action alternatives would include openings that would be managed to promote regeneration. Prescribed fire would be an important tool for creating receptive seedbeds for successful regeneration by consuming surface fuels, creating bare, mineral soil, allowing seeds better contact with soil. As seedlings and small saplings mature, fire and competition would thin trees, maintaining the desired trajectory for a fire-adapted landscape.

In the long term, fire would help maintain a shifting, sustainable, resilient mosaic of groups, interspaces, and openings. Without regeneration openings, even with fire, the space occupied by incoming regeneration would begin to fill in the interspaces and, in the long run, as the seedlings mature, it would increase horizontal and vertical canopy continuity so that, if crown fire did initiate, there would be potential for larger areas of high severity effects.

First entry burns are those burns which are the first time fire occurs in an area that has missed several fire cycles (for the project area, this would be 10 – 20 years). In ponderosa pine and other Fire Regime 1 ecosystems, first entry burns:

- Consume or lethally scorch needles/scales/leaves on the lower branches of trees and shrubs, effectively raising the Canopy Base Height, decreasing Canopy Bulk Density, and decreasing the likelihood of crown fire initiation (direct effects). May include burning activity fuels resulting from thinning.
- Consume/reduce a large portion of surface fuels, with the amount of dead/down woody fuels less than 3 inches in diameter consumed depending primarily on fuel moisture and environmental conditions at the time of the burn) (direct effects).
- Are likely to decrease rotten coarse woody debris and increase sound coarse woody debris in the short term (2-4 years) as some shrubs, branches, or small trees are killed (Waltz et al. 2003) (direct and indirect effects).

- Thin out some small trees, particularly seedlings, maintaining a mosaic of groups and interspaces (Figure 45) (direct effects). Those that survive are healthier because of reduced competition for resources, a flush of post-burn nutrients and, their lower branches/fuels are removed, making them more resistant to future fires.

Objectives in a first entry burn are usually related to consumption of accumulated surface fuels, raising canopy base height, decreasing canopy bulk density, and some group or single tree torching to reduce canopy closure (direct effects). When these are the primary objectives, the ideal timing for the burn may be different than the timing of prescribed fires intended as maintenance burns. In areas where fire has been excluded for many decades, a single prescribed fire is inadequate to reduce fuels (Lynch et al. 2000).

Second entry burns are those burns which occur within a few years of a first entry burn. For second entry burns, fuel loads would be significantly lower than in first entry burns, producing much less smoke and with lower potential for high severity fire. A second entry burn should occur after surface fuels have recovered sufficiently to produce fire behavior sufficient to meet burn objectives. Objectives are likely to relate to reducing the fuel loading as it has been augmented by the effects of the first entry burn. If a branch is alive following a burn, it will drop the scorched needles sooner; if the branch itself has been killed, the needles tend to be retained until removed by weathering (Ryan 1982). Scorched and blackened needles usually drop from the crown within one year of the fire. For a second entry burn, dead wood from seedlings and shrubs top-killed in the first entry burn are part of the fuel load (Figure 45). Dead needles from the lower branches have fallen to the ground and are now part of the surface fuel load (Figure 46). Canopy Base Heights have been raised, so only minimal scorching is likely.

Figure 45. Dead seedlings that will be part of the fuel load for the next fire (Mogollon Rim District of the Coconino National Forest)

Figure 46. Needle-fall from a first entry burn becomes fuel loading for a second entry

Maintenance burns in ponderosa pine generally begin with the third burn in an area that is being restored. This could apply in areas within the treatment area that have burned from wildfire or prescribed fire within the last 10 – 15 years. Maintenance burns occur when ecosystem conditions are such that fire can play its historic role on the ecosystem, as a disturbance that establishes site-specific and landscape scale patterns, regulates flora and fauna, etc. In ponderosa pine, these burns produce low severity effects, fewer emissions, and are able to be conducted with fewer resources. The timing of maintenance burns should mimic the natural seasonality of fire as closely as possible. For those areas which have had two or more fires (wildfire or prescribed fire) in the last twenty years, prescribed fires would be true maintenance burns, with minimal emissions, and only 'maintenance' needed from the fire.

For many acres of the treatment area, prescribed fires would be maintenance burning and, from an ecological perspective, should occur in the summer months if possible. Figure 47 displays the number of fires by the month for which they were reported for those ranger districts on the Coconino and Kaibab National Forests which are included in the treatment area for 4FRI. Note: this shows the number of wildfires, not the acres burned. The number of fires is not analogous to the number of acres burned. Conditions from March through early July are often dry, hot and windy, so fires that escape initial attack are likely to burn more acres than fires that start during the monsoon season when rain is likely to extinguish or slow fires that are started.

Large/old trees

Where site specific mitigation is needed to limit damage or mortality to large or old trees, it is best accomplished by reducing accumulations of fuels within the dripline and in the immediate vicinity of the trees. These fuels may include litter, duff, accumulations of woody fuels, ladder fuels, or any fuel that could produce sufficient heat to lethally damage a tree. This can be accomplished manually, mechanically, or though fire treatments. Potential measures include implementing prescription parameters, ignition techniques, raking, wetting, leafblowing, thinning, or otherwise mitigating fire impacts to the degree necessary to meet burn objectives. Throughout the life of this project, it is likely that some large and/or old trees would be damaged or killed by prescribed fire. It would not be possible to mitigate every large and/or old tree over 30,000 to 40,000 acres of prescribed fire units each year.

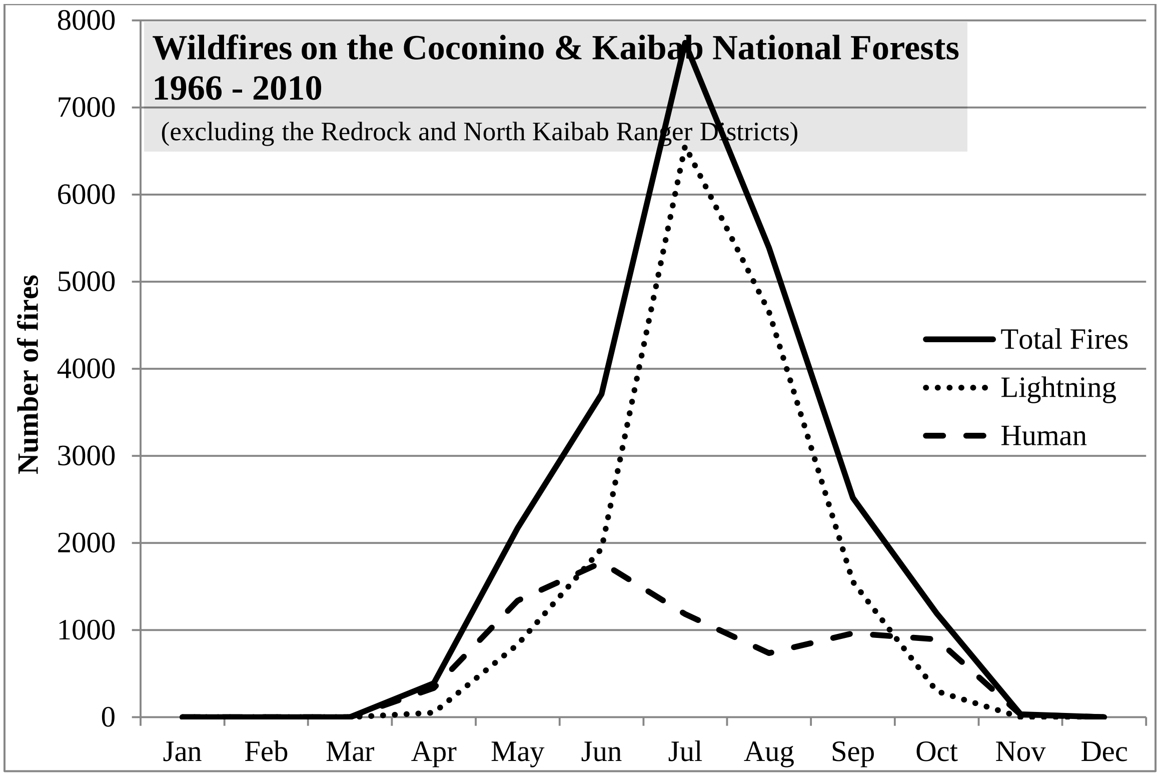


Figure 47. Number of fires within the treatment area

Crowning and Torching Indices

In response to public comments and requests, an analysis was added to compare changes in crowning and torching indices for ponderosa forests where future management would include prescribed fire, and forests for which there are no treatments or fires beyond what is in the proposed actions.

Crowning and Torching indices are measures of how strong the wind must blow for crownfire to occur and are one indicator of the vulnerability of a forest to the high severity effects that result from crown fire (Fule et al., 2012). The Torching Index (TI) indicates the wind speed at which crown fire could initiate. The Crowning Index (CI) indicates the wind speed at which a crown fire that has initiated could be sustained as an active crown fire. In a healthy ponderosa pine forest, both indices would be high, meaning that the forest can withstand high wind speeds without the occurrence of crown fire. Historically, frequent fires maintained that condition by regulating surface fuel loading (limiting potential fireline intensity/flame length), maintaining a mosaic of seedlings/saplings/shrubs (reducing ladder fuels and breaking up horizontal and vertical fuel structure), and maintaining canopy base heights that would make it unusual for crown fire to initiate, and very unusual for active crown fire to be sustained.

This analysis compares the modeled response of one of the most common stand conditions across the ponderosa pine in the project area following one thinning and two prescribed fires.

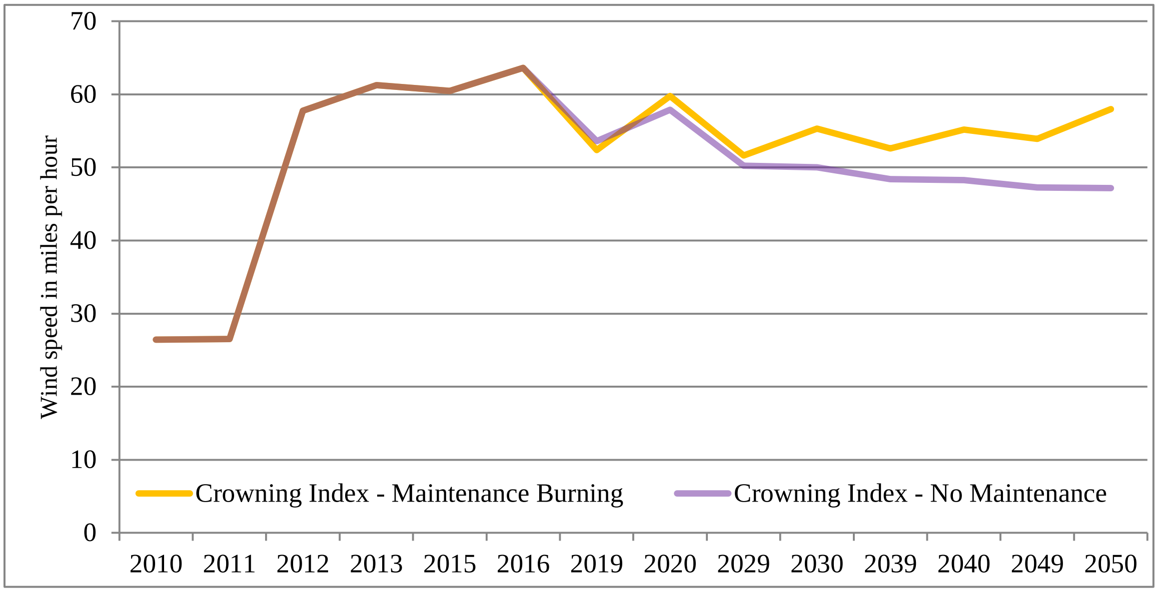
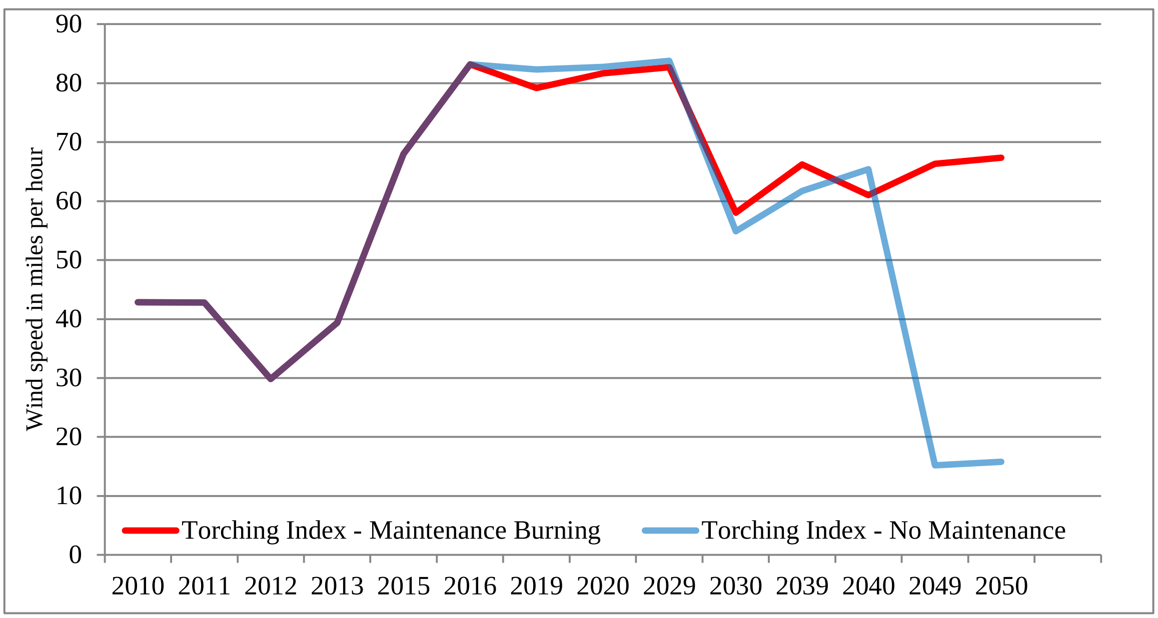


Figure 48. Crowning and torching indices over time with and without maintenance burns. Modeling was done with the Forest Vegetation Simulator – Fire/Fuels Extension (FVS and



The modeling was done with the Forest Vegetation Simulator – Fire/Fuels Extension (FVS and FFE). In 2010, the stand show indices that would be expected from a stand that could support conditional crown fire because the stand has a high canopy density (0.11 kg/m^3), high canopy closure (51%) and a low canopy base height (13). The surface would be shaded and/or has sufficient surface litter to suppress surface vegetation – including ladder fuels. In its 2010 condition, the stand can support crown fire if it moves into the stand as crown fire at a wind speed of 26 mph (Figure 48). It can support torching (torching is another name for passive crown fire) at a wind speed of 43 mph – the speed at which surface fire would burn with an intensity high enough to produce flame lengths of at least 6.5 feet (1/2 the height of the canopy base height) (Figure 49). Following thinning in 2012, the crowning index jumps, because thinning breaks up the horizontal and vertical continuity of the canopy fuels. Conversely, the torching index decreases further, because the additional surface fuels resulting from thinning alone have increased the potential surface fire intensity. Prescribed fires in 2015 and 2019 increase both indices, raising canopy base height, decreasing surface fuels, and decreasing canopy bulk density. The largest increase in the torching index which goes from 30, following thinning, to 83 following the second prescribed fire as canopy base height increases.

Following the prescribed fire in 2019, the indices remain statistically identical until the prescribed burn in 2029. At that point, both indices increase in the stand that had the prescribed fire, and both decrease in the stand without fire. For the next two burn cycles (2039 and 2049), the trend is for both indices to increase in the stand that is being ‘treated’ with prescribed fire, and decreases in the stand with no treatments. Regeneration is modeled to initiate following the prescribed fires in 2015 and 2019, but plays little role in these indices until it matures to a point that it plays a role as a ladder fuel, and the program adjusts canopy base height to show the effect. This regeneration ‘pulse’ is most obvious in 2040 where the TI drops precipitously to 15. The CI continues a slow, steady decrease as canopy fuels become more contiguous.

The effects of maintenance burning are clear to see in graphs for both indices, as well as the effects of no treatments.

Figure 48 and Figure 49 show the changes in TI and CI in a stand that was thinned in 2012, and had prescribed fires implemented in 2015 and 2019. Following 2019 the stand was modeled for; 1) no treatments of any kind and; 2) prescribed fires implemented every 10 years (2029, 2039, 2049).

Alternative B

From a fire ecology perspective, direct and indirect effects of Alternative B relate primarily to treatments that include using mechanical thinning, prescribed fire, or both to meet the purpose and need of the 4FRI. This alternative proposes to implement approximately 587,923 acres of restoration Up to 45,000 acres of vegetation would be mechanically treated annually. Up to 40,000 acres of prescribed fire would be implemented annually across the forests. Two prescribed fires[6] would be conducted on all acres proposed for prescribed fire over the 10-year period. Restoration activities would:

- Mechanically cut trees and apply prescribed fire on approximately 388,489 acres. This includes: (1) mechanically treating up to 16-inch dbh within 18 Mexican spotted owl protected activity centers, (2) cutting 99 acres of trees by hand on slopes greater than 40 percent, and, (3) using low-severity prescribed fire within 72 MSO PACs (excluding core areas)
- Utilize prescribed fire-only on approximately 199,435 acres. This includes acres available for ‘Operational Burn’ only which include grasslands, Pinyon/Juniper (PJ), oak woodland that are situated within, or adjacent to aspen or ponderosa pine such that logistics indicate it should be included in the burn unit to facilitate proposed prescribed fire treatments
- Construct 517 miles of temporary roads for haul access and decommission when treatments are complete (no new permanent roads would be constructed)
- Reconstruct up to 40 miles of existing, open roads for resource and safety concerns (no

[6] The first prescribed fire may include pile burning followed by a broadcast burn.

new permanent roads would be constructed). Of these miles, approximately 30 miles would be improved to allow for haul (primarily widening corners to improve turn radiuses) and about 10 miles of road would be relocated out of stream bottoms. Relocated roads would include rehabilitation of the moved road segment.

- Decommission 770 miles of existing system and unauthorized roads on the Coconino NF
- Decommission 134 miles of unauthorized roads on the Kaibab NF
- Restore 74 springs and construct up to 4 miles of protective fencing
- Restore 39 miles of ephemeral channels
- Construct up to 82 miles of protective (aspen) fencing
- Allocate as old growth 40 percent of ponderosa pine and 77 percent of pinyon-juniper woodland on the Coconino NF and 35 percent of ponderosa pine and 58 percent of pinyon-juniper on the Kaibab NF

Three non-significant forest plan amendments would be required on the Coconino NF to implement the proposed action:

- Amendment 1 would allow the use of mechanical treatments to improve habitat structure and allow for mechanical treatment up to 16-inch dbh within 18 MSO PACs to improve nesting and roosting habitat. All Mexican spotted owl monitoring would defer to the project's Biological Opinion issued by US Fish and Wildlife Service.
- Amendment 2 would : 1) add the desired percentage of interspace within uneven-aged stands to facilitate restoration and defines interspace, (2) add the interspace distance between tree groups, (3) add language clarifying where canopy cover is and is not measured, (4) allows 29,017 acres to be managed for an open reference condition (figure 47), which affects canopy cover guidelines for VSS 4 through VSS 6 groups and reserve trees, and (5) add a definition to the forest plan glossary for the terms interspaces, open reference condition, and stands.
- (3) Amendment 3 would allow for managing to achieve a "No Adverse Effect" determination for significant, or potentially significant, inventoried heritage sites.

Two non-significant forest plan amendment would be required on the Kaibab NF to implement the proposed action.

- Amendment 1 would 1) add the desired percentage of interspace within uneven-aged stands to facilitate restoration and defines interspace, (2) add the interspace distance between tree groups, (3) add language clarifying where canopy cover is and is not measured, (4) allows 27,637 acres to be managed for an open reference condition (figure 47), which affects canopy cover guidelines for VSS 4 through VSS 6 groups and reserve trees, and (5) add a definition to the forest plan glossary for the terms interspaces, open reference condition, and stands.
- Amendment 2 would defer all Mexican spotted owl monitoring to the project's Biological Opinion issued by US Fish and Wildlife Service.

Two non-significant forest plan amendment would be required on the Kaibab NF to implement the proposed action.

- Amendment 1 would 1) add the desired percentage of interspace within uneven-aged stands to facilitate restoration and defines interspace, (2) add the interspace distance between tree groups, (3) add language clarifying where canopy cover is and is not

measured, (4) allows 27,637 acres to be managed for an open reference condition, which affects canopy cover guidelines for VSS 4 through VSS 6 groups and reserve trees, and (5) add a definition to the forest plan glossary for the terms interspaces, open reference condition, and stands.

- Amendment 2 would defer all Mexican spotted owl monitoring to the project's Biological Opinion issued by US Fish and Wildlife Service.

Thinning, whether or not slash was removed from the site, would give managers more control of the amount and timing of emissions. As thinning and first-entry burns were completed, burn windows would expand for larger areas so more burning could occur when ventilation was good. Fewer and healthier trees, as a result of thinning and would be more fire resistant, and understory and surface vegetation would become established. With lower surface fuel loading, and canopy fuels adapted to fire, burn windows would be broader than for initial entry burns. Decision space for managing unplanned ignitions would expand as 4FRI (and other projects) are implemented. Up to two prescribed fires would be implemented, which may include pile burning months in advance of broadcast burns. Ideally, prescribed fires would occur on an average of every 10 years, depending on yearly fluctuations in climate/weather at different locations within the treatment area. Some areas will have had prescribed fire or wildfire within the last 10 – 15 years, so prescribed fires that are implemented will be maintenance burns. Limitations (wildlife concerns, smoke, funding, resource availability, etc.) may make it difficult to attain an average of a 10 year fire return interval across the proposed treatment area. Burning some areas on a slightly longer return interval may be acceptable (drier areas such as Tusayan) and/or may specifically target to reduce smoke in sensitive receptors as mitigation for prescribed fires.

This alternative would meet direction in the Forest Service Manual 5100 (page 9) which includes direction on USFS use of prescribed fire to meet land and resource management goals and objectives. Objectives of fire management on lands managed by the USFS include:

1. Forest Service fire management activities shall always put human life as the single, overriding priority. The proposed actions of the 4FRI fully support incorporation of the highest standards for firefighter and public safety and are expected to improve and enhance the safety of the public as it relates to wildland fire.

2. Forest Service fire management activities should result in safe, cost-effective fire management programs that protect, maintain, and enhance National Forest System lands, adjacent lands, and lands protected by the Forest Service under cooperative agreement. 4FRI proposes to achieve restoration by restoring ecosystems within the treated area to a condition so that fire, when it occurs, would be beneficial to the ecosystems in which it burns without threatening lives, property, or resources. This will be achieved by fully integrating local industry, mechanical and fire prescriptive treatments, and providing for sustainable supplies of goods, services, and social values though implementation of appropriate fire management activities.

Direct and Indirect Effects

Changes to potential fire behavior are the indirect effects of changes to fuel loading and structure. The effects of implementing Alternative B are discussed in the following order:

1. Fire behavior is discussed at the treatment area scale

2. Potential fire behavior is discussed by vegetation type

3. Within Restoration Units and Subunits, fire behavior is broken out by vegetation/habitat types
4. Canopy characteristics and fuel loading and how they affect fire behavior, fire effects and air quality are presented by desired openness

Amendment 1 (Coconino NF): If amendment 1 is implemented, the resulting decreases in CBH, CBD, and CC would have the indirect effect of slightly decreasing crown fire potential for the 18 MSO PACs that would receive mechanical treatments. An additional indirect would be to increase the ability of fire managers to implement prescribed fire within PACs because of decreased potential fire behavior. If amendment 1 is not implemented on the Coconino NF, these 18 PACs (~10,700 acres) would retain the current forest structure that places them at high risk of high severity fire. Potential fire behavior would make it difficult to implement prescribed fire because of narrow burn windows (weather and fuel conditions that would produce the desired fire effects and behavior). If prescribed fires were implemented on acres adjacent to PACs, it is more likely that some firelines would need to be created to avoid burning, producing ground disturbance that would be less likely under the proposed amendment. There would be little effect on emissions, except for a slight decrease in potential emissions in the event of wildfire following mechanical treatments within the PACs.

Amendment 2 (Coconino NF): If amendment 2 is implemented, it would allow 29,017 acres to be managed for an open reference condition. An indirect effect of managing for open conditions would be to have little potential for active crown fire, moving these acres towards the desired conditions. Open conditions would, in the long run, produce fewer emissions because of less litter and debris from trees, and greater herbaceous component to surface fuels, which is a flashier fuel, burning faster and more cleanly quickly than woody fuels. If amendment 2 is not implemented on the Coconino NF, some treatments could be implemented, but would not move these acres as far towards desired conditions as they would be under the amendment.

Amendment 3 (Coconino NF): If amendment 3 is implemented, it would allow fire to be used to meet objectives if it was determined to be the best tool. Additionally, it would allow all significant, or potentially significant inventoried sites that are not considered 'fire sensitive' to be included in burn units. If amendment 3 is not implemented, all significant, or potentially significant inventoried sites within burn units, regardless of if they are considered 'fire sensitive' or not, would be managed for 'no effect'.

Amendment 1 (Kaibab NF): If amendment 1 is implemented, the same effects that are described above (Amendment 2 for the Coconino) would apply to the 27,637 acres to be managed for an open reference condition.

Amendment 2 (Kaibab NF): If amendment 2 is implemented, it would have minimal effect on the implementation of prescribed fire proposed under alternative B on the KNF because there would be only minor differences from the current conditions.

In the short term (<20 years), across the treatment area the potential for undesirable fire behavior and effects would be reduced by breaking up the vertical and horizontal continuity of canopy fuels, decreasing excessive surface fuel loads of litter and duff (all direct effects), and replacing them with the light, flashy fuels that would be stimulated by post-treatment conditions (second order effects). Wildfire behavior would benefit the ecosystems in which it burned, and would not threaten lives, resources, or infrastructure, except where they are near or downslope from wildlife habitat that could not be treated as intensively as the rest of the treatment area at this time. Air quality impacts (indirect effects) could increase some as prescribed fires are implemented.

In the long term (>20 years), potential for undesirable fire behavior, as assessed by changes to canopy fuels, would remain lower than existing condition for approximately 68 percent of the ponderosa pine in the treatment area. Potential for undesirable fire effects, as assessed by changes to canopy fuels and surface fuel loading, would remain lower than existing condition for approximately 35 percent of the ponderosa pine in the treatment area. Air quality impacts could decrease some as the majority of the treatment area would be in maintenance burn mode, producing fewer emissions per acre.

When analyzed at the scale of the treatment area, Alternative B would meet the purpose and need by moving the project area towards the desired condition of having potential for less than 10 percent crown fire as modeled under the conditions that produced the Schultz Fire (Table 49) crown fire. Table 49 displays modeled fire behavior for Alternative B across the entire treatment area. Non-burnable substrates constitute ~2 percent of the treatment area and were not included in the acres shown fire potential fire behavior.

Table 49. Modeled fire type for Alternative B and Existing Condition

Modeled Fire Behavior (% area)	Existing Condition	Alternative B
Surface fire	64	94
Passive crown fire	9	3
Active crown fire	25	2

Under Alternative B, the horizontal and vertical continuity of canopy fuels are broken up (direct effect), decreasing the potential for crown fire from 34 percent of the treatment area to 5 percent of the treatment area, with potential for active crown fire decreasing from 25 percent to 2 percent (indirect effect). The amount of potential crown fire remaining after proposed treatments would be well within the historic ranges of ponderosa pine in this area. As illustrated by Figure 50, much of the remaining potential for active crown fire would be in Restoration Units 1 and 3 In most cases, it would occur in MSO and goshawk habitat (Table 50). Non-burnable substrates constitute ~2 percent of the treatment area and were not included in the acres shown fire potential fire behavior.

Ponderosa Pine

At the project area scale, ponderosa pine would meet desired conditions under Alternative B (<10 percent crown fire). When ponderosa pine is considered by habitat type across the whole treatment area, at least 17,988 acres of protected habitat (25 percent) would have potential for crown fire (Figure 50). Decreasing the horizontal and vertical continuity of canopy fuels (direct effect) would allow sunlight to reach the surface, increasing surface temperatures, and decreasing dead fuel moisture content at the surface. This, combined with increased surface winds with fewer trees blocking the wind, would increase surface fire intensity, flame length, and rate of spread even if surface fuels were the same before and after thinning (Omi and Martinson 2004, Scott 2003). Therefore, canopy fuel treatments reduce the potential for crown fire (indirect effect) at the expense of slightly increased surface fire behavior (fireline intensity, flame length, and rate of spread). However, critical levels of fire behavior (limits of manual or mechanical control) are less likely to be reached in stands treated to withstand crown fires, as all crown fires are uncontrollable. Although surface intensity may be increased after treatment, a fire that remains on the surface beneath a timber stand is generally more controllable (Scott 2003).

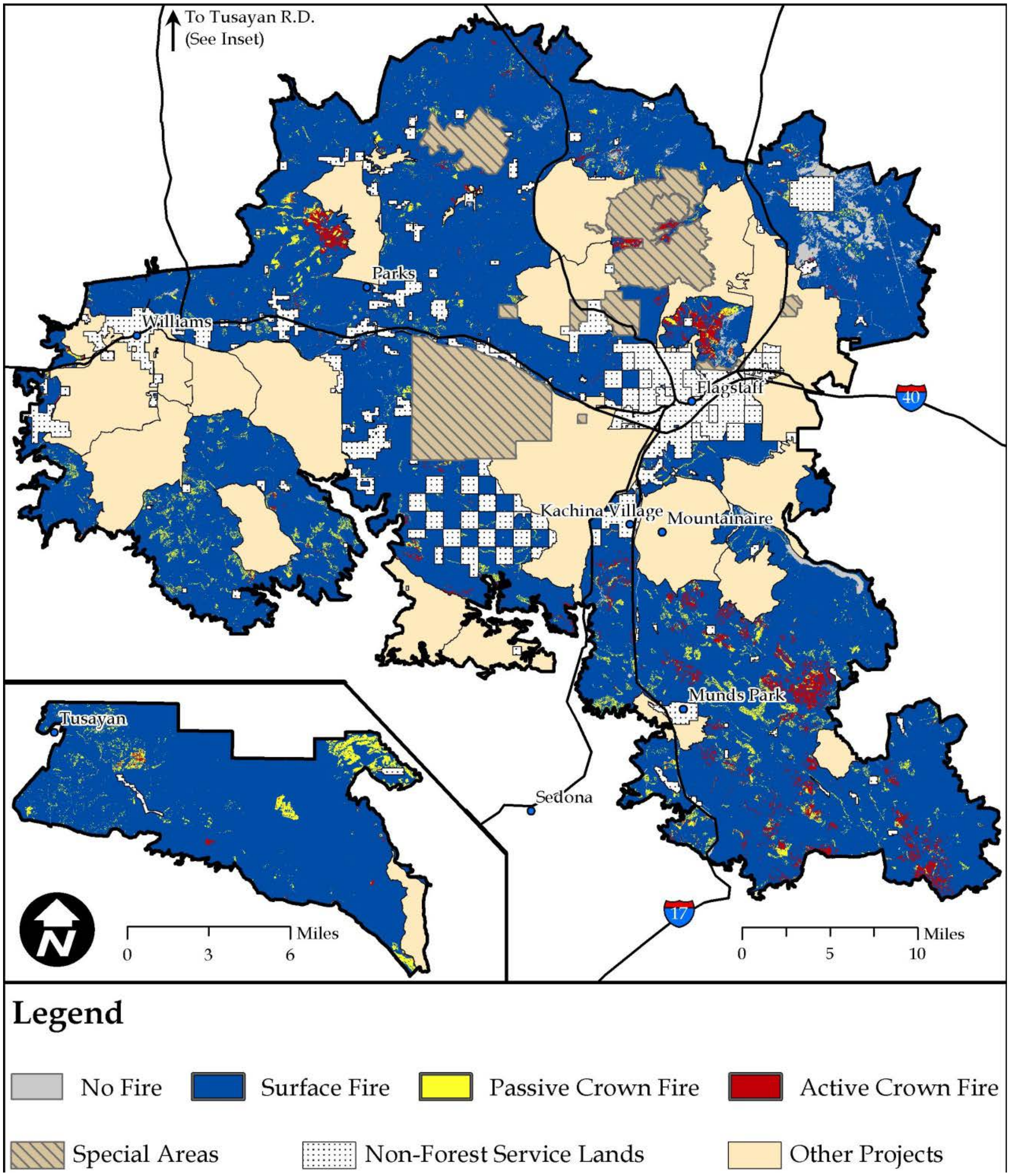


Figure 50. Modeled fire type for Alternative B, 2020

Table 50. Modeled fire type in ponderosa pine by habitat for 2020, Alternative B

Vegetation Type	Fire Type	Existing Conditions	2020

			Acres	Percent	Acres	Percent
Ponderosa Pine	**All Pine**	**Surface fire**	**313,423**	**62**	**481,206**	**95**
		Passive crown fire	**48,523**	**10**	**16,133**	**3**
		Active crown fire	**145,113**	**29**	**9,717**	**2**
	MSO Protected	Surface fire	18,610	51	27,319	75
		Passive crown fire	3,141	9	2,191	6
		Active crown fire	14,847	41	7,087	19
	MSO Target/ Threshold	Surface fire	4,292	49	8,236	95
		Passive crown fire	926	11	109	1
		Active crown fire	3,479	40	353	4
	MSO Restricted	Surface fire	35,465	53	60,373	90
		Passive crown fire	6,608	10	6,512	10
		Active crown fire	25,187	37	375	1
	Goshawk PFA/ dPFA/ Nest Stand	Surface fire	18,737	62	28,409	93
		Passive crown fire	2,952	10	1,560	5
		Active crown fire	8,756	29	476	2
	Landscapes outside of PFAs	Surface fire	236,320	65	356,872	98
		Passive crown fire	34,896	10	5,761	2
		Active crown fire	92,844	26	1,426	0

Pine/Sage

A direct effect of thinning the pine in this 16,064 acre area would be decreased shading of the surface vegetation, including sage. Other direct effects of prescribed fire in ponderosa pine would include, thinning of seedlings and some saplings, and consumption of surface fuels. Indirect effects of prescribed fire would be the maintenance of a mosaic of sage, other shrubs, and herbaceous vegetation at the surface by consuming decadent woody shrub debris, nutrient recycling, and providing the mineral soil seedbed preferred for sage regeneration by seed. Some shrubs would sprout in the years following a fire, further maintaining a multi-aged stands of shrubs, and a shifting mosaic of shrubs and herbaceous vegetation.

Large/old trees

Mechanical treatments and prescribed fire will be implemented to help sustain large/old trees across the landscape, and make them more resistant and resilient to natural disturbances such as fire. Throughout the life of this project, it is likely that some large and/or old trees may be damaged or killed by prescribed fire, by direct and/or indirect effects, despite mitigation measures. However, under this alternative thinning and prescribed fire would decrease potential fire effects in the vicinity of most old and/or large trees, decreasing the likelihood of lethal damage in the event of a wildfire. Under Alternative B, the potential for fire-related mortality of large and/or old trees would be reduced across the landscape. Ignition techniques or other mitigations would be employed to minimize residence time in duff adjacent to old trees whenever possible. Under this alternative, low severity fire would be used in the vicinity of old trees and, to the degree it is practicable, ladder fuels and excessive surface fuel buildups adjacent to old trees would be removed before burning. Scorch is one of the primary factors in large and old tree mortality (Jerman et al. 2004), and is influenced by the vertical arrangement of fuels. Prescribed fire and mechanical treatments in the vicinity of old and/or large trees would decrease fuel loading in the immediate vicinity of these trees, decreasing the potential for crown scorch.

Mitigation measures (page 222) are unpredictable, and site specific (Kolb et al. 2007, Hood 2008), and some can have negative effects of their own. Raking, for example, can remove fine, live roots in the surface organic layers, which may compound the effects of additional shallow roots being damaged by fire, though it is unlikely to actually kill the tree. Low intensity fire that causes little crown scorch can stimulate resin production in old trees, but may attract bark beetles, increasing tree mortality. Mitigation measures implemented a year or more before a burn, such as thinning or raking, may improve the health of the tree, improving its response to fire.

Aspen

The most common indirect effect on aspen is to sucker in response to fire, regardless of the fire type. An indirect effect of alternative B is the reduction of active crown fire potential to 0 percent, while increasing passive crown fire to 16 percent with no change to the percent surface fire. Many stands in the project area are stressed, but are still likely to respond to a low severity fire by suckering, though the timing of a fire would be important, with fall fires likely to be more beneficial. Where encroaching conifers are cut out of aspen and prescribed fires are implemented, the expected result would be a decrease in decadent, unhealthy stems and an increase in suckering. Decadent stems would either be partially consumed or topkilled by fire. The death of mature aspen stems, by fire (direct effect) would not in itself cause for alarm because of the natural ability of aspen roots to readily regenerate after death of the overstory trees. The decreased albedo of the soil surface (indirect effect) would encourage the suckering for the first growing season, allowing the new sprouts to grow tall fast enough to compete with herbaceous vegetation, most of which would also be rejuvenated.

The suckers would be at risk of browsing from ungulates who would be attracted by the new growth so fencing or other deterrents would be implemented where possible to minimized access by ungulates. Under Alternative B, up to 82 miles of fencing or other deterrent would be implemented to protect aspen from browsing ungulates. If jackstrawing was employed, it would increase the resistance to control of fires burning in jackstrawed areas, and could limit access to fires in the vicinity. If prescribed fire was implemented in a stand where jackstrawing has been completed, objectives for the stand and the burn would have to be carefully assessed to determine what fire behavior is appropriate and safe for meeting both control and resource objectives. Surface fire effects, should the jackstrawing burn under conditions that allow fire to consume most of it at once (wildfire), would be high or very high severity to vegetation and soil in the immediate vicinity.

Fire is a valuable tool that would be used to help regenerate aspen clones, and would be particularly effective when combined with mechanical treatment where the degree of conifer encroachment is too high to be managed with fire alone (Strand 2009, Jones and DeByle 1985). Although pure aspen stands usually do not burn well, those with enough fuel to carry a fire would be expected to respond well to treatments (Shepperd 1986).

Gambel Oak

Within the project area, fire is a keystone process with which the habitat for the northern goshawk and Mexican spotted owl evolved. Fire, along with bunch grass competition, helps keep pine from out-competing Gambel oak (Abella 2008, Reynolds et al. 1992), an important forage plant for many wildlife species. Fire is a recommended management tool for improving goshawk habitat, and fire suppression is credited with degrading goshawk habitat by changing forest structure and composition (Reynolds et al. 1992).

The effects to Gambel oak under Alternative B would be beneficial and, at the scale of the treatment area, would decrease potential for crown fire in 3,368 acres of oak woodlands from 23 percent (15 percent active crown fire) to 0 percent to 10 percent crown fire. Oak is a component of restricted habitat within the ponderosa pine type. Alternative B would decrease crown fire potential in restricted habitat from 47 percent (existing condition) to 11 percent post treatment.

Fire of any kind is unlikely to eliminate Gambel oak from a site. Intense wildfires that remove competing vegetation often facilitate development of oak brushfields on sites formerly dominated by ponderosa pine (Abella and Fulé 2008), but low intensity surface fire is likely to benefit Gambel oak.

The thinning of ponderosa pine stems in areas dominated by Gambel oak, combined with decreased canopy fuels from prescribed burning (decreased CBD and CC) would decrease excessive shading from ponderosa pine (direct effect) which has been, in part, responsible for the decline of larger diameter oak (>6"dbh). It is likely that there would be some mortality in large diameter oak from prescribed fire (direct effects), particularly in areas where fire has been removed from the system for 20 years or more but, in general, prescribed fires would be low severity and, to the degree it is practical, care would be taken to minimize impacts to larger diameter oak (see design features, page 321).

Direct effects would include some small and medium diameter oak being topkilled by fire, but few oak stems greater than 6 inches would be expected to be topkilled by prescribed fire (Abella, 2008b). The immediate result would be a decrease in small diameter oak (less than 2"), but oak sprout following low severity burns so, after 2-4 years, the result would be an increase in small diameter oak stems from prolific sprouting (Harrington 1985). Burning oak with a return interval of less than 10 years on most cites, with summer burns when possible, would move oak towards presettlement conditions (Fulé et al. 1997a, Fulé et al. 2005), with more larger diameter oak, and fewer small diameter. The overall effect of Alternative B on Gambel oak would be a shift in the ratio of small to large diameter oak as very few large ones are killed, but small ones increase.

Grasslands

Alternative B proposes to implement prescribed fire on 48,493 acres of grassland vegetation. However, it is Operational Burn only, so these acres would only be burned if/as needed to facilitate burning in pine and aspen. If all the Operational Burns analyzed were implemented, prescribed fires would benefit the grasslands by decreasing woody encroachment, and decreasing the potential for crown fire from 9 percent (4,115 acres) to 7 percent (3,346 acres) (Table 51). On those acres with potential for active crown fire, there would be potential for undesirable fire behavior and effects. Ponderosa pine encroachment into grassland areas has been in progress for so long that on at least 3,346 acres, trees are too large for fire to be an effective thinning tool. While the first fire or two may kill some trees and reduce the potential for crown fire, they also significantly increase the resistance of the trees from future fires by consuming or killing fine fuels (needles) on the lower branches so heat from subsequent fires does no additional damage. That would render the trees effectively fireproof. Mechanically cutting the larger tree would allow fire to remove the smaller ones, in addition to resuming other natural roles of fire in grasslands (recycling nutrients, killing some pathogens, scarifying seeds, etc.).

Table 51. Modeled fire type in grasslands by Restoration Unit for Alternative B

Grassland RU	Fire Type	Vegetation type acres	Existing		Alternative B 2020	
			Acres	Percent	Acres	Percent
RU1	Surface	8,133	6,151	76	6,558	81
	Passive crown		1,321	16	1,011	12
	Active crown		239	3	143	2
RU3	Surface	12,775	11,703	92	11,892	93
	Passive crown		683	5	561	4
	Active crown		172	1	105	1
RU4	Surface	22,599	21,082	93	21,228	94
	Passive crown		753	3	675	3
	Active crown		613	3	545	2
RU5	Surface	4,595	2,577	56	2,604	57
	Passive crown		225	5	212	5
	Active crown		105	2	91	2
RU6	Surface	93	89	96	89	97
	Passive crown		3	3	2	3
	Active crown		1	1	1	1

Fire effects in grasslands would include:

- Killing woody encroachment, particularly ponderosa pine (direct effect)
- Rejuvenating ‘wolfy’ grasses and decadent shrubs (indirect effect)
- Scarifying seeds with smoke and/or heat (direct effect – the germination of these seeds would be an indirect effect)
- Recycling nutrients (indirect)

Pinyon/Juniper (PJ)

Pinyon/Juniper (PJ) is not a candidate for restoration under the 4FRI. There are 535 acres that are being mechanically treated in RU6 with a fuels reduction objective, and 25,117 acres that are being included under ‘operational burn’, with the objective of facilitating prescribed fire in ponderosa pine as needed. The intent is to burn these acres only if needed to facilitate prescribed fire in adjacent grasslands or ponderosa pine. The objective if they are burned would be to use a fire that would produce low severity effects that would provide a 'black-line' for the associated restoration unit. An occasional tree may torch, that is the nature of PJ, but it would be isolated. As modeled, potential fire crown fire in all PJ would be decreased (Table 52) by 14 percent. Potential crown fire in that area of RU6 being treated with fuels reduction objectives would reduce crown fire by 27 percent virtually eliminating it (Table 53).

Table 52. Modeled fire type in all Pinyon/Juniper

	Fire Type	Existing Condition 2010 Percent/Acres	Alternative B 2020 Percent/Acres	Alternative C 2020 Percent/Acres
Pinyon/ Juniper	Surface fire	84/19,367	98/22,516	98/22,524
	Passive crown fire	7/1,535	2/384	2/379
	Active crown fire	9/2,041	0/43	0/41

Table 53. Modeled fire type in the Pinyon Juniper in Restoration Unit 6

	Fire Type	Existing Condition 2010 Percent/Acres	Alternative B 2020 Percent/Acres	Alternative C 2020 Percent/Acres
Pinyon/ Juniper	Surface fire	74/595	100/533	100/533
	Passive crown fire	25/132	0/2	0/2
	Active crown fire	2/8	0/0	0/0

A little over 25,000 acres of PJ would have operational burning only, and direct effects would be expected to be minimal, with maximum fire behavior being scattered torching on less than 385 acres out of ~23,000. Huffman et al. (2009) found that prescribed fire in Pinyon/Juniper, when implemented by hand crews, produced few significant reductions in hazardous fuel loads. Fuel reduction by fire alone would require more extreme weather conditions and fire behavior than are normally used for prescribed fire because the natural fire regime of much of the PJ in the project area is for small, high severity fires. Broadening the range of acceptable weather and fire behavior increases the risk of fire escape. A burn-only approach is likely to be unsuitable for pinyon/juniper projects in the wildland–urban interface which is where the units of PJ fuels reduction in the treatment area are located.

Restoration Units

At the scale of the Restoration Unit, Alternative B would meet desired conditions for fire behavior. Post-treatment potential for crown fire ranges from 2 percent in RU5 to 8 percent in RU1 (Table 54). "No fire" includes acres on which there were insufficient fuels to carry fire under the conditions modeled, including water, rock, cinders, areas of sparse vegetation, etc.

Table 54. Modeled fire type for Alternative B by Restoration Unit

Alt. B (2020)	RU	Surface (acres)	Passive crown	Active crown	No Fire (acres)	Surface (percent)	Passive crown	Active crown	No fire (percent)

			(acres)	(acres)			(percent)	(percent)	
	RU 1	142,723	6,110	6,514	957	91	4	4	0.6
	RU 3	140,055	6,636	2,142	886	94	4	1	0.6
	RU 4	160,389	3,444	1,141	633	97	2	1	0.4
	RU 5	68,331	1,127	837	5,800	90	1	1	7.6
	RU 6	41,459	1,921	107	42	95	4	0	0.1
	Total	**552,958**	**19,238**	**10,741**	**8,319**	**94**	**3**	**2**	**1.41**

Restoration Unit 1

Restoration Unit 1 is of particular concern because the Lake Mary watershed is a source of water for the city of Flagstaff, as well as being a popular recreation site. There is also an observatory just north of Lower Lake Mary, and Walnut Canyon National Monument is adjacent to the treatment area. There would be adjacency concerns in the area of Mormon Mountain because of heavy fuel loading in mixed conifer adjacent to the treatment area. However, potential fire behavior adjacent to these areas would be reduced from existing conditions. Under Alternative B, potential fire behavior would decrease, reducing the chance of fire spreading into the mixed conifer upslope and adjacent to the treatment area on Mormon Mountain. It would also decrease the risk of fire to the city of Flagstaff to the northwest.

Ponderosa pine occupies 146,037 acres of pine, more than the other restoration units. Modeled post-treatment conditions indicate that 7 percent (11,277 acres) of the pine would have potential for crown fire, with 4 percent (6,273 acres) of it being active crown fire (Table 55). Overall, the ponderosa pine vegetation type in RU1 would meet desired conditions for fire behavior. However, post-treatment conditions for protected habitat show 25 percent (7,605 acres) would have potential for crown fire, 19 percent (5,711 acres) of which would be active crown fire. Restoration Unit 1 has the most PACs of any RU, including all, or parts of approximately 35. Over 90 percent of all crown fire is in MSO or goshawk habitat (not counting Landscapes outside of PFAs). The majority of active crown fire in RU1 would be in protected habitat, accounting for over 67 percent of the crown fire in the ponderosa pine in RU1.

Table 55. Modeled fire type by vegetation and habitat for Restoration Unit 1

RU 1 (156,305 acres) Vegetation/Habitat Type		Vegetation Type Acres	Fire Type	Existing Condition		Alternative B (2020)	
				Acres	Percent	Acres	Percent
Ponderosa Pine	**All Pine**	146,037	Surface	81,276	56	134,258	92
			Passive crown	15,960	11	5,004	3
			Active crown	48,300	33	6,273	4
	MSO Protected	30,240	Surface	15,669	52	22,581	75
			Passive crown	2,346	8	1,894	6
			Active crown	12,172	40	5,711	19
	MSO Target/	4,814	Surface	2,252	47	4,534	94

RU 1 (156,305 acres) Vegetation/Habitat Type		Vegetation Type Acres	Fire Type	Existing Condition		Alternative B (2020)	
				Acres	Percent	Acres	Percent
	Threshold		Passive crown	506	11	62	1
			Active crown	2,045	42	207	4
	MSO Restricted	26,421	Surface	13,074	49	23,946	91
			Passive crown	2,655	10	2,375	9
			Active crown	10,660	40	67	0
	Goshawk PFA/ dPFA/ nest stand	4,670	Surface	2,592	56	4,561	98
			Passive crown	521	11	80	2
			Active crown	1,556	33	29	1
	Landscapes outside PFAs	79,892	Surface	47,689	60	78,636	98
			Passive crown	9,932	12	593	1
			Active crown	21,867	27	259	0
	Aspen	420	Surface	241	57	267	63
			Passive crown	40	10	77	18
			Active crown	138	33	77	18
	Grassland	8,133	Surface	6,151	76	6,558	81
			Passive crown	1,321	16	1,011	12
			Active crown	239	3	143	2
	Juniper Woodland	286	Surface	232	81	286	100
			Passive crown	14	5	0	0
			Active crown	41	14	0	0
	Oak Woodland	287	Surface	194	68	280	97
			Passive crown	62	22	2	1
			Active crown	31	11	5	2
	Pinyon/ Juniper	1,141	Surface	896	78	1,075	94
			Passive crown	115	10	16	1
			Active crown	96	8	16	1

Aspen occupy 420 acres in RU1, of which 154 acres (36 percent) would have potential for crown fire under modeled conditions. In areas that burn with moderate to high severity, fire would probably top-kill most aspen stems but, in most cases, the clone would respond by vigorous sprouting. Alternative B proposes one burn in aspen stands by 2020. This would be low to moderate severity fire, benefiting the aspen by consuming accumulations of litter, some CWD, and killing conifer seedlings/saplings encroaching into the stands. Following fire, the decreased surface albedo, decreased shade, and the flush of nutrients would contribute to sprouting.

Grasslands would benefit from wildfire or prescribed fire because, where fuels are herbaceous, the intensity at it which it could burn, even under extreme conditions, would benefit the system. Where there would be potential for crown fire in 1,154 acres (14 percent) of grassland in RU1, the fire would decrease woody encroachment (Table 57). In the 143 acres (2 percent) of grasslands with potential for active crown fire, there would be potential for undesirable fire effects such as high burn severity (detrimental soil effects), including killing the existing seed bank and potentially giving invasive plant species a foothold. The decrease in potential crown fire by 5 percent indicates a decrease in ponderosa pine, most likely pine that was young enough to have low canopy base heights. Treatments proposed in Alternative B would move the grasslands towards desired conditions, modeled post-treatment fire behavior.

Oak woodlands occupy 236 acres of RU1. Potential for crown fire in oak woodlands under Alternative B would decrease to 3 percent, with 2 percent (31 acres) being active crown fire. In the short run it would increase sprouting and small-diameter stems. It is also possible that there would be some mortality of large oak in the prescribed burns, particularly initial entry though, in the long run, it would decrease the risk to large oak.

Pinyon/Juniper woodlands occupy 1,427 acres in RU1. Crown fire potential in Pinyon/Juniper woodland would decrease to 16 acres (down from 266 in the existing condition). Pinyon/Juniper in RU1 is Operational Burning, but the effects of these burns would be beneficial.

Subunits

Subunit 1-1 includes Walnut Canyon, and is adjacent to Flagstaff and the Pulliam Airport, and is the closest subunit in RU1 to the city of Flagstaff. Following treatments, there is potential for 3 percent (308 acres) of crown fire (Table 56). Active crown fire is only 63 acres, and scattered. Subunit 1-3 includes the Lake Mary basin, a source watershed for the town of Flagstaff. Following treatments proposed in Alternative B, 8 percent of it would have potential for crown fire, 4 percent of which is active crown fire. The majority of the active crown fire in Subunit 1-3 is on the south and west sides of the Subunit, furthest away from the lakes in PACs. The potential for crown fire is decreased in Subunits 1-4 to 3 percent and 1-5 to 5 percent. Almost all of the active crown fire is in PACs, with passive crown fire scattered throughout the units. Alternative B would meet desired behavior for all Subunits in RU1.

Table 56. Modeled fire type in subunits of RU1 by vegetation type for 2020

RU 1 Subunits	Alternative B 2020						
	Total Acres	Surface (acres)	Passive crown (acres)	Active crown (acres)	Surface (percent)	Passive crown (percent)	Active crown (percent)
1-1	**10,169**	**9,697**	**245**	**63**	**95**	**2**	**1**
Ponderosa Pine	8,914	8,697	72	29	98	1	0
Grassland	567	353	166	34	62	29	6
Oak Woodland	173	173	0	0	100	0	0
Pinyon-Juniper	515	474	6	0	92	1	0
1-2	**8,054**	**7,773**	**206**	**16**	**97**	**3**	**0**
Ponderosa Pine	6,517	6,368	125	2	98	2	0
Grassland	1,537	1,406	80	14	91	5	1

RU 1 Subunits	Alternative B 2020						
	Total Acres	Surface (acres)	Passive crown (acres)	Active crown (acres)	Surface (percent)	Passive crown (percent)	Active crown (percent)
1-3	**41,652**	**37,882**	**1,568**	**1,780**	**91**	**4**	**4**
Ponderosa Pine	38,324	35,373	1,158	1,687	92	3	4
Aspen	88	32	16	40	36	19	45
Grassland	3,240	2,478	394	53	76	12	2
1-4	**18,250**	**17,437**	**200**	**598**	**96**	**1**	**3**
Ponderosa Pine	17,285	16,559	138	582	96	1	3
Grassland	519	450	54	5	87	10	1
Oak Woodland	83	76	2	5	92	2	6
Pinyon-Juniper	363	352	7	5	97	2	1
1-5	**78,179**	**69,934**	**3,891**	**4,057**	**89**	**5**	**5**
Ponderosa Pine	74,996	67,262	3,512	3,974	90	5	5
Aspen	332	235	60	37	71	18	11
Grassland	2,270	1,871	316	35	82	14	2
Juniper Woodland	286	286	0	0	100	0	0
Oak Woodland	32	31	1	0	98	2	0
Pinyon-Juniper	262	249	3	10	95	1	4

Restoration Unit 3

Winds on the Mogollon Rim, particularly during the fire season, are generally out of the southwest, so this RU has a high strategic importance in regards to fire movement. To the north and east, Interstates 40 and 17 are adjacent to RU3, so that smoke from wildfires would have potential to impact travel, as well as the communities of Flagstaff, Belmont, Parks, and Williams. Other adjacency concerns for fire behavior include Flagstaff at the top right of the RU, Kachina Village, and Oak Creek and Sycamore Canyons. Under Alternative B, the potential for undesirable fire behavior and effects in Restoration Unit 3 would be reduced sufficiently to meet desired conditions (<10 percent potential for crown fire). Crown fire potential is reduced to 5 percent of the treatment area (8,778 acres) with 1 percent being active crown fire (2,142 acres). There would still be potential for active crown fire in PACs in Kelly Canyon and Pumphouse Wash, including potential for some active and passive crown fire on slopes greater than 30 and 40 percent. Passive crown fire is scattered across the RU.

Ponderosa pine occupies 129,225 acres in RU3. Following proposed treatments, 7 percent (7,983 acres) would have potential for crown fire, and 2 (2,016 acres) percent would be active crown fire. MSO protected habitat would account for 1, 023 acres of the active crown fire, about 16 percent of the crown fire in ponderosa pine in RU3 .

Table 57. Modeled fire type by vegetation and habitat for Restoration Unit 3

RU 3 Acres: 149,718			Vegetation Type Acres	Alternative B	
Vegetation/Habitat Type		Fire Type		Acres	Vegetation Type Percent
Ponderosa Pine	**All Pine**	Surface	**129,225**	**120,597**	**93**
		Passive crown		**5,967**	**5**
		Active crown		**2,016**	**2**
	MSO Protected	Surface	4,507	3,136	70
		Passive crown		264	6
		Active crown		1,023	23
	MSO Target/ Threshold	Surface	3,899	3,702	95
		Passive crown		47	1
		Active crown		146	4
	MSO Restricted	Surface	38,748	34,381	89
		Passive crown		3,999	10
		Active crown		290	1
	Goshawk PFA/ dPFA/ nest stand	Surface	5,452	4,952	91
		Passive crown		373	7
		Active crown		124	2
	Landscapes outside PFAs	Surface	76,619	74,426	97
		Passive crown		1,283	2
		Active crown		433	1
Other Vegetation	Aspen	Surface	201	144	71
		Passive crown		58	29
		Active crown		0	0
	Grassland	Surface	12,775	11,892	93
		Passive crown		561	4
		Active crown		105	1
	Juniper Woodland	Surface	1,851	1,834	99
		Passive crown		8	0
		Active crown		3	0
	Oak Woodland	Surface	1,633	1,616	99
		Passive crown		6	0
		Active crown		2	0
	Pinyon/ Juniper	Surface	4,033	3,972	98
		Passive crown		36	1
		Active crown		18	0

Aspen occupies 201 acres of RU1, 58 acres (29 percent) would have potential for crown fire, all of which would be passive crown fire. Effects would be as described for RU1, pg. 140.

Grasslands would benefit from wildfire or prescribed fire because, where fuels are herbaceous, the intensity at it which it could burn, even under extreme conditions, would benefit the system. Where there would be potential for crown fire on 666 acres (5 percent) of grassland in RU3, the fire would decrease woody encroachment. In the 105 acres (1 percent)) of grasslands with potential for active crown fire, there would be potential for undesirable fire effects such as high burn severity (detrimental soil effects), including killing the existing seed bank and potentially giving invasive plant species a foothold. Treatments proposed in Alternative B would move the grasslands towards desired conditions in RU3.

Oak woodlands occupy 1,633 acres of RU3. The potential for crown fire in oak woodlands under Alternative B would decrease to 1 percent, of which <1 percent (2 acres) would be active crown fire. In the short run, proposed treatments would increase sprouting and small-diameter stems (indirect effect). It is also possible that there would be some mortality of large oak in the prescribed burns (direct effect), particularly initial entry though, in the long run, it would decrease the risk to large oak.

Pinyon/juniper woodlands occupy 5,884 acres in RU3. Crown fire potential in Pinyon/Juniper woodland would decrease to 65 acres (down from 266 in the existing condition). Pinyon/Juniper in RU3 is all Operational Burning, but would benefit from the prescribed fires that would be implemented.

Subunits

Crown fire potential in all subunits in RU3 (Table 58) would meet desired conditions for fire behavior, ranging from 4 percent in SU 3-2 (1,097 acres) to 8 percent in SUs 3-4 (700 acres) and 3-5 (2,689 acres). Subunit 3-4 includes that part of Flagstaff south of I-40 and west of I-17, including Kachina Village. There are PACs in the southern part of Subunit 3-4 that would have potential for both passive and active crown fire, some of it on slopes steeper than 30 or 40 percent). PACs in Subunits 3-3 and 3-5 also have most of the active crown fire potential within each Subunit.

Table 58. Modeled fire type (passive or active crown fire vs. surface fire) in RU3 subunits

Vegetation Type by Subunit	Acres	Alternative B 2020					
		Surface (acres)	Passive crown (acres)	Active crown (acres)	Surface (percent)	Passive crown (percent)	Active crown (percent)
3-1	**23,148**	**21,664**	**1,299**	**117**	**94**	**6**	**1**
Ponderosa Pine	18,805	17,444	1,209	108	93	6	1
Aspen	91	60	31	0	66	34	0
Grassland	593	523	46	7	88	8	1
Juniper Woodland	907	899	5	0	99	1	0
Oak Woodland	845	839	4	1	99	0	0
Pinyon-Juniper	1,908	1,899	4	1	100	0	0

Vegetation Type by Subunit	Acres	Alternative B 2020					
		Surface (acres)	Passive crown (acres)	Active crown (acres)	Surface (percent)	Passive crown (percent)	Active crown (percent)
3-2	**32,726**	**31,352**	**895**	**202**	**96**	**3**	**1**
Ponderosa Pine	22,885	21,856	732	162	96	3	1
Aspen	59	40	18	0	69	31	0
Grassland	9,611	9,284	145	40	97	2	0
Oak Woodland	172	171	0	0	100	0	0
3-3	**48,434**	**45,745**	**2,051**	**543**	**94**	**4**	**1**
Ponderosa Pine	44,426	41,940	1,902	511	94	4	1
Aspen	50	42	8	0	83	17	0
Grassland	1,353	1,196	125	25	88	9	2
Juniper Woodland	873	865	3	2	99	0	0
Oak Woodland	232	222	1	1	96	0	0
Pinyon-Juniper	1,500	1,481	11	4	99	1	0
3-4	**9,019**	**8,104**	**277**	**423**	**90**	**3**	**5**
Ponderosa Pine	8,920	8,051	252	417	90	3	5
Grassland	99	53	26	6	54	26	6
Oak Woodland	0	0	0	0	100	0	0
3-5	**36,392**	**33,190**	**2,114**	**856**	**91**	**6**	**2**
Ponderosa Pine	34,190	31,306	1,872	817	92	5	2
Aspen	2	2	0	0	100	0	0
Grassland	1,120	836	219	26	75	20	2
Juniper Woodland	70	70	0	0	100	0	0
Oak Woodland	384	383	1	0	100	0	0
Pinyon-Juniper	626	592	21	13	95	3	2

Restoration Unit 4

Located west and north of Flagstaff, and north of Williams and Interstate 10, RU4 has potential to affect the communities of Flagstaff, Williams, Parks, and Belmont, though the prevailing winds would tend to blow fire away from most of the populations in Williams, Parks and Belmont. There is also potential to impact the Fort Valley Experimental Station northwest of Flagstaff. Over the last 20 years, has been impacted by some large fires, including the Hockderffer (2004, 16,000 acres) and Pumpkin (2000, 8,700 acres) fires. Under Alternative B, RU4 would have the potential for 4,585 acres of crown fire (3 percent) of which 1,141 acres (1 percent) would be active crown fire. Most of the crown fire in RU4 would be in scattered patches, with few areas of contiguous active crown fire greater than about 15 acres, mostly in areas classified as grasslands or other non-pine vegetation (Table 59). There would be larger contiguous acreages of passive crown fire in PFAs and areas of lower intensity treatments, and some burn only treatments. Ponderosa Pine in RU4 would have less than 1 percent (587 acres) having potential for active crown fire, and 2 percent with potential for passive crown fire.

Table 59. Modeled fire type by vegetation type and habitat for RU4, alternative B

RU 4 Acres: 165,607			Vegetation Type Acres	Alternative B 2020	
Vegetation/Habitat Type		Fire Type		Acres	Vegetation Type Percent
Ponderosa Pine	All Pine	Surface	134,301	130,551	97
		Passive crown		2,718	2
		Active crown		587	0
	MSO Protected	Surface	558	504	90
		Passive crown		15	3
		Active crown		39	7
	MSO Restricted	Surface	1,575	1,419	90
		Passive crown		133	8
		Active crown		16	1
	Goshawk PFA/ dPFA/ nest stand	Surface	13,484	12,470	92
		Passive crown		812	6
		Active crown		198	1
	Landscapes outside PFAs	Surface	118,683	116,157	98
		Passive crown		1,759	1
		Active crown		334	0
Other Vegetation	Aspen	Surface	499	455	91
		Passive crown		41	8
		Active crown		1	0
	Grassland	Surface	22,599	21,228	94
		Passive crown		675	3
		Active crown		545	2
	Juniper Woodland	Surface	118	115	98
		Passive crown		0	0
		Active crown		0	0
	Oak Woodland	Surface	926	921	99
		Passive crown		1	0
		Active crown		2	0
	Pinyon/ Juniper	Surface	7,165	7,119	99
		Passive crown		9	0
		Active crown		5	0

Aspen occupy 499 acres in RU4. Potential for crown fire in aspen would be reduced to 8 percent (41 acres), of which none would be active crown fire. A direct effect of implementing alternative

B would be decreased fuel loading in decadent aspen stands, where some aspen stands had over 40 tons/acre of CWD. Decreased conifer encroachment would help decrease crown fire potential so that the passive crown fire that did occur would be less likely to topkill entire clones, allowing some sprouting and the survival of some large stems.

Grasslands occupy 22,599 acres in Restoration Unit 4, including Government Prairie, a grassland area of ~20,000 acres, as well as other scattered grasslands units. These grassland areas would be included as Operational Burn. Potential crown fire would be 5 percent (1,220 acres) across all the grasslands in RU4 following prescribed fires. Although the effects of wildfires that would occur subsequent to treatments would move grasslands towards desired conditions, modeled post-treatment fire behavior does not meet desired conditions for RU1.

Pinyon/Juniper woodlands would have only 14 acres of potential crown fire, of which only 5 acres would be active crown fire. As with grasslands, these areas would be Operational Burn and, post-treatment, would include 7,234 acres of surface fire. Under Alternative B, Oak woodlands would only support 3 acres of crown fire out of a total of 921 acres.

At the subunit level (Table 60) SU 4-5, though the smallest SU in the project (6,943 acres), is adjacent to the city of Flagstaff, and has steep topography, so that the second order fire effects of any high severity fires have good potential to impact neighborhoods and schools. Under Alternative B, Subunit 4-5 would have potential for only 127 acres of crown fire, of which 69 acres would be active crown fire. None of the contiguous crown fire in Subunit 4-5 should be more than ½ acre. The majority of crown fire in RU4 is in Subunit 4-3, on the northwest and north side of the peaks, and west of Sitgreaves. All Subunits in RU4 would meet desired conditions for fire behavior.

Table 60. Fire type in subunits of RU4 by major vegetation type as modeled for 2020

Vegetation Type by Subunit	Total Acres	Alternative B 2020					
		Surface (acres)	Passive crown (acres)	Active crown (acres)	Surface (percent)	Passive crown (percent)	Active crown (percent)
4-2	**10,231**	**9,912**	**171**	**48**	**97**	**2**	**0**
Ponderosa Pine	7,381	7,139	161	41	97	2	1
Aspen	1	1	0	0	67	0	0
Grassland	332	297	7	1	89	2	0
Juniper Woodland	8	8	0	0	97	1	1
Oak Woodland	567	562	1	2	99	0	0
Pinyon-Juniper	1,941	1,906	2	4	98	0	0
4-3	**67,013**	**64,587**	**1,538**	**567**	**96**	**2**	**1**
Ponderosa Pine	55,311	53,403	1,304	299	97	2	1
Aspen	232	225	5	0	97	2	0
Grassland	6,951	6,451	222	267	93	3	4
Juniper Woodland	31	31	0	0	100	0	0
Oak Woodland	325	325	0	0	100	0	0

Vegetation Type by Subunit	Total Acres	Alternative B 2020					
		Surface (acres)	Passive crown (acres)	Active crown (acres)	Surface (percent)	Passive crown (percent)	Active crown (percent)
Pinyon-Juniper	4,162	4,152	7	1	100	0	0
4-4	**81,421**	**79,087**	**1,677**	**457**	**97**	**2**	**1**
Ponderosa Pine	65,003	63,501	1,226	188	98	2	0
Aspen	255	223	32	0	87	12	0
Grassland	14,988	14,192	419	268	95	3	2
Juniper Woodland	78	76	0	0	97	0	0
Oak Woodland	35	35	0	0	100	0	0
Pinyon-Juniper	1,062	1,061	0	0	100	0	0
4-5	**6,943**	**6,804**	**58**	**69**	**98**	**1**	**1**
Ponderosa Pine	6,605	6,508	27	59	99	0	1
Aspen	11	7	4	0	63	35	2
Grassland	327	289	27	9	88	8	3

Restoration Unit 5

Restoration Unit 5 includes parts of the area that was burned in the Schultz fire (2010, ~17,000 acres) and the Radio Fire (1977, 2,600 acres). Adjacency concerns include housing developments, including Doney Park, and the city of Flagstaff, which would be downslope from many wildfires occurring in this RU. Under Alternative B, RU5 would have potential for 1,964 (2 percent) acres of crown fire, of which 837 (1 percent) would be active crown fire. There are many areas, some larger than 500 acres, in the north and eastern areas of this RU that are cinder substrate, and have no potential for fire. These areas consist of cinder cones, and cinder soils which generally support sparse vegetation. In these areas, active crown fire is less likely because of decreased potential for high intensity surface fire. These areas, though they have little fuel, have been reported to attract lightning, increasing the potential for lightning starts in the vicinity.

Ponderosa pine in RU5 meets desired conditions (Table 61),, with 2 percent of the area having potential for crown fire, of which 1 percent would be active crown fire. Some of the active crown fire in PACs on the northwest side of Mt. Eldon would occur on slopes greater than 30 to 40 percent. Protected habitat would maintain potential for 23 percent (332 acres) of crown fire, of which 314 acres would be active crown fire.

Table 61. Fire type by vegetation type and habitat for Restoration Unit 5

RU 5 Acres: 76,096				Alternative B 2020	
Vegetation/Habitat Type		Fire Type	Vegetation Type Acres	Acres	Vegetation Type Percent
Ponderosa Pine	All Pine	Surface	61,730	56,366	91
		Passive crown		841	1
		Active crown		735	1

RU 5 Acres: 76,096				Alternative B 2020	
	Vegetation/Habitat Type	Fire Type	Vegetation Type Acres	Acres	Vegetation Type Percent
	MSO Protected	Surface	1,452	1,098	76
		Passive crown		18	1
		Active crown		314	22
	MSO Restricted	Surface	634	627	99
		Passive crown		4	1
		Active crown		2	0
	Goshawk PFA/ dPFA/ nest stand	Surface	2,944	2,652	90
		Passive crown		118	4
		Active crown		28	1
	Landscapes outside PFAs	Surface	56,700	51,989	92
		Passive crown		701	1
		Active crown		391	1
Other Vegetation	Aspen	Surface	403	333	83
		Passive crown		65	16
		Active crown		0	0
	Grassland	Surface	4,595	2,604	57
		Passive crown		212	5
		Active crown		91	2
	Juniper Woodland	Surface	74	74	100
		Passive crown		0	0
		Active crown		0	0
	Oak Woodland	Surface	523	497	95
		Passive crown		1	0
		Active crown		0	0
	Pinyon/ Juniper	Surface	8,771	8,457	96
		Passive crown		9	0
		Active crown		5	0

Aspen occupies 403 acres within RU5. Potential for crown fire in aspen would be reduced to 16 percent (65 acres), of which none would be active crown fire. Under Alternative B, prescribed fire and mechanical treatments would decrease excessive fuel loading in decadent aspen stands, where some aspen stands had over 40 tons/acre of CWD. Decreased conifer encroachment would help decrease crown fire potential so that the passive crown fire that did occur would be less likely to topkill entire clones, allowing some sprouting and the survival of some large stems.

Grasslands, would benefit ecologically from wildfire or prescribed fire because, where fuels are herbaceous, the intensity at it which it could burn, even under extreme conditions, would benefit the system. Where there would be potential for crown fire in 303 acres (7 percent) of grassland in RU1, the fire would decrease woody encroachment (direct effect). On the 91 acres (2 percent) of grasslands with potential for active crown fire, there would be potential for undesirable fire effects such as detrimental soil effects, including killing the existing seed bank (direct effect) and potentially giving invasive plant species a foothold (indirect effect). Although the effects of wildfires that would occur subsequent to treatments proposed in Alternative B would further move the grasslands towards desired conditions, modeled post-treatment fire behavior does not meet desired conditions for RU1.

Oak woodlands, under Alternative B, would have decreased potential for crown fire, down to 0 percent (<1 acre). In the short run that would increase sprouting and small-diameter stems (indirect effects). It is also possible that there would be some mortality of large oak in the prescribed burns (direct effects), particularly initial entry though, in the long run, it would decrease the risk to large oak. This would meet desired conditions of <10 percent crown fire in Gambel oak woodlands.

Pinyon/Juniper crown fire potential would decrease to 16 acres (down from 266 in the existing condition). PJ in RU1 is all Operational Burning, but would benefit from the prescribed fires that would be implemented.

Subunit 5-1 has potential for a few areas of contiguous active crown fire, one in a PAC at roughly 130 acres, some of which is on slopes greater than 30 percent. Other patches are close to 30 acres, on the northwest side of the Peaks. Subunit 5-2 includes much of the youngest, most sparsely vegetated cinder cones, as well as areas that were affected by the second order fire effects resulting from the Schultz Fire. Table 62 shows that, under Alternative B, at the subunit scale, both subunits would meet desired conditions.

Table 62. Modeled fire type in subunits of Restoration Unit 5 by vegetation type for 2020

Vegetation Type by Subunit	Alternative B 2020						
	Total Acres	Surface Acres	Passive crown (acres)	Active crown (acres)	Surface (percent)	Passive crown (percent)	Active crown (percent)
5-1	**24,172**	**22,119**	**514**	**670**	**92**	**2**	**3**
Ponderosa Pine	20,674	18,847	365	645	91	2	3
Aspen	392	324	63	0	83	16	0
Grassland	1,299	1,179	82	19	91	6	1
Oak Woodland	232	223	1	6	96	0	2
Pinyon-Juniper	1,574	1,547	3	0	98	0	0
5-2	**51,924**	**46,212**	**613**	**167**	**89**	**1**	**0**
Ponderosa Pine	41,055	37,519	476	90	91	1	0
Aspen	10	8	2	0	83	17	0
Grassland	3,297	1,425	130	72	43	4	2
Juniper Woodland	74	74	0	0	100	0	0
Oak Woodland	291	274	0	0	94	0	0
Pinyon-Juniper	7,196	6,911	6	5	96	0	0

Restoration Unit 6

Restoration Unit 6 is the smallest of the RUs, and lies immediately south of and adjacent to Grand Canyon National Park. It is the driest of all the RUs, and has had more recent fire than most of the rest of the proposed treatment area. Modeled post-treatment conditions indicate only 107 (<1 percent) acres would have potential for active crown fire, all of which would be in four areas, the largest of which is of less than 30 acres (Table 63). There would be 1,921 acres (4 percent) of passive crown fire widely dispersed, with concentrations in areas with components of juniper and oak, particularly on the northeastern and southeastern corners. Alternative B would meet desired conditions in RU6 at the Restoration Unit scale. When considered by vegetation/habitat type, all types would have potential for less than 10 percent crown fire, with 91 percent (97 acres) of crown fire in ponderosa pine occurring in PFA/DPFA/Nest Stand habitat.

Table 63. Modeled fire type by vegetation and habitat for Restoration Unit 6

RU 6 Acres: 43,529			Vegetation Type Acres	Alternative B 2020	
Vegetation/Habitat Type		Fire Type		Acres	Vegetation Type Percent
Ponderosa Pine	All Pine	Surface	41,188	39,438	96
		Passive crown		1,602	4
		Active crown		107	0
	Goshawk PFA/ dPFA/ nest stand	Surface	4,050	3,773	93
		Passive crown		177	4
		Active crown		97	2
	Landscapes outside PFAs	Surface	37,138	35,664	96
		Passive crown		1,426	4
		Active crown		9	0
	Grassland	Surface	93	89	97
		Passive crown		2	3
		Active crown		1	1
	Juniper Woodland	Surface	13	11	84
		Passive crown		2	16
		Active crown		0	0
	Oak Woodland	Surface	30	29	98
		Passive crown		1	2
		Active crown		0	0
	Pinyon/ Juniper	Surface	2,206	1,892	86
		Passive crown		314	14
		Active crown		0	0

Grasslands occupy 93 acres in RU6, of which 3 acres would have potential for crown fire. These 93 acres would be burned as Operational Burn, so there would be no restoration objectives for prescribed fire but, with potential for only 3 acres of undesirable effects from fire behavior, they would benefit from whatever fire occurred. Alternative B would meet the intent of desired conditions for grasslands in RU6, coming within an acre of the desired condition for fire behavior.

Oak woodlands (30 acres) would be Operational Burn, with less than an acre having potential for crown fire.

Pinyon/Juniper woodland in RU6 has fuel reduction objectives. Under Alternative B (Table 64), There would be potential for 427 acres of passive crown fire, and no active crown fire. Most of the Pinyon/Juniper in RU6 would be Operational Burn. There are 535 acres for which the objective is fuels reduction. Under Alternative B, there would be potential for just 2 acres of crown fire in PJ in those acres.

Table 64. Modeled fire type in Pinyon/Juniper

Vegetation Type	Fire Type	Alternative B 2020 (all PJ)		Alternative B 2020 (PJ with fuels objective)	
		Percent	Acres	Percent	Acres
Pinyon/ Juniper	Surface	98	22,516	100	533
	Passive crown	2	384	0	2
	Active crown	0	43	0	0

As indicated in Table 65, Subunits 6-2 and 6-3 would meet desired conditions for fire behavior under Alternative B, with less than 1 percent of each vegetation type in each subunit having potential for active crown fire. In Subunit 6-4, there is diverse vegetation in most of the stands showing potential for passive crown fire, including juniper and Gambel oak. Figure 29 shows the structure of the area, with multiple ladder fuels, but open areas between clumps of vegetation, with ponderosa pine as the dominant species.

Table 65. Modeled fire type in subunits of Restoration Unit 6 by vegetation type for 2020

Vegetation Type by Subunit	Alternative B 2020	Fire type					
	Total Acres	Surface (acres)	Passive crown (acres)	Active crown (acres)	Surface (percent)	Passive crown Percent	Active crown Percent
6-2	**5,551**	**5,377**	**167**	**0**	**97**	**3**	**0**
Ponderosa Pine	5,069	4,897	165	0	97	3	0
Pinyon-Juniper	483	480	2	0	99	0	0
6-3	**34,109**	**33,103**	**868**	**105**	**97**	**3**	**0**
Ponderosa Pine	32,635	31,743	756	105	97	2	0
Grassland	85	82	2	1	96	3	1
Juniper Woodland	13	11	2	0	84	16	0

Pinyon-Juniper	1,375	1,267	108	0	92	8	0
6-4	**3,870**	**2,979**	**886**	**1**	**77**	**23**	**0**
Ponderosa Pine	3,484	2,798	682	1	80	20	0
Grassland	7	7	0	0	100	0	0
Oak Woodland	30	29	1	0	98	2	0
Pinyon-Juniper	348	145	203	0	42	58	0

Surface fuels and canopy characteristics affecting fire behavior and effects

Canopy characteristics and surface fuel loading are discussed in this section by desired openness. As described on page 9, desired openness is an indication of the relative desired post treatment interspace/tree group condition.

In relation to fire behavior, canopy characteristics primarily affect the potential for crown fire which produces undesirable fire effects and is extremely difficult to control. In regards to fire effects, canopy characteristics relate to crown fire, which is lethal because ponderosa pine does not sprout. In regards to fire behavior, surface fuel loading from litter, duff, and CWD can smolder for long periods of time, making it difficult to detect across a very recently burned landscape. ‘Mop up’, following a fire, is almost always in these fuel types. “Mop up” refers to carefully surveying a burned area on foot to ensure there are no remaining embers or ‘smokes’. Regarding fire effects, surface fuel loading can produce desirable or undesirable effects, depending on the initial loading and the conditions under which it burns (see page 71 for more details).

Canopy characteristics affecting fire behavior

Changes to Canopy Cover (CC), Canopy Base Height (CBH), and Canopy Bulk Density (CBD) are direct effects, though they are not always apparent in the fire behavior data (indirect effects). Post-treatment canopy characteristics (2020), under Alternative B would support fire behavior that would meet desired conditions for fire behavior (Table 63). Desired conditions for CBH are 18 feet or higher; desired conditions for canopy bulk density (CBD) are 0.05 kg/m3 or less. Table 66 displays modeled changes in canopy characteristics from 2010 through 2050 with no mechanical treatments or fire (wildfire or prescribed fire) after 2020. Shaded cells indicate a condition that does not meet desired conditions. Note: desired conditions for CBH and CBD do not apply to PACs or Core Areas.

Table 66. Modeled changes in canopy characteristics for Alternative B

Desired openness	CBH (feet)			CBD (kg/m^3)			CC (%)			percent ponderosa pine
	2010	2020	2050	2010	2020	2050	2010	2020	2050	
High	15.18	28.15	28.56	0.067	0.028	0.035	68	52	61	35
Moderate	14.77	25.31	25.66	0.061	0.030	0.040	66	54	63	27
Low (Mechanical)	16.13	26.35	28.42	0.060	0.036	0.042	66	57	65	6
Low (Burn Only)	13.98	20.06	24.48	0.046	0.036	0.037	58	53	60	20
Very Low (Burn Only)	15.95	23.84	29.31	0.062	0.049	0.050	69	66	71	4

Desired openness	CBH (feet)			CBD (kg/m^3)			CC (%)			percent ponderosa
Very Low (Mechanical)	14.30	22.59	28.99	0.063	0.050	0.050	70	67	71	2
Very Low (PAC Burn Only)	14.29	17.3	23.12	0.067	0.065	0.064	72	72	75	4
None (Core Areas)	14.09	15.88	22.24	0.071	0.071	0.070	76	74	76	1
Weighted Average[7]	**14.84**	**24.73**	**26.67**	**0.61**	**0.34**	**0.4**	**66**	**55**	**63**	**100**

Table 66 shows modeled changes from existing condition (2010 data) through post-treatment (2020) and 20 years post-treatment (2050). Those areas receiving the lowest intensity treatment would remain in a condition that would be likely to support crown fire. The rest of the treatments show improved conditions that would remain within desired conditions though 2050. Canopy Bulk Density decreases from 2010 to 2020, showing clearly the results of treatments, except in Core Areas which are not treated under this Alternative. By 2050, CBD would be increasing, as trees mature and canopies grew. Higher CBDs increase the probability of crown fire initiation and propagation through the canopy as active crown fire. From 2010 to 2020, proposed treatments would increase canopy base height by almost 18 feet for 35 percent of the ponderosa pine, and over 10 feet for almost 70 percent.

Figure 51 shows the trend in CBH, CBD, and canopy cover (CC). Assumptions are that treatments were completed in 2019, and from 2020 through 2050 there were no additional treatments (mechanical or fire). With the exception of the lowest intensity treatments, the trends indicated from 2010 to 2020 would be expected to increase surface fire and decrease crown fire.

Trends from 2020 to 2050 show increasing potential for conditional crown fire. The increased canopy cover and increased CBH would trend towards conditions that would allow crown fire to carry though the canopies of trees, though it would need to initiate in an adjacent stand because CBH would be too high.

Surface fuels: Litter, Duff, and Coarse Woody Debris greater than 3" diameter

Changes to surface fuel loading are direct effects of proposed treatments, that have indirect effects on fire behavior and effects. Litter, duff, and Coarse Woody Debris greater than 3" diameter (CWD>3") contribute to multiple characteristics of a fire regime, including, but not limited to: flammability, surface fire intensity, scorch height, flame length, and surface fire effects.

They contribute more than other fuels to emissions. High surface fuel loading can cause high severity effects, both direct and indirect, to soils , and surface biota (such as roots, seeds, forbs, and other species adapted to low severity fire), as well producing air quality impacts. Mechanical thinning alone can contribute significantly to decreasing the potential for crown fire by breaking up vertical and horizontal canopy fuel continuity, but does not decrease surface fuel loading (Fulé et al. 2012). Initial thinning impacts may include temporary fire 'breaks' where there are skid trails, or other surface disturbance, but surface fuels are generally not removed from the treatment area, and remain a potential source of heat and emissions. Surface effects may be spottier

[7] Weighted averages for desired openness are based on the number of acres of ponderosa pine proposed for treatment under each alterantive.

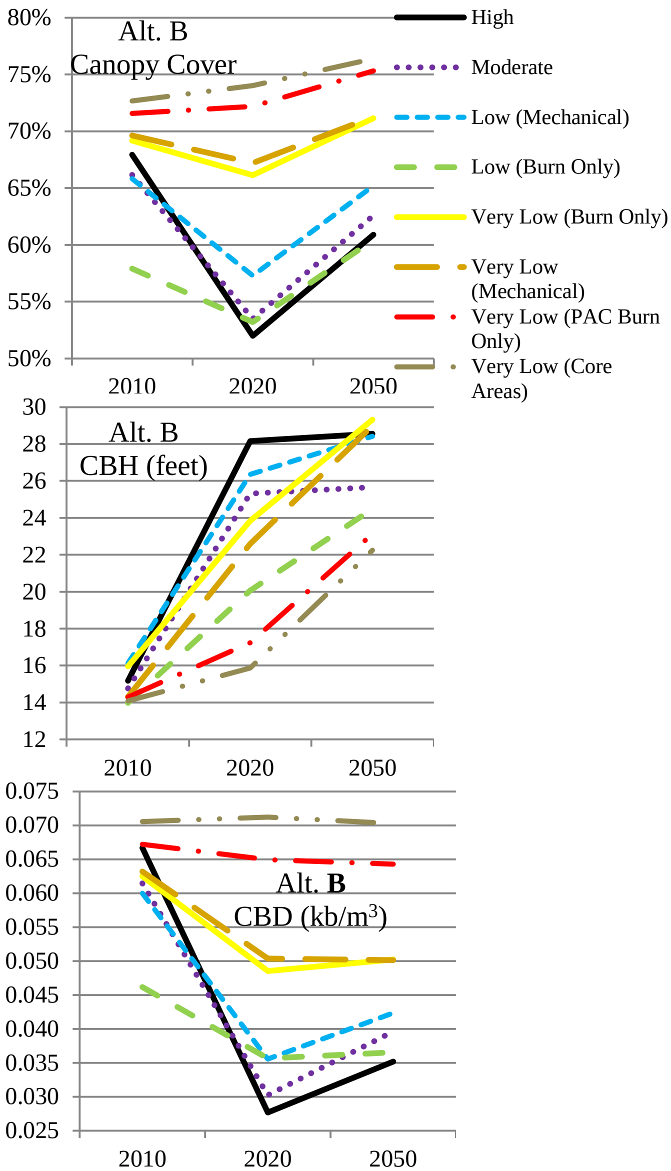


Figure 51. Graphed changes in canopy characteristics showing trends over 40 years.

following thinning because residual fuels often include jackpots or small piles. Where fuels have been pushed into piles or furrows, by design or happenstance, they may smolder for a long time.

As with fire behavior and canopy characteristics, a direct effect on fuel loading in regards to fire effects and emissions would be an improvement for all levels of desired openness except the lowest two (Figure 52). There are no specific desired conditions for litter or duff, but they are an important component of the effects of the proposed treatments. Forest plan direction for CWD would be met for all but Very Low (PAC Burn Only) in 2020.

A direct effect of prescribed fires would be the consumption of some CWD and, although more is often produced as an indirect effect of the burn (Waltz et al. 2003), it may be of a different stage of decay that does not fill the same ecological niche. Surface fuel loading can be managed with fire and felling techniques to increase or decrease woody debris in different size classes. A direct effect of Alternative B could be that some areas would be deficit in CWD for a few years following treatment but, given the trend shown, it would only be a few years before it met desired conditions again and, with maintenance burning, it should be possible to maintain desired levels.

Historical values were around 5 tons per acre on the high end for CWD and less than 2.5 tons/acre for duff (Brown et al, 2003) so, assuming ~2.5 for litter, all of the areas except the lowest two would be within the historical range of surface fuel loading in 2020, and would exceed it by 2050.

Figure 52 shows changes in fuel loading for 2010, 2020, and 2050 by desired openness. The areas with lower desired openness are primarily those associated with MSO habitat, have the highest fuel loading in all modeled years, as well as the lowest canopy base heights (CBH), the higher canopy bulk density (CBD), and the highest canopy cover (CC). Alternative B project-level changes in surface fuel loading (litter, duff, and CWD>3”) area a result of the ability of different treatment types to attain a mosaic of interspaces and tree groups.

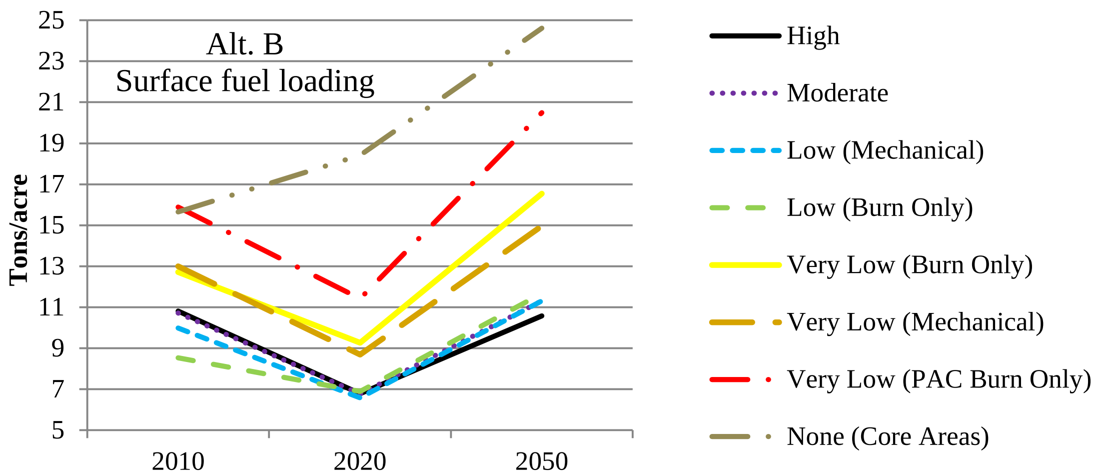


Figure 52. Modeled changes in surface fuel loading (litter, duff, CWD>3" combined) for Alternative B

The decreased litter, duff, and canopy fuels indicated in the last section would allow more precipitation to reach the surface, because there would be fewer canopy fuels to intercept it. Increased light to the surface would stimulate an increase in surface vegetation, providing light, flashy fuels that would produce low intensity, low severity surface fires in the future, the behavior and effects of which ponderosa pine and its associated species are well adapted to.

Out of these three categories of surface fuels, CWD is the one that increases the fastest by tons/acre, and is easily managed with fire and felling techniques to increase or decrease woody debris in different size classes should adjustments need to be made to ensure forest plan guidelines for CWD are met (Table 67). Table 67 shows modeled changes in litter, duff, and CWD>3" for Alternative B over 40 years (2010, 2020, 2050). Assumptions are that treatments 1 mechanical treatment and two prescribed burns occur between 2012 and 2019 and from 2020 to 2050, there are no additional treatments of any kind. Shaded cells indicate a condition that does not meet forest plan guidelines of 5-7 tons/acre for CWD.

Table 67. Modeled changes in litter, duff, and CWD > 3" for Alternative B

Desired openness	CWD>3"			Litter			Duff			CWD>3” + Litter + Duff			Percent ponderosa pine
	2010	2020	2050	2010	2020	2050	2010	2020	2050	2010	2020	2050	
High	3.95	3.00	5.14	3.48	1.43	2.74	3.39	2.35	2.70	10.82	6.78	10.57	35
Moderate	3.66	2.83	5.27	3.93	1.75	3.41	3.14	2.19	2.64	10.72	6.77	11.32	27
Low (Mechanical)	3.58	2.62	5.51	3.22	1.74	3.17	3.20	2.22	2.64	9.99	6.58	11.32	6
Low (Burn Only)	3.16	2.78	6.19	2.48	1.57	2.59	2.90	2.54	2.89	8.54	6.9	11.91	20
Very Low (Burn	4.71	3.14	7.25	4.43	2.59	5.09	3.58	3.55	4.21	12.71	9.27	16.55	4

Only)													
Very Low (Mechanical)	4.61	2.46	5.93	4.44	2.12	4.41	3.96	4.11	4.63	13.00	8.69	14.97	2
Very Low (PAC Burn Only)	5.99	3.18	8.36	4.80	2.96	6.10	5.09	5.28	6.03	15.88	11.42	20.49	4
None (Core Areas)	5.85	7.66	12.4 2	4.98	5.66	6.21	4.83	5.09	5.99	15.66	18.41	24.62	1
Weighted average[8]	**4.44**	**3.46**	**7.01**	**3.97**	**2.48**	**4.22**	**3.76**	**3.42**	**3.97**	10.7	7.3	11.9	

As indicated in Table 67, the average total fuel loading under Alternative B decreases from over 12 tons per acre in before treatment, to a little over 9 tons/acre following treatments, and by 2050 surpass pre-treatment levels at 15.02 tons. The areas with the lowest desired openness (None (Core Areas)) begins at 15.66 tons/acre, and increases to o 18.41 tons per acre following treatments in 2020. By 2050, total fuel loading in the lowest treatment is at almost 25 tons/acre, exceeding pre-treatment levels by 10 tons per acre. The biggest increases are in CWD>3”.

Figure 53 shows the distribution of surface fuel loading across the project area. Assumptions are that from 2012 to 2020, thinning and two prescribed burns were completed and after 2020, there was no mechanical treatment, prescribed fire, or wildfire. As described on page 71, there is no forest plan guidance on total surface fuel loading. However, the effects of surface fuel loading are potentially significant, because it has the potential to cause the death of large/old trees, destroy wildlife habitat, and cause irreversible high severity effects if it burns under the wrong conditions. Combining litter, duff, and CWD, it seems reasonable to assume that if these three total >20 tons/acre (discussion on page 19), the potential fire effects could include sufficient heat to increase tree mortality, consume organic matter in the top layers of soil, including living roots, seeds, mycorrhizae, or cause other undesirable fire effects, such as the impacts of emissions on humans and wildlife if those areas burn under conditions that are not optimum for smoke dispersal. While this does not represent a ‘desired condition’, it can inform a discussion on the potential fire direct and indirect fire effects from surface fuel loading. This does not specifically relate to wildlife requirements, but includes other fuel loading components and considerations.

Under Alternative B, in 2020 there would be approximately 1,107 acres with surface fuel loading greater than 20 tons/acre, and 4,331 acres in the 15 – 20 tons/acre range. By 2040 there would be 5,751 acres with surface fuel loading exceeding 20 tons/acre, and 55,488 in the 15 – 20 tons/acre range. In Figure 53 it can be seen that, following treatment, surface fuels have been reduced to recommended levels over most of the treatment area. The exceptions (bottom right) are mostly in RU 1 in PACs, with some areas of exceedence north and northwest of San Francisco Peaks.

[8] Weighted averages for desired openness are based on the number of acres of ponderosa pine proposed for treatment under each alterantive.

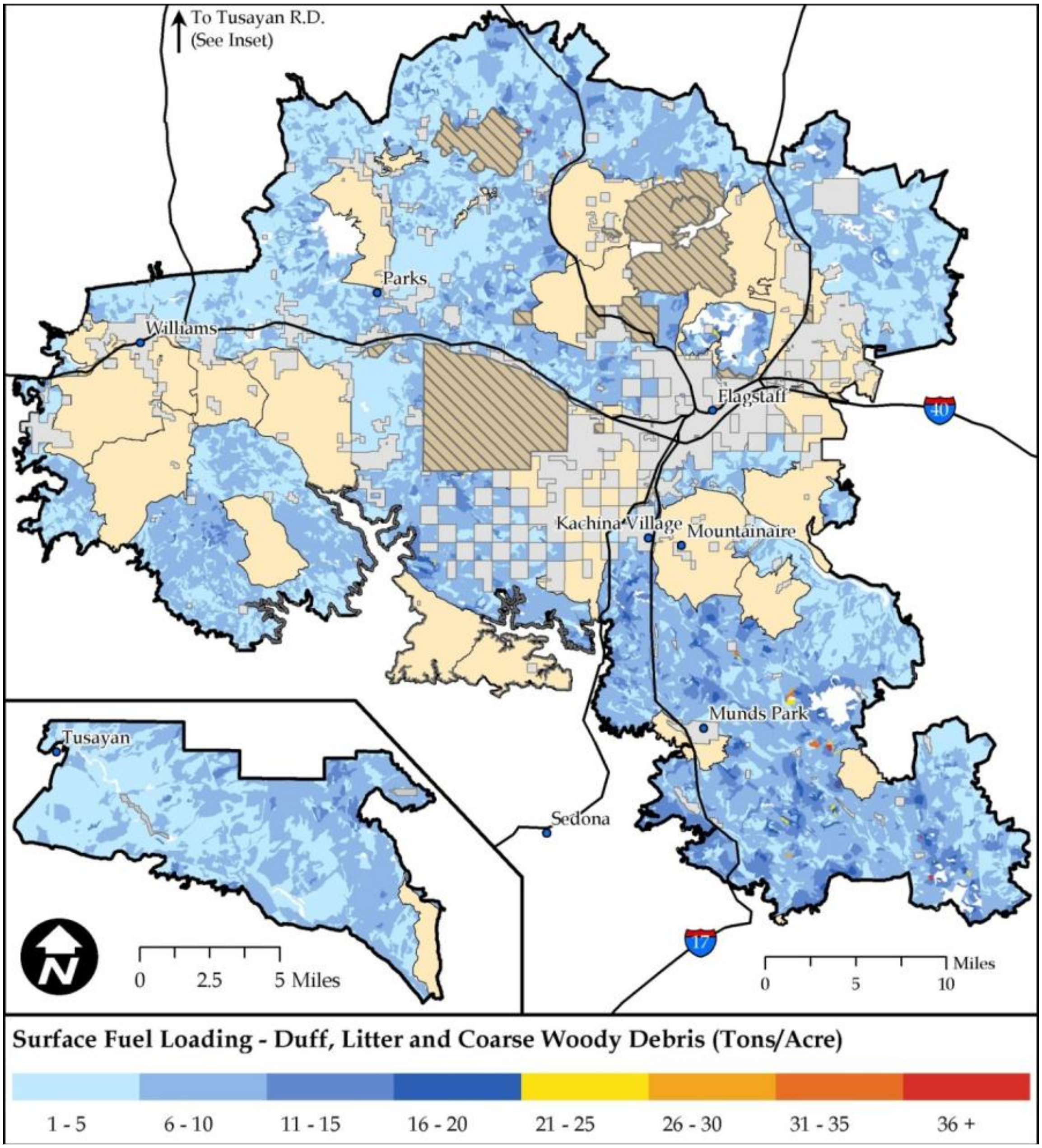


Figure 53. Modeled surface fuel loading, including duff, litter, and coarse woody debris

Fire Regime/Condition Class

Under Alternative B, Fire Regime/Condition Class (FRCC) would move toward the desired condition. The desired condition is for the entire landscape to be in FRCC1. However, it is not possible to move the entire landscape to FRCC1 in just 10 years when so much of it is so highly departed. Alternative B moves the majority of the ponderosa pine and grasslands within the treatment area out of FRCC 3, putting them at a lower risk. Changes in grasslands are more subtle and, with the exception of woody encroachment, not as obvious because the matrix species dominance (grasses, as opposed to forbs) shifts more slowly than pine. Although treatments in grasslands under Alternative B would only occur as Operational Burning, prescribed fire treatments would improve the stability of key ecosystem elements by shifting approximately 4,500 acres of grassland from FRCC3 to FRCC2, and increasing FRCC 1 acres by 1,683 acres (Table 68). Treatments proposed under Alternative B would shift over 277,000 acres of ponderosa pine from FRCC3 to FRCC2, and increase acres of FRCC1 by over 20,000 acres.

Table 68. Fire Regime/Condition Class for ponderosa pine and grasslands, Alternative B

Alternative B		2010		2020		2050	
		Acres	Percent	Acres	Percent	Acres	Percent
Ponderosa Pine	FRCC1	70,680	14	90,874	18	75,729	15
	FRCC2	136,311	27	393,788	78	247,380	49
	FRCC3	297,866	59	20,194	4	181,748	36
Grasslands	FRCC1	10,097	18	8,414	15	5,610	10
	FRCC2	40,389	72	43,193	77	44,876	80
	FRCC3	5,610	10	4,488	8	5,610	10

Fire Return Interval

Fire return intervals, as described on page 26, are a characteristic of a fire regime, and a coarse measure of the health of a system. This analysis uses running averages of acres treated by planned and unplanned fire for each alternative as a fixed number per year in order to make broad comparisons between alternatives. In reality, there are wide fluctuations in the number of acres treated each year which depend on weather, resource availability, public tolerance, funding, and logistics.

The estimated fire return interval for the proposed treatment area is currently about 40 years, double the desired maximum average for ponderosa pine on the Mogollon Rim. Table 69 shows the calculated fire return intervals from 2001 through 2010 based on an average of 15,000 acres burning annually. Averages begin in 2001 as an estimate for the 4FRI treatment area When the acres proposed for annual burning under this alternative are added, and the total is averaged over 20 years (2001 – 2020), the average fire return interval would be 10 years. Assuming there are no more fires of any kind between 2020 and 2050, average annual acres burned in 2020 is averaged over the 50 year period (2001 – 2050) as a 20 year fire return interval. Under Alternative B, the fire return interval over the treatment area would return to the desired frequency, and move the fire regime back towards a sustainable, resilient condition. For those areas that are not proposed for burning, the FRI would not reach, or move towards a sustainable, resilient fire regime.

This should be interpreted with caution, however, because it is the long term cycle of fire return intervals that regulates a system. Two prescribed fires would set the treatment area on a trajectory towards a restored condition, but maintenance fires would continue to be needed to avoid the ecosystem slipping back to an unsustainable condition.

Table 69. Fire Return Intervals for Alternative B

	# of years averaged	Average annual acres burned	Fire Return Interval over years averaged

Current 10 year average	10 (2001 -2010)	15,000 (2001 -2010)	40
Alt B 2020	20 (2001- 2020)	58,792 (2001- 2020)	10
Alt B 2050	40 (2001- 2050)	29,396 (2001- 2050)	20

Air Quality and Smoke Effects

This alternative would meet the purpose and need, and desired conditions for Air Quality. During windows of opportunity, whenever fire weather and expected fire effects are favorable, fire managers on the Coconino and Kaibab National Forests strive to treat as many acres with wildland fire as possible every year, while remaining within legal, climatological, social, and logistical limits. This means that the only change that is likely to occur under this Alternative would be from the greater flexibility in blocking out burn units, because so much more area would have been treated and/or planned and analyzed for prescribed fire. There may also be room some potential for increased coordination of resources between forests in the area. Impacts on air quality are indirect effects of implementing prescribed fire. Although the impact of this is not quantifiable at this time, it would likely be an increase in annual acres burned with no increase in air quality impacts, because it could increase the number of acres that could be burned in a single burn period.

Potential air quality impacts during implementation of Alternative B, and the necessary maintenance burning after the initial implementation has been completed may be noticeable, although National Ambient Air Quality Standards would not be exceeded. Initial entry burns produce much more emissions per acre than subsequent burns (see discussion on page 26). However, even if the slash was removed from the forest and although the prescribed burning would be spread over many years, the area to be burned would increase significantly and periodic burning would be required across the treatment area to maintain a low fuel load and a healthy forest.

Under this alternative, prescribed fire would be implemented on up to 58,792 acres annually to produce an average fire return interval of 10 years across 584,924 acres proposed for prescribed fire. Implementing prescribed fire as proposed in Alternative B would result in lower emissions than if the area burned in a wildfire because there would be less biomass to burn.

Air quality provides an example of short- and long-term trade-offs in implementing restoration across large areas. There is a risk of short-term human health impacts from prescribed fire. The emissions from prescribed fires, as opposed to wildfires, can be managed by carefully distributing (prescribed) fire over time and space, as well as under appropriated weather conditions (Cohesive Strategy 2002, page 39). Under Alternative B, air quality impacts would be most likely to those portions of the Little Colorado River Airshed east and northeast of Flagstaff; the Colorado River Airshed north of Williams and including all of the treatment area in RU6; and the Verde River Airshed. There is a small chance that there could be some impact to the northern portions of the Lower Salt River Airshed.

The combination of prescribed fire and mechanical thinning is the most effective means of limiting emissions from wildland fires by reducing and breaking up fuel continuity. Mechanical treatments proposed by 4FRI would reduce fuels by combinations of cutting and burning. In some cases, thinning would be implemented prior to prescribed burning, allowing higher intensity fire to be used where appropriate, and effectively minimizing potential wildfire emissions by removing some canopy fuels. Thinning generally increases surface fuel loading somewhat because of slash and other debris that break or fall off trees as they are processed, even when the majority of the material is removed from site (Fule et al. 2012). Disturbance of surface fuels may provide temporary fuel breaks by re-arranging surface fuels where there are skid trails, tire tracks, and other surface disturbances which break up surface fuel continuity while slightly increasing the amount. In other areas, prescribed fire may precede thinning. This may be appropriate if an area would not be thinned for several years in order to reduce flammability in the interim by beginning the process of reducing surface fuel loads, increasing canopy base height, and decreasing canopy bulk density. It may also occur if there is an opportunity to expand an adjacent burn unit to include part of the treatment area to increase efficiency. It may also facilitate timelier implementation of prescribed fires if there is no need to wait a year or two for the mechanical treatments to be completed. In some cases, it may be preferable to use fire as a thinning agent when the site is to steep or remote to access with mechanical methods.

During the day, when units are ignited, smoke would be expected to travel on prevailing winds, away from sensitive receptors, and dissipate. Most smoke would dissipate, but some may surface. Short-term nighttime nuisance smoke could settle down the drainages into the towns below, particularly during early morning hours. Nighttime smoke would be expected to reside in low areas down slope from the burn units, because night time winds are generally calm. Daytime smoke would be expected to dissipate mostly downwind from the burn unit. Burn plans written for implementation of the proposed prescribed fires would include modeling to determine the most appropriate conditions under which to burn in order to minimize smoke impacts.

The amount of smoke allowed by the DEQ would not increase, and any burning done in the proposed treatment areas would comply with the National Ambient Air Quality Standards (NAAQS). The number of days of smoke impacts, as well as nuisance smoke (emissions that comply with NAAQS but are considered by the public to be a nuisance) may increase under these alternatives, for the following reasons. Both the Coconino and Kaibab National Forests already burn on the high end of what would be their maximum acres and allowed emissions. Under Alternatives B, the number of acres available for prescribed fire would increase by 584,924 acres, which would average an additional 58,792 acres a year. This, in turn, would increase the flexibility for the forests in laying out burn units and managing prescribed fires. With potential for larger burn units, it would be possible to burn ‘hotter’, so that, although more acres may be burned at one time, the heat created by increased fire behavior is could provide more ‘lift’ for the smoke, increasing dispersal and minimizing smoke impacts.

In the long term, once an area has been burned once, there is less fuel and, thus, lower emission potential. The combination of lower fuel loads and larger burn units would allow more acres to be burned without exceeding NAAQS.

In the short term, as ‘1st entry’ burns are implemented, impacts would increase noticeably. Acres with high fuel loading would be burned, in a first step toward restoring the natural fire regime. In the long term, the same acres would produce less smoke, along with maintaining an ecosystem that is resilient to fire, and benefits from it.

In the short term, implementing acres of prescribed fire produces low severity effects that are beneficial for the landscape. In the long term, high severity fires are no longer possible on the majority of acres that are treated.

Air quality impacts can be predicted from prescribed fire, and the public notified of when and where to expect impacts in advance of a burn. Wildfires are less predictable and, though general patterns of smoke movement on the landscape are known, there is much less surety of where and when there will be impacts.

Figure 53 shows post-treatment surface fuel loading would decrease to post-treatment levels, decreasing the volume of potential emissions from wildfires and future prescribed fires. However, there is no change in CWD fuel loading for Very Low (PAC Burn Only) treatments (19,975 acres). In these areas, smoldering fuels would produce high levels of smoke, as well as a high likelihood of high severity fire effects.

Ecological effects of smoke

From an ecological perspective, the indirect effects of smoke are important to the germination of many native plants, and in some cases appears to be more important than heat (Abella 2006; Abella et al. 2007, Abella, 2009, Keeley and Fotheringham 2002, Schwilk and Zavala 2012), many of which occur in the treatment area, including *Nama dichotomum, Heliomersis longifolia, Penstemon spp. , Artemisia ludoviciana, Erigeron speciosus, and Symphyotrichum falcatum. S*moke may also be a natural control for mistletoe and other tree infections (Parmeter and Uhrenholdt, 1975; Zimmerman et al. 1987). This Alternative would increase, the area over which smoke could maintain its ecological roles, and help to restore the natural diversity of surface vegetation.

Stream/spring restoration

Restoration of 39 miles of ephemeral streams, and 74 springs would occur inside of existing treatments, with post-treatment conditions meeting desired conditions, but would not be expected to have much effect on fire behavior or effects in the short run. In the long run, restored hydrology in these areas, particularly springs, may result in increased surface fuel loading near springs, allowing wildfire or prescribed fire to creep closer to the water source than is generally possible now. Forest plan direction includes using prescribed fire to manage fuels in riparian areas.

Roads

Under this alternative, there would be 906 miles of roads decommissioned. From 2001 through 2010, over 30,555 acres of human ignited wildfires burned on Williams, Tusayan, Flagstaff, and Mogollon Rim Ranger Districts, 17 percent of all acres burned in wildfires. Many wildfires that are started by humans begin in proximity to roads so, under this Alternative, there could be fewer human-started wildfires. The more heavily used of these roads have functioned as fire breaks in the past. Once decommissioned, surface fuel loading will eventually grow back, allowing fire to burn across the area. During the implementation of the mechanical treatments, roads constructed or reconstructed for access (517 miles) would be available for access to burn units, and/or to be used as firelines for prescribed burns.

Unavoidable Adverse Effects, Irreversible and Irretrievable Commitment of Resources

There would be impacts to air quality, as an indirect effect associated with the implementation of the proposed prescribed fire treatments, however NAAQS would not be exceeded. Before any prescribed fires can be implemented, a prescribed burn plan must be written and signed by the authorizing line officer. For prescribed fire, burn plans include burn techniques, prescriptions, Emission Reduction Techniques, etc. That would be expected to maintain emissions levels at acceptable levels. Approval to burn on a given day must be approved by the Arizona Department of Environmental Quality, before a burn can be initiated. None of the proposed actions are expected to exceed NAAQs, though nuisance smoke may increase to the degree that the public will tolerate it in those areas discussed earlier in the Air Quality and Smoke Effects section of Alternative B in this report.

Alternative C

As with Alternative B, from a fire ecology perspective, the direct and indirect effects of Alternatives C relate to treatments that include mechanical thinning, prescribed fire, or both. The majority of these effects are identical to, or nearly identical to those described for alternative B. The Coconino and Kaibab NFs would conduct restoration activities on approximately 593,211 acres over a period of 10 years or until objectives are met. Up to 45,000 acres of vegetation would be mechanically treated annually. Up to 40,000 acres of prescribed fire would be implemented annually across the forests. Two prescribed fires[9] would be conducted on all acres proposed for treatment over the 10-year period. Restoration activities would

- Mechanically cut trees on approximately 434,001 acres. This includes: (1) mechanically treating up to 18-inch dbh within 18 Mexican spotted owl protected activity centers, (2) cutting trees by hand on 99 acres on slopes greater than 40 percent, and, (3) using low-severity prescribed fire within 72 Mexican spotted owl protected activity areas (including 56 core areas).

- Utilize prescribed fire-only on approximately 159,211 acres. This includes acres available for ‘Operational Burn’ only. These areas consist of grasslands, Pinyon/Juniper (PJ), oak woodland cover types that are situated within, or adjacent to aspen or ponderosa pine such that logistics indicate it should be included in the burn unit to facilitate proposed prescribed fire treatments.

    - Construct 517 miles of temporary roads for haul access and decommission when treatments are complete (no new permanent roads would be constructed)
    - Reconstruct up to 40 miles of existing, open roads for resource and safety concerns (no new permanent roads would be constructed). Of these miles, approximately 30 miles would be improved to allow for haul (primarily widening corners to improve turn radiuses) and about 10 miles of road would be relocated out of stream bottoms. Relocated roads would include rehabilitation of the moved road segment.
    - Decommission 770 miles of existing system and unauthorized roads on the Coconino NF
    - Decommission 134 miles of unauthorized roads on the Kaibab NF
    - Restore 74 springs and construct up to 4 miles of protective fencing
    - Restore 39 miles of ephemeral channels
    - Construct up to 82 miles of protective (aspen) fencing

[9] The first prescribed fire may include pile burning followed by a broadcast burn

- Construct up to 15 weirs and 20 weather stations (up to 3 total acres of disturbance) to support watershed research
- Allocate as old growth 40 percent of ponderosa pine and 77 percent of pinyon-juniper woodland on the Coconino NF and 35 percent of ponderosa pine and 58 percent of pinyon-juniper woodland on the Kaibab NF

Three non-significant forest plan amendments would be required on the Coconino NF to implement alternative C:

- Amendment 1 would: (1) allow the use mechanical treatments to improve habitat structure and mechanically treat up to 18-inch dbh within 18 MSO PACs, (2) allow the use of low-intensity prescribed fire within 56 PAC core areas, and (4) allow for managing e acres of restricted target and threshold habitat for a minimum range of 110 to 150 basal area, and, (5) would defer all Mexican spotted owl monitoring to the project's Biological Opinion issued by the US Fish and Wildlife Service.
- Amendment 2 would: 1) add the desired percentage of interspace within uneven-aged stands to facilitate restoration and defines interspace, (2) add the interspace distance between tree groups, (3) add language clarifying where canopy cover is and is not measured, (4) allows 29,017 acres to be managed for an open reference condition (figure 47), which affects canopy cover guidelines for VSS 4 through VSS 6 groups and reserve trees, and (5) add a definition to the forest plan glossary for the terms interspaces, open reference condition, and stands.
- (3) Amendment 3 would allow for managing to achieve a "No Adverse Effect" determination for significant, or potentially significant, inventoried heritage sites.

Three non-significant forest plan amendments would be required on the Kaibab NF to implement alternative C:

- Amendment 1 would: 1) add the desired percentage of interspace within uneven-aged stands to facilitate restoration and defines interspace, (2) add the interspace distance between tree groups, (3) add language clarifying where canopy cover is and is not measured, (4) allows 27,675 acres to be managed for an open reference condition (figure 47), which affects canopy cover guidelines for VSS 4 through VSS 6 groups and reserve trees, and (5) add a definition to the forest plan glossary for the terms interspaces, open reference condition, and stands.
- Amendment 2 would allow for mechanically treating and prescribed burning approximately 400 acres in the proposed Garland Prairie RNA.
- Amendment 3 would defer all Mexican spotted owl monitoring to the project's Biological Opinion issued by US Fish and Wildlife Service.

This alternative would meet Forest Service Manual 5100 (page 9) direction on the USFS use of prescribed fire to meet land and resource management goals and objectives. See Alternative B, pg. 132 for details on Forest Service Manual direction.

Direct and Indirect Effects

Changes to potential fire behavior are the indirect effects of changes to fuel loading and structure. The effects of implementing Alternative C are discussed in the following order.

1. Fire behavior is discussed at the treatment area scale
2. Potential fire behavior is discussed by vegetation type
3. Within Restoration Units and Subunits, fire behavior is broken out by vegetation/habitat types
4. Canopy characteristics and fuel loading and how they affect fire behavior, fire effects and air quality are presented by desired openness

Amendment 1 (Coconino NF): If amendment 1 is implemented, the resulting decreases in CBH, CBD, and CC would have the indirect effect of slightly decreasing crown fire potential for the 18 MSO PACs that would receive mechanical treatments. An additional indirect would be to increase the ability of fire managers to implement prescribed fire within PACs because of decreased potential fire behavior. The ability to implement prescribed fire in 56 core areas would decrease potential fire behavior, increasing the potential for undesirable fire behavior and effects. If amendment 1 is not implemented on the Coconino NF, these 18 PACs (~10,700 acres) would retain the current forest structure that places them at high risk of high severity fire. Potential fire behavior would make it difficult to implement prescribed fire because of narrow burn windows (weather and fuel conditions that would produce the desired fire effects and behavior). If prescribed fires were implemented on acres adjacent to PACs, or core areas, it is more likely that firelines would need to be created to keep fire out of PACs and/or core areas, producing ground disturbance that would be less likely under the proposed amendment. There would be little effect on emissions, except for a slight decrease in potential emissions in the event of wildfire following mechanical treatments within the PACs.

Amendment 2 (Coconino NF): If amendment 2 is implemented, it would allow 29,054 acres to be managed for an open reference condition. An indirect effect of managing for open conditions would be to have little potential for active crown fire, moving these acres towards the desired conditions. Open conditions would, in the long run, produce fewer emissions because of less litter and debris from trees, and greater herbaceous component to surface fuels, which is a flashier fuel, burning faster and more cleanly quickly than woody fuels. If amendment 2 is not implemented on the Coconino NF, some treatments could be implemented, but would not move these acres as far towards desired conditions as they would be under the amendment.

Amendment 3 (Coconino NF): If amendment 3 is implemented, it would allow fire to be used to meet objectives if it was determined to be the best tool. Additionally, it would allow all significant, or potentially significant inventoried sites that are not considered ‘fire sensitive’ to be included in burn units. If amendment 3 is not implemented, all significant, or potentially significant inventoried sites within burn units, regardless of if they are considered ‘fire sensitive’ or not, would be managed for ‘no effect’.

Amendment 1 (Kaibab NF): If amendment 1 is implemented, the same effects that are described above (Amendment 2 for the Coconino) would apply to the 27,765 acres to be managed for an open reference condition.

Amendment 2 (Kaibab NF): If amendment 2 is implemented, there would be an additional 400 acres of mechanical and prescribed fire treatments would move those acres toward desired condition (over alternatives B and D), as well as allowing more flexibility for laying out burn units in adjacent areas. If amendment 2 is not implemented, some of those acres could be burned under ‘Operational Burn’, but most would not move as far, or at all, toward desired condition.

Amendment 3 (Kaibab NF): If amendment 3 is implemented, the effects would be minimal, because the Biological Opinion from the US Fish and Wildlife Service is expected to differ only minimally from current direction.

When analyzed at the landscape scale, Alternative C would meet the purpose and need and move the majority of the acres towards the desired condition of having potential for less than 10 percent crown fire as modeled under the conditions that produced the Schultz Fire (Table 72). Non-burnable substrates constitute ~2 percent of the treatment area and was not included in the acres shown fire potential fire behavior.

In the short term (<20 years), across the treatment area the potential for undesirable fire behavior and effects would be reduced by breaking up the vertical and horizontal continuity of canopy fuels, decreasing excessive surface fuel loads of litter and duff, and replacing them with the light, flashy fuels that would be stimulated by post-treatment conditions (Noble 2012). Wildfire behavior would benefit the ecosystems in which it burned, and would not threaten lives, resources, or infrastructure. Air quality impacts (nuisance smoke) could increase some as first and second entry prescribed fires are implemented.

In the long term (>20 years), potential for undesirable fire behavior, as assessed by changes to canopy fuels, would remain lower than existing condition for approximately 68 percent of the ponderosa pine in the treatment area. Potential for undesirable fire effects, as assessed by the direct effects on canopy fuels and surface fuel loading, would remain lower than existing condition for approximately 34 percent of the ponderosa pine in the treatment area. Air quality impacts (indirect effects) could decrease some as the treatment area is in maintenance mode for prescribed fires, producing fewer emissions per acre.

Table 70. Modeled fire type for Alternative C

All acres proposed for treatment	2010	2020
Surface fire	64	94
Passive crown fire	9	3
Active crown fire	25	1

Under Alternative C, the horizontal and vertical continuity of canopy fuels are broken up, decreasing the potential for crown fire from 34 percent of the treatment area to 4 percent of the treatment area, with potential for active crown fire decreasing from 25 percent to 1 percent. Non-burnable substrates constitute ~2 percent of the treatment area and was not included in the acres shown fire potential fire behavior. The amount of potential crown fire remaining after proposed treatments would be well within the historic ranges of ponderosa pine in this area. As illustrated by Figure 54, much of the active crown fire that remains following treatment is in Restoration Units 1 and, in most cases, would occur in MSO and goshawk habitat (Table 71).

Ponderosa Pine

The majority of ponderosa pine acres would meet desired conditions under Alternative C when acres are analyzed at the landscape scale. At the scale of ponderosa pine vegetation, the crown fire risk and effects are identical to Alternative B. When broken out by habitat type, 22 percent (8,072 acres) of protected habitat in ponderosa pine would still be at risk of crown fire, of which 17 percent (6,163 acres) would be active crown fire (Table 73).

Pine/Sage

Effects for Pine/Sage would be identical to Alternative B, as discussed on page 133.

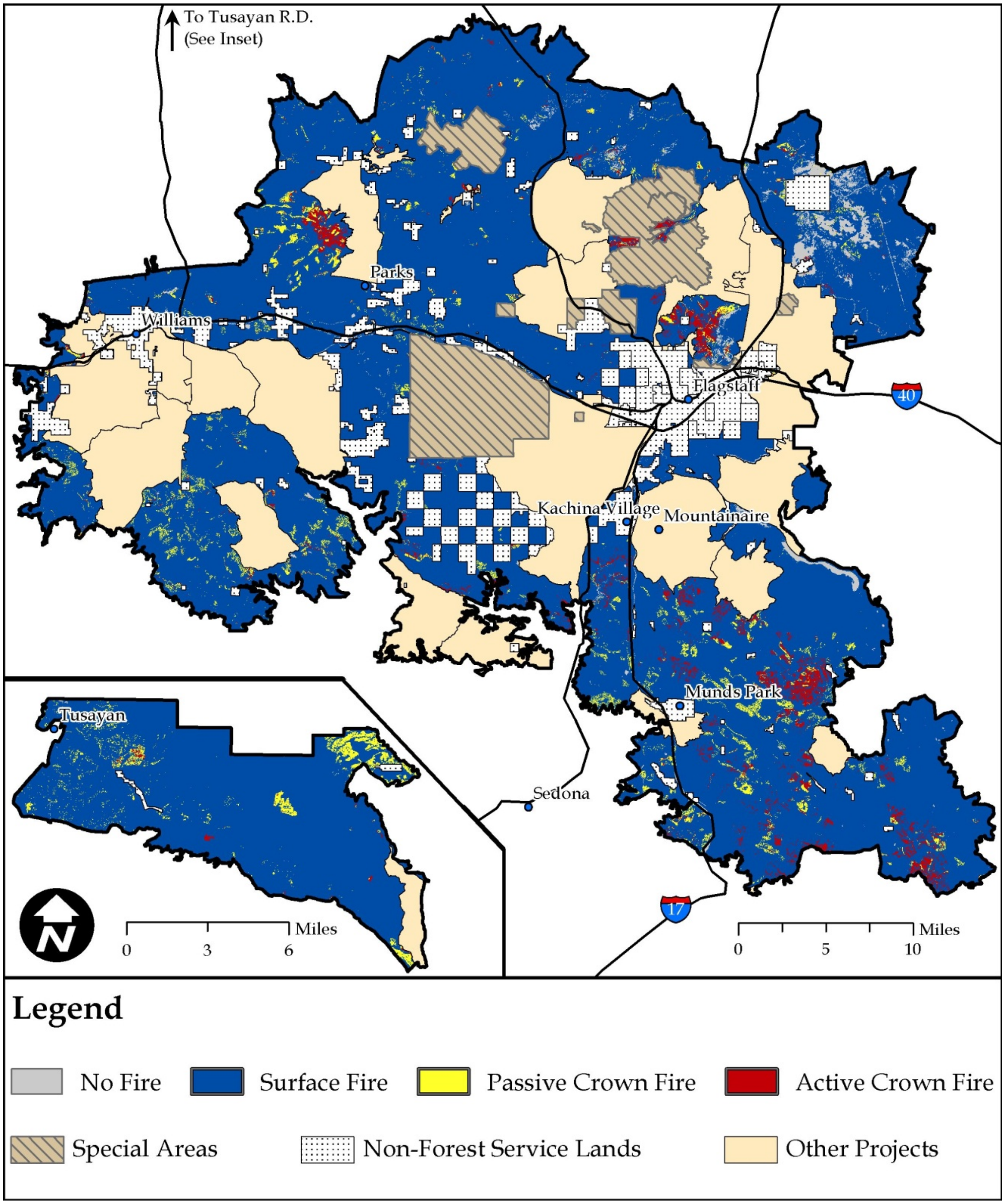


Figure 54. Modeled fire type for Alternative C, 2020

Table 71. Modeled fire type in ponderosa pine by habitat for Alternative C

Vegetation Type		Fire Type	Existing Condition		2020	
			Acres	Percent	Acres	Percent
Ponderosa Pine	All Pine	Surface	313,423	62	482,879	95
		Passive crown	48,523	10	15,508	3
		Active crown	145,113	29	8,672	2
	MSO Protected	Surface	18,610	51	28,525	78
		Passive crown	3,141	9	1,908	5
		Active crown	14,847	41	6,163	17
	MSO Target/ Threshold	Surface	4,292	49	8,194	94
		Passive crown	926	11	126	1
		Active crown	3,479	40	377	4
	MSO Restricted	Surface	35,465	53	60,623	90
		Passive crown	6,608	10	6,270	9
		Active crown	25,187	37	366	1
	Goshawk PFA/ dPFA/ Nest Stand	Surface	18,737	62	28,445	93
		Passive crown	2,952	10	1,535	5
		Active crown	8,756	29	465	2
	Landscapes outside PFAs	Surface	236,320	65	357,090	98
		Passive crown	34,896	10	5,668	2
		Active	92,844	26	1,301	0

Aspen

There are 17 more acres of aspen treatments proposed in Alternative B than in Alternative C. Effects would be the same as those described in Alternative B under 'Aspen', page 133.

Gambel Oak

Effects would be identical to those discussed on page 135 (Alternative B) under 'Gambel Oak'.

Grasslands

Alternative C proposes to implement mechanical treatments and prescribed fire on 48,196 acres, and prescribed fire only on an additional 579 acres, for a total of 48,774 acres of grassland treatments. Desired Conditions are met at all scales of analysis (Table 72 and Table 73).

Table 72. Modeled fire type in grasslands under Alternative C

Fire type	Existing Conditions		2020	
	Percent	Acres	Percent	Acres

Surface fire	86	41,602	95	45,600
Passive crown fire	6	2,984	0	103
Active crown fire	2	1,131	0	15

Table 73. Modeled fire type in grasslands by Restoration Unit under Alternative C

Grassland RU	Fire Type	Veg type acres	2010		Alternative C 2020	
			Acres	Percent	Acres	Percent
RU1	Surface	8,133	6,151	76	7,636	94
	Passive crown		1,321	16	68	1
	Active crown		239	3	7	0
RU3	Surface	12,775	11,703	92	12,532	98
	Passive crown		683	5	24	0
	Active crown		172	1	2	0
RU4	Surface	22,599	21,082	93	22,437	99
	Passive crown		753	3	8	0
	Active crown		613	3	3	0
RU5	Surface	4,595	2,577	56	2,902	63
	Passive crown		225	5	3	0
	Active crown		105	2	2	0
RU6	Surface	93	89	96	92	100
	Passive crown		3	3	0	0
	Active crown		1	1	0	0

When broken out by subunit, grasslands meet desired conditions in all Subunits (Table 74). Fire behavior is close to what would be expected in healthy grassland units in the treatment area, with most of the crown fire being passive. Those acres indicated as active crown fire in grasslands are not contiguous, so the effects on the ground would be similar to passive crown fire.

Table 74. Modeled fire behavior in grasslands by RU 1 subunits, Alternative C

Subunit	Acres	Alternative C Fire Behavior (Acres)		
		Surface	Passive crown	Active crown
1-1	**10,169**	**9,946**	**43**	**16**
Grassland	567	548	6	0
1-2	**8,054**	**7,877**	**117**	**1**
Grassland	1,537	1,500	0	0
1-3	**41,652**	**38,831**	**931**	**1,468**

Subunit	Acres	Alternative C Fire Behavior (Acres)		
		Surface	Passive crown	Active crown
Grassland	3,240	2,906	14	5
1-4	**18,250**	**17,412**	**228**	**595**
Grassland	519	510	0	0
1-5	**78,179**	**71,133**	**3,288**	**3,461**
Grassland	2,270	2,172	48	1
3-1	**23,148**	**21,719**	**1,253**	**108**
Grassland	593	574	2	0
3-2	**32,726**	**31,655**	**685**	**110**
Grassland	9,611	9,462	6	0
3-3	**48,434**	**45,927**	**1,920**	**493**
Grassland	1,353	1,343	2	1
3-4	**9,019**	**8,241**	**171**	**392**
Grassland	99	84	0	0
3-5	**36,392**	**33,486**	**1,861**	**812**
Grassland	1,120	1,068	13	1
4-2	**10,231**	**9,921**	**163**	**47**
Grassland	332	302	1	1
4-3	**67,013**	**65,046**	**1,349**	**297**
Grassland	6,951	6,938	1	0
4-4	**81,421**	**79,651**	**1,403**	**167**
Grassland	14,988	14,872	6	2
4-5	**6,943**	**6,850**	**24**	**56**
Grassland	327	325	0	0
5-1	**24,172**	**22,279**	**418**	**606**
Grassland	1,299	1,277	2	1
5-2	**51,924**	**46,428**	**476**	**87**
Grassland	3,297	1,625	1	1
6-3	**34,109**	**33,107**	**866**	**105**
Grassland	85	85	0	0
6-4	**3,870**	**2,979**	**886**	**1**
Grassland	7	7	0	0

Pinyon/Juniper (PJ)

Effects on fire type for PJ under Alternative C are virtually identical to those discussed in

Alternative B (Table 75), differing by 7 acres. Effects are as discussed under Alternative B on page 136. Table 76 displays modeled fire behavior in pinyon-juniper with a fuels objective.

Table 75. Fire type in all Pinyon/Juniper under Alternative C

Vegetation Type	Fire Type	2010 Percent/Acres	Alternative B 2020 Percent/Acres	Alternative C 2020 Percent/Acres
Pinyon/ Juniper	Surface crown fire	84/19,367	98/22,516	98/22,524
	Passive crown fire	7/1,535	2/384	2/379
	Active crown fire	9/2,041	0/43	0/41

Table 76. Fire type in the Pinyon/Juniper in Restoration Unit 6 (fuels reduction objective)

Vegetation Type	Fire Type	2010 Percent/Acres	Alternative B 2020 Percent/Acres	Alternative C 2020 Percent/Acres
Pinyon/ Juniper	Surface crown fire	74/595	100/533	100/533
	Passive crown fire	25/132	0/2	0/2
	Active crown fire	2/8	0/0	0/0

Restoration Units

When analyzed at the scale of the Restoration Unit, Alternative C would meet desired conditions for fire behavior. Post-treatment potential for crown fire ranges from 2 percent in RU4 and RU5 to 7 percent in RU1 (Table 77).

Table 77. Fire type for Alternative C by restoration units

	RU	Fire Type Acres			Fire Type Percent		
		Surface	Passive	Active	Surface	Passive	Active
Alt. C (2020)	RU 1	145,200	4,607	5,540	93	3	4
	RU 3	141,029	5,890	1,914	94	4	1
	RU 4	161,469	2,939	566	98	2	0
	RU 5	68,708	894	693	90	1	1
	RU 6	41,463	1,918	106	95	4	0
	Total	557,868	16,249	8,820	94	3	1

Restoration Unit 1

Restoration Unit 1 is of particular concern because Lake Mary is a source watershed for Flagstaff, and fire behavior in this RU could affect an observatory just north of Lower Lake Mary, and Walnut Canyon. There are adjacency concerns in the area of Mormon Mountain (center right, where the legend scale is) because of heavy fuel loading in mixed conifer, as well as the city of Flagstaff to the northwest. Post-treatment modeling shows 7 percent (10,147 acres) of RU1 would have crown fire potential, of which 4 percent (5,540 acres) would be active crown fire.

Ponderosa pine occupies 146,037 acres in Restoration Unit 1, more than the other restoration units. Post-treatment, 7 percent 10,985 acres) of the pine vegetation type would have potential for high severity effects from crown fire, with 4 percent (5,439) of it would be active crown fire (Table 78). The pine vegetation type meets desired conditions for fire behavior. All, or parts of over 50 PACs occur in RU1, accounting for over 30,000 acres (20 percent) of the ponderosa pine. There is no desired fire behavior for protected habitat which, post-treatment, has potential for 22 percent (5,649 acres) of crown fire, of which 16 percent (4,911) would be active crown fire. The majority of active crown fire in ponderosa pine in RU1 would be in protected habitat, accounting for over 60 percent of the crown fire in RU1.

Table 78. Modeled fire type for Restoration Unit 1 by vegetation type for 2020

RU 1 acres (156,305)			Vegetation type acres	Existing Condition		Alternative C 2020	
	Vegetation Type	Type		Acres	Percent	Acres	Percent
Ponderosa Pine	All Pine	Surface	146,037	81,276	56	135,651	93
		Passive		15,960	11	4,446	3
		Active		48,300	33	5,439	4
	MSO Protected	Surface	30,240	15,669	52	23,538	78
		Passive		2,346	8	1,738	6
		Active		12,172	40	4,911	16
	MSO Target/ Threshold	Surface	4,814	2,252	47	4,485	93
		Passive		506	11	73	2
		Active		2,045	42	244	5
	MSO Restricted	Surface	26,421	13,074	49	24,035	91
		Passive		2,655	10	2,282	9
		Active		10,660	40	72	0
	Goshawk PFA/ dPFA/ Nest Stand	Surface	4,670	2,592	56	4,587	98
		Passive		521	11	62	1
		Active		1,556	33	21	0
	Landscapes outside PFAs	Surface	79,892	47,689	60	79,007	99
		Passive		9,932	12	291	0
		Active		21,867	27	191	0
Other Vegetation	Aspen	Surface	420	241	57	267	64
		Passive		40	10	75	18
		Active		138	33	78	19
	Grassland	Surface	8,133	6,151	76	7,636	94

RU 1 acres (156,305)			Vegetation type acres	Existing Condition		Alternative C 2020	
Vegetation Type		Type		Acres	Percent	Acres	Percent
		Passive		1,321	16	68	1
		Active		239	3	7	0
	Juniper Woodland	Surface	286	232	81	283	99
		Passive		14	5	3	1
		Active		41	14	0	0
	Oak Woodland	Surface	287	194	68	286	100
		Passive		62	22	1	0
		Active		31	11	1	0
	Pinyon/ Juniper	Surface	1,141	896	78	1,077	94
		Passive		115	10	15	1
		Active		96	8	15	1

Aspen effects differ from Alternative B by just 3 acres and were considered to be identical (see discussion under Alternative B in 'Restoration Unit 1' on page 133).

Grasslands in Restoration Unit 1, would meet desired conditions for fire behavior. The addition of mechanical treatments combined with fire reduces potential fire behavior in grasslands to 1 percent, meeting desired conditions for fire behavior. This means the potential for undesirable fire effects and behavior in grasslands is zero.

Pinyon/Juniper woodland effects differ from Alternative B by 5 acres and were considered to be identical (See discussion Alternative B page 138).

Oak woodland effects differ from Alternative B by 5 acres and were considered identical. See discussion on page 138. Under Alternative C, there would be no crown fire in oak woodland.

Subunits

When considered by the subunit (Table 79), four of the five subunits meet desired conditions for fire behavior. Modeled fire behavior in Subunit 1-5 shows potential for crown fire would be 13 percent (78,179 acres), of which 9 percent (3,288 acres) would be active crown fire. Ponderosa pine in Subunit 1-5 has the same ages, with 13 percent (42,996 acres) of crown fire, of which 9 percent (68,166 acres) would be active crown fire. This can be attributed to the presence of all, or parts, of approximately 35 PAC within the Subunit. Crown fire in the PACs accounts for the majority of fire in this Subunit.

Table 79. Modeled fire type in Restoration Unit 1 subunits by vegetation type for 2020

Vegetation Type	Alternative C 2020 Fire Type

by Sub-Unit	Total Acres	Surface (acres)	Passive crown (acres)	Active crown (acres)	Surface (percent)	Passive crown (percent)	Active crown (percent)
1-1	**10,169**	**9,946**	**43**	**16**	**98**	**0**	**1**
Ponderosa Pine	8,914	8,750	32	16	98	0	1
Grassland	567	548	6	0	97	1	1
Oak Woodland	173	173	0	0	100	0	0
Pinyon-Juniper	515	476	5	0	92	1	1
1-2	**8,054**	**7,877**	**117**	**1**	**98**	**1**	**1**
Ponderosa Pine	6,517	6,377	117	1	98	2	2
Grassland	1,537	1,500	0	0	98	0	0
1-3	**41,652**	**38,831**	**931**	**1,468**	**93**	**2**	**6**
Ponderosa Pine	38,324	35,890	903	1,424	94	2	6
Aspen	88	36	14	38	40	16	60
Grassland	3,240	2,906	14	5	90	0	1
1-4	**18,250**	**17,412**	**228**	**595**	**95**	**1**	**5**
Ponderosa Pine	17,285	16,468	221	589	95	1	5
Grassland	519	510	0	0	98	0	0
Oak Woodland	83	82	0	1	99	0	1
Pinyon-Juniper	363	352	7	5	97	2	3
1-5	**78,179**	**71,133**	**3,288**	**3,461**	**91**	**4**	**9**
Ponderosa Pine	74,996	68,166	3,173	3,410	91	4	9
Aspen	332	232	60	40	70	18	30
Grassland	2,270	2,172	48	1	96	2	2
Juniper Woodland	286	283	3	0	99	1	1
Oak Woodland	32	31	1	0	98	2	2
Pinyon-Juniper	262	249	3	10	95	1	5

Restoration Unit 3

Winds on the Mogollon Rim are generally out of the southwest, so this RU has a high strategic importance in regards to fire movement. Adjacency concerns for fire behavior include Interstates 40 and 17 which are adjacent to RU3 to the north and east, respectively, so that smoke from wildfires would have good potential to impact travel, as well as the communities of Flagstaff, Belmont, Parks, Williams, and Kachina Village. Additional concerns include Oak Creek, Oak Creek Canyon, and Sycamore Canyon. Under Alternative C, RU3 there would be potential for 7,804 (5 percent) of crown fire, of which 1,914 acres (1 percent) would be active crown fire. Outside of PACs where there are some contiguous areas of both passive and active crown fire, the majority of crown fire is scattered passive crown fire.

At the vegetation/habitat scale (Table 80), the ponderosa pine would have potential for 7,650 (5 percent) acres of crown fire of which 1,890 acres (1 percent) would be active crown fire. In the ponderosa pine in RU1, over 50 percent of the crown fire occurs in restricted habitat, of which 11 percent would have potential for crown fire.

Table 80. Fire type by vegetation type and habitat for Restoration Unit 3

RU 3 acres (149,718)			Vegetation type acres	Existing Condition		Alternative C 2020	
	Vegetation Type	Fire Type		Acres	Percent	Acres	Percent
Ponderosa Pine	All Pine	Surface	129,225	72,734	56	120,930	94
		Passive		12,618	10	5,760	4
		Active		43,227	33	1,890	1
	MSO Protected	Surface	4,507	1,930	43	3,303	73
		Passive		586	13	163	4
		Active		1,907	42	956	21
	MSO Target/ Threshold	Surface	3,899	2,040	52	3,709	95
		Passive		420	11	53	1
		Active		1,435	37	132	3
	MSO Restricted	Surface	38,748	21,183	55	34,540	89
		Passive		3,683	10	3,852	10
		Active		13,804	36	279	1
	Goshawk PFA/ dPFA/ Nest Stand	Surface	5,452	2,891	53	4,954	91
		Passive		588	11	371	7
		Active		1,972	36	124	2
	Landscapes outside PFAs	Surface	76,619	44,689	58	74,422	97
		Passive		7,342	10	1,320	2
		Active		24,110	31	399	1
Other Vegetation	Aspen	Surface	201	145	72	144	72
		Passive		40	20	57	28
		Active		16	8	0	0
	Grassland	Surface	12,775	11,703	92	12,532	98
		Passive		683	5	24	0
		Active		172	1	2	0
	Juniper Woodland	Surface	1,851	1,552	84	1,834	99
		Passive		50	3	8	0
		Active		243	13	3	0
	Oak Woodland	Surface	1,633	1,276	78	1,616	99

RU 3 acres (149,718)		Vegetation type acres	Existing Condition		Alternative C 2020	
Vegetation Type	Fire Type		Acres	Percent	Acres	Percent
	Passive		77	5	5	0
	Active		271	17	2	0
Pinyon/ Juniper	Surface	4,033	3,343	83	3,973	98
	Passive		176	4	36	1
	Active		507	13	17	0

Aspen effects in RU3 differ from Alternative B by just 1 acre and were considered to be identical. (See discussion under Alternative B in ‘Restoration Unit 3’ on page141).

Grasslands would meet desired conditions for fire type under Alternative C. The addition of mechanical treatments combined with fire reduces potential fire behavior in grasslands to less than 1 percent (26 acres out of over 12,000), meeting desired conditions for fire behavior. This means the potential for undesirable fire effects and behavior in grasslands is zero.

Pinyon/Juniper woodland effects differ from Alternative B by just 1 acre and were considered to be identical (See discussion under Alternative B in ‘Restoration Unit 3’ on page141).

Oak woodland effects under Alternative C would be identical to those in Alternative B (See discussion under Alternative B in ‘Restoration Unit 3’ on page 141). Under Alternative C, there would be no crown fire in oak woodland.

Subunit

All subunits would meet desired conditions for fire behavior scale (Table 81). Subunit 3-5 has the most crown fire potential, with 7 percent (2,673 acres) of the area having potential for crown fire. Subunit 3-5 has all, or parts of approximately 11 PACs accounting for most of the active crown fire. There is potential for small areas of crown fire on slopes >30 percent in Subunits 3-5 (on the edge of the rim), but these areas would be less than ½ acre and would be rare.

Table 81. Modeled fire type for Restoration Unit 3 subunits by vegetation type for 2020

Vegetation Type by Sub-Unit	Alternative C 2020						
	Total Acres	Surface (acres)	Passive crown (acres)	Active crown (acres)	Surface (percent)	Passive crown (percent)	Active crown (percent)
3-1	**23,148**	**21,719**	**1,253**	**108**	**94**	**5**	**0**
Ponderosa Pine	18,805	17,448	1,207	105	93	6	1
Aspen	91	60	31	0	66	34	0
Grassland	593	574	2	0	97	0	0
Juniper Woodland	907	899	5	0	99	1	0

Vegetation Type by Sub-Unit	Alternative C 2020						
	Total Acres	Surface (acres)	Passive crown (acres)	Active crown (acres)	Surface (percent)	Passive crown (percent)	Active crown (percent)
Oak Woodland	845	839	4	1	99	0	0
Pinyon-Juniper	1,908	1,899	4	1	100	0	0
3-2	**32,726**	**31,655**	**685**	**110**	**97**	**2**	**0**
Ponderosa Pine	22,885	21,980	661	110	96	3	0
Aspen	59	41	18	0	70	30	0
Grassland	9,611	9,462	6	0	98	0	0
Oak Woodland	172	172	0	0	100	0	0
3-3	**48,434**	**45,927**	**1,920**	**493**	**95**	**4**	**1**
Ponderosa Pine	44,426	41,975	1,894	485	94	4	1
Aspen	50	42	8	0	83	17	0
Grassland	1,353	1,343	2	1	99	0	0
Juniper Woodland	873	865	3	2	99	0	0
Oak Woodland	232	222	1	1	96	0	0
Pinyon-Juniper	1,500	1,481	11	4	99	1	0
3-4	**9,019**	**8,241**	**171**	**392**	**91**	**2**	**4**
Ponderosa Pine	8,920	8,156	171	392	91	2	4
Grassland	99	84	0	0	86	0	0
Oak Woodland	0	0	0	0	100	0	0
3-5	**36,392**	**33,486**	**1,861**	**812**	**92**	**5**	**2**
Ponderosa Pine	34,190	31,370	1,826	799	92	5	2
Aspen	2	2	0	0	100	0	0
Grassland	1,120	1,068	13	1	95	1	0
Juniper Woodland	70	70	0	0	100	0	0
Oak Woodland	384	383	0	0	100	0	0
Pinyon-Juniper	626	593	21	12	95	3	2

Restoration Unit 4

Located west and north of Flagstaff, and north of Williams and Interstate 10, RU4 has potential to affect the communities of Flagstaff, Williams, Parks, and Belmont, though the prevailing winds would tend to blow fire away from most of the populations in Williams, Parks and Belmont. There is also potential to impact the Fort Valley Experimental Station northwest of Flagstaff. Over the last 20 years, has been impacted by some large fires, including the Hockderffer (2004, 16,000 acres) and Pumpkin (2000, 8,700 acres) fires.

Under Alternative C, there would be potential for 3,505 acres (2 percent) of the treatment area in RU4 to burn with crown fire, of which 566 acres (<1 percent) would be crown fire. Most of the crown fire in RU4 would be in scattered patches, with few areas of contiguous active crown fire greater than about 15 acres, mostly in areas classified as grasslands or other non-pine vegetation. There would be larger contiguous acreages of passive crown fire in PFAs and areas of lower intensity treatments, and some burn only treatments.

Ponderosa pine accounts for 98 percent of the crown fire in the RU4 (Table 82). There would be potential for 3,439 (2 percent) of the ponderosa pine in this RU to burn with crown fire, of which 556 acres would be active crown. Approximately 30 percent of the crown fire in RU4 would occur in PFA/DPFA/Nest Stand habitat.

Table 82. Modeled fire type for Restoration Unit 4 under Alternative C for 2020

RU 4 acres = 165,607			Acres of Veg type in RU	Existing Condition		Alt. C 2020	
Vegetation Type		Fire Type		Acres	Percent	Acres	Percent
Ponderosa Pine	All Pine	Surface	134,301	83,435	62	130,417	97
		Passive crown		10,615	8	2,883	2
		Active crown		39,806	30	556	0
	MSO Protected	Surface	558	379	68	531	95
		Passive crown		46	8	0	0
		Active crown		133	24	27	5
	MSO Restricted	Surface	1,575	749	48	1,422	90
		Passive crown		197	13	133	8
		Active crown		622	39	13	1
	Goshawk PFA/ dPFA/ NestStand	Surface	13,484	8,007	59	12,476	93
		Passive crown		1,242	9	809	6
		Active crown		4,231	31	196	1
	Landscapes outside PFAs	Surface	118,683	74,300	63	115,988	98
		Passive crown		9,130	8	1,941	2
		Active crown		34,820	29	321	0
Other Vegetation	Aspen	Surface	499	411	82	455	91
		Passive crown		30	6	40	8
		Active crown		55	11	1	0
	Grassland	Surface	22,599	21,082	93	22,437	99
		Passive crown		753	3	8	0
		Active crown		613	3	3	0
	Juniper Woodland	Surface	118	68	58	115	98
		Passive crown		4	3	0	0
		Active crown		43	37	0	0

RU 4 acres = 165,607			Acres of Veg type in RU	Existing Condition		Alt. C 2020	
Vegetation Type		Fire Type		Acres	Percent	Acres	Percent
	Oak Woodland	Surface	926	669	72	921	99
		Passive crown		85	9	1	0
		Active crown		170	18	2	0
	Pinyon/ Juniper	Surface	7,165	5,864	82	7,124	99
		Passive crown		454	6	6	0
		Active crown		815	11	4	0

Aspen effects in RU3 differ from Alternative B by just 1 acre and were considered to be identical. (See discussion on page 144).

Grasslands in RU4 would meet desired conditions for fire behavior. The addition of mechanical treatments combined with fire reduces potential fire behavior in grasslands to less than 1 percent (12 acres out of over 22,599), meeting desired conditions for fire behavior. This means the potential for undesirable fire effects and behavior in grasslands is zero.

Pinyon/Juniper woodland effects differ from alternative B by 4 acres and were considered to be identical (See discussion on page 144).

Oak woodland effects under Alternative C would be identical to those in Alternative B (See discussion on page 144). Under Alternative C, there would be no crown fire in oak woodland.

Subunits

At the subunit scale, all subunits would meet desired conditions for fire behavior. Subunit 3-5 has the most crown fire potential, with 7 percent (2,673 acres) of the area having potential for crown fire. Subunit 3-5 has all, or parts of approximately 11 PACs accounting for most of the active crown fire. There is potential for small areas of crown fire on slopes >30 percent in subunits 3-5 (on the edge of the rim), but these areas would be less than ½ acre and would be rare.

At the subunit level (Table 83) SU 4-5, though the smallest SU in the project (6,943 acres), is adjacent to the city of Flagstaff, and has steep topography, so that the second order fire effects (flooding, debris flows, etc.) of high severity fire has good potential to impact neighborhoods and schools. Under Alternative C, 1 (80 acres) of SU 4-5 would have potential for crown fire, with 1 percent (56 acres) would be active crown fire. There would be no areas of contiguous crown fire greater than 2 acres in subunit 4-5. In subunit 4-3, there would be areas of contiguous passive crown fire of over 100 acres in burn-only units and/or PFAs. Passive crown fire could become active crown fire if the wind increased, or other conditions, such as fuel moisture, temperature, or humidity deteriorated. However, wind is the most important factor in fire behavior and this was modeled with winds at the 98^{th}ile. These areas are surrounded by surface fire.

Table 83. Modeled fire type for Restoration Unit 4 subunits under Alternative C for 2020

Vegetation Type	Alternative C 2020

by Sub-Unit	Total Acres	Surface Fire (acres)	Passive Crown (acres)	Active Crown (acres)	Surface (percent)	Passive crown (percent)	Active crown (percent)
4-2	**10,231**	**9,921**	**163**	**47**	**97**	**2**	**2**
Ponderosa Pine	7,381	7,142	158	41	97	2	3
Aspen	1	1	0	0	67	0	0
Grassland	332	302	1	1	91	0	1
Juniper Woodland	8	8	0	0	97	1	3
Oak Woodland	567	562	1	2	99	0	1
Pinyon-Juniper	1,941	1,907	2	4	98	0	0
4-3	**67,013**	**65,046**	**1,349**	**297**	**97**	**2**	**2**
Ponderosa Pine	55,311	53,372	1,339	296	96	2	3
Aspen	232	225	5	0	97	2	2
Grassland	6,951	6,938	1	0	100	0	0
Juniper Woodland	31	31	0	0	100	0	0
Oak Woodland	325	325	0	0	100	0	0
Pinyon-Juniper	4,162	4,155	4	0	100	0	0
4-4	**81,421**	**79,651**	**1,403**	**167**	**98**	**2**	**2**
Ponderosa Pine	65,003	63,385	1,366	164	98	2	2
Aspen	255	223	32	0	88	12	12
Grassland	14,988	14,872	6	2	99	0	0
Juniper Woodland	78	76	0	0	97	0	0
Oak Woodland	35	35	0	0	100	0	0
Pinyon-Juniper	1,062	1,061	0	0	100	0	0
4-5	**6,943**	**6,850**	**24**	**56**	**99**	**0**	**1**
Ponderosa Pine	6,605	6,518	20	56	99	0	1
Aspen	11	7	4	0	63	35	37
Grassland	327	325	0	0	99	0	0

Restoration Unit 5

Restoration Unit 5 includes parts of the area that was burned in the Schultz fire (2010, ~17,000 acres) and the Radio Fire (1977, 2,600 mostly on Mount Eldon, immediately upslope and adjacent to northern Flagstaff). Adjacency concerns include housing developments, including Doney Park, and the city of Flagstaff, which would be mostly downslope from any fire occurring in this RU. There are many areas, some larger than 500 acres, in the north and eastern areas of this RU that are cinder substrate, and have no potential for fire. These areas consist of cinder cones, and cinder soils which generally support sparse vegetation. In these areas, active crown fire is less likely because of decreased potential for high intensity surface fire. These areas, though they have little fuel, have been reported to attract lightning, increasing the potential for lightning starts in the vicinity.

Under Alternative C (Table 84), there would be potential for 1,587 (1 percent) acres of crown fire, of which 693 would be active. Crown fire is scattered, with the majority of it in small areas on the north side of the Peaks, in PACs on the southwest aspect of the Peaks or the north aspect near Schultz Pass on Mount Eldon.

Ponderosa pine accounts for 1,499 acres of crown fire (2 percent of the pine) of the pine would support crown fire after treatment, 681 acres (1 percent) would be active crown fire.

Table 84. Modeled fire type for Restoration Unit 5 under Alternative C, 2020

RU 5: 76,096 acres			Acres of Vegetation type in RU	Existing Condition		Alt. C 2020	
Vegetation Type		Fire Type		Acres	Percent	Acres	Percent
Ponderosa Pine	All Pine	Surface	61,730	42,304	69	56,443	91
		Passive crown		7,105	12	818	1
		Active crown		8,532	14	681	1
	MSO Protected	Surface	1,452	631	43	1,153	79
		Passive crown		164	11	7	0
		Active crown		635	44	270	19
	MSO Restricted	Surface	634	460	73	627	99
		Passive crown		72	11	4	1
		Active crown		101	16	2	0
	Goshawk PFA/ dPFA/ Nest Stand	Surface	2,944	1,745	59	2,654	90
		Passive crown		490	17	116	4
		Active crown		563	19	28	1
	Landscapes outside PFAs	Surface	56,700	39,468	70	52,008	92
		Passive crown		6,380	11	691	1
		Active crown		7,233	13	381	1
Other Vegetation	Aspen	Surface	403	333	83	333	83
		Passive crown		22	5	65	16
		Active crown		42	11	0	0
	Grassland	Surface	4,595	2,577	56	2,902	63
		Passive crown		225	5	3	0
		Active crown		105	2	2	0
	Juniper Woodland	Surface	74	66	89	74	100
		Passive crown		8	10	0	0
		Active crown		0	1	0	0
	Oak	Surface	523	443	85	497	95

RU 5: 76,096 acres		Acres of Vegetation type in RU	Existing Condition		Alt. C 2020	
Vegetation Type	Fire Type		Acres	Percent	Acres	Percent
Woodland	Passive crown		35	7	1	0
	Active crown		25	5	6	1
Pinyon/ Juniper	Surface		7,797	89	8,459	96
	Passive crown	8,771	279	3	8	0
	Active crown		395	5	4	0

Aspen effects in RU5 would be identical to those in Alternative B. See discussion on page 147.

Grasslands in RU4 would meet desired conditions for fire behavior. Mechanical treatments combined with fire would reduce potential crown fire in grasslands to less than 1 percent (5 acres out of 4,595), meeting desired conditions for fire behavior. This means there is no potential for undesirable fire effects and behavior in grasslands.

Pinyon/Juniper woodland effects would be identical to those in Alternative B. See discussion Alternative B on page 146.

Oak woodland effects under Alternative C differ from those in Alternative B by 6 acres, and were considered nearly identical. See discussion on under Alternative B, page 146. Under Alternative C, there would be potential for 7 acres of crown fire, of which 6 acres would be active crown fire.

Subunits

Subunit 5-2 (Table 85) includes sparsely vegetated cinder cones, as well as areas that sustained second order fire effects from the Schultz Fire. Both subunits in RU5 would meet desired conditions for fire behavior. There is a PAC on the northwest side of Mt. Eldon (in Schultz Pass) of about 70 acres of mostly contiguous active crown fire of which about 20 acres are on 30 – 40 slopes. This area is adjacent to and uphill from the Schultz Pass road.

Table 85. Modeled fire type in Restoration Unit 5 subunits by vegetation type for 2020

Vegetation Type by Subunit	Total Acres						
	Total Acres	Surface (acres)	Passive crown (acres)	Active crown (acres)	Surface (percent)	Passive crown (percent)	Active crown (percent)
5-1	**24,172**	**22,279**	**418**	**606**	**92**	**2**	**4**
Ponderosa Pine	20,674	18,908	350	599	91	2	5
Aspen	392	324	63	0	83	16	16
Grassland	1,299	1,277	2	1	98	0	0
Oak Woodland	232	223	1	6	96	0	3
Pinyon-Juniper	1,574	1,547	3	0	98	0	0

Vegetation Type by Subunit	Total Acres						
	Total Acres	Surface (acres)	Passive crown (acres)	Active crown (acres)	Surface (percent)	Passive crown (percent)	Active crown (percent)
5-2	**51,924**	**46,428**	**476**	**87**	**89**	**1**	**1**
Ponderosa Pine	41,055	37,535	468	82	91	1	1
Aspen	10	8	2	0	83	17	17
Grassland	3,297	1,625	1	1	49	0	0
Juniper Woodland	74	74	0	0	100	0	0
Oak Woodland	291	274	0	0	94	0	0
Pinyon-Juniper	7,196	6,912	5	4	96	0	0

Restoration Unit 6

Restoration Unit 6 is the smallest of the RUs, and lies immediately south of Grand Canyon National Park. It is the driest of all the RUs, and has had more recent fire than most of the rest of the proposed treatment area. Modeled post-treatment fire behavior shows 4 percent (2,204 acres) would have potential for crown fire, of which <1 percent (106 acres) would be active crown fire. Alternative C would meet fire behavior objectives in RU6.

In RU6, most active crown fire is in the ponderosa pine vegetation type and mostly in three areas. PFA/dPFA/Nest Stand habitat accounts for 97 of the 106 acres of active crown fire (Table 86).

Table 86. Modeled fire type for Restoration Unit 6 under Alternative C, for 2020

RU 6: 43,529 acres			Acres of Vegetation type in RU	Existing Condition		Alternative C 2020	
Vegetation/ Habitat Type		Fire Type		Acres	Percent	Acres	Percent
Ponderosa Pine	All Pine	Surface	41,188	33,675	82	39,438	96
		Passive crown		2,224	5	1,602	4
		Active crown		5,247	13	106	0
	Goshawk PFA/ dPFA/ Nest Stand	Surface	4,050	3,502	86	3,773	93
		Passive crown		111	3	177	4
		Active crown		433	11	97	2
	Landscapes outside PFAs	Surface	37,138	30,173	81	35,665	96
		Passive crown		2,113	6	1,425	4
		Active crown		4,814	13	9	0
Other Vegetation	Grassland	Surface	93	89	96	92	100
		Passive crown		3	3	0	0
		Active crown		1	1	0	0

	Juniper Woodland	Surface	13	10	78	11	84
		Passive crown		3	22	2	16
		Active crown		0	0	0	0
	Oak Woodland	Surface	30	9	29	29	98
		Passive crown		21	69	1	2
		Active crown		1	2	0	0
	Pinyon/ Juniper	Surface	2,206	1,468	67	1,892	86
		Passive crown		511	23	314	14
		Active crown		227	10	0	0

Grasslands in RU4 would meet desired conditions for fire behavior. The addition of mechanical treatments combined with fire removed the potential for any crown fire on 92 acres of grassland in RU6, meeting desired conditions for fire behavior. This means the potential for undesirable fire effects and behavior in grasslands is zero.

Pinyon/Juniper woodland effects would be identical to those in Alternative B. See discussion under on page 150.

Oak woodland effects under Alternative C are identical to those in Alternative B, with 2 acres difference in crown fire. See discussion on page 150.Under Alternative C (Table 87), there would be potential for 7 acres of crown fire, 6 acres of which would be active crown fire.

Subunits

Under Alternative C, desired conditions fire behavior would be met in Subunits 6-2 and 6-3. Subunit 6-2, exceeds desired conditions for fire behavior, but has decreased by over 10 percent from existing conditions and is moving towards desired conditions.

Table 87. Modeled fire type in Restoration Unit 6 subunits by vegetation type for 2020

Vegetation Type by Sub-Unit	Alternative C 2020						
	Total Acres	Surface Fire (acres)	Passive crown (acres)	Active crown (acres)	Surface (percent)	Passive crown (percent)	Active crown (percent)
6-2	**5,551**	**5,377**	**167**	**0**	**97**	**3**	**3**
Ponderosa Pine	5,069	4,897	165	0	97	3	3
Pinyon-Juniper	483	480	2	0	99	0	0
6-3	**34,109**	**33,107**	**866**	**105**	**97**	**3**	**3**
Ponderosa Pine	32,635	31,744	755	104	97	2	3
Grassland	85	85	0	0	100	0	0
Juniper Woodland	13	11	2	0	84	16	16
Pinyon-Juniper	1,375	1,267	108	0	92	8	8
6-4	**3,870**	**2,979**	**886**	**1**	**77**	**23**	**23**

Ponderosa Pine	3,484	2,798	682	1	80	20	20
Grassland	7	7	0	0	100	0	0
Oak Woodland	30	29	1	0	98	2	2
Pinyon-Juniper	348	145	203	0	42	58	58

Surface fuels and canopy characteristics affecting fire behavior and effects

Canopy characteristics and surface fuel loading are discussed in this section by desired openness. As described on page 9, desired openness is an indication of the relative desired post treatment interspace/tree group condition.

Relationships between surface fuels and canopy characteristics affecting fire behavior and effects are discussed on page 155. Regarding fire effects, surface fuel loading can produce desirable or undesirable effects, depending on the initial loading and the conditions under which it burns (see page 71 for more details).

Canopy characteristics affecting fire behavior

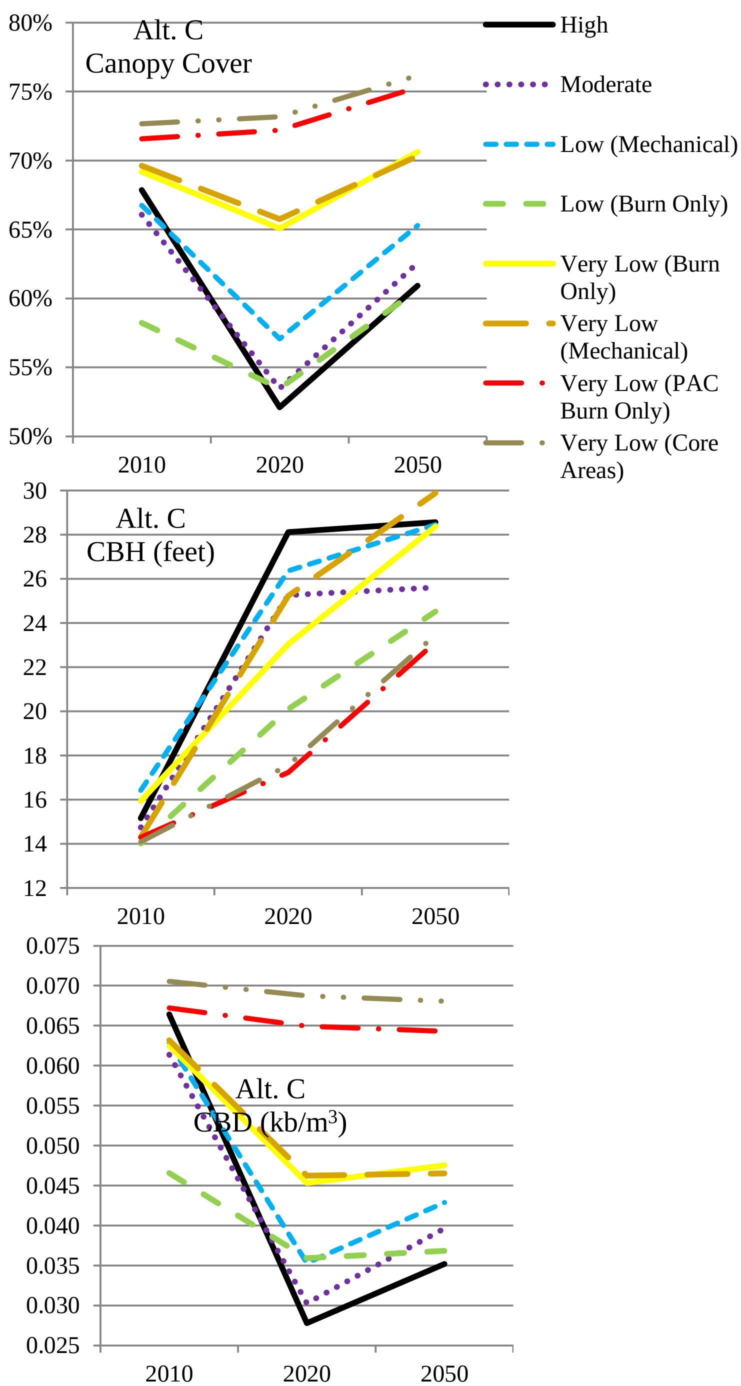
Changes to Canopy Cover (CC), Canopy Base Height (CBH), and Canopy Bulk Density (CBD) are direct effects, though they are not always apparent in the fire behavior data (indirect effects). Post-treatment conditions (2020), under alternative C show changes in canopy cover significant enough that the treatment area would meet desired conditions (Table 88). Desired conditions for canopy base height (CBH) are 18 feet or higher; desired conditions for canopy bulk density (CBD) are for 0.05 or less. Alternative C would meet desired conditions for CBH and CBD.

Table 88. Modeled changes in canopy characteristics for Alternative C

Desired Openness	CBH (feet)			CBD (kg/m3)			CC (%)			Percent of ponderosa pine
	2010	2020	2050	2010	2020	2050	2010	2020	2050	
High	15.16	28.11	28.56	0.066	0.028	0.035	68	52	61	34
Moderate	14. 74	25.26	25.61	0.061	0.030	0.040	66	53	63	27
Low (Mechanical)	16.42	26.36	28.44	0.063	0.035	0.043	67	57	65	7
Low (Burn Only)	14.01	20.10	24.52	0.047	0.036	0.037	58	53	61	21
Very Low (Burn Only)	15.95	23.04	28.37	0.062	0.045	0.048	69	65	71	4
Very Low (Mechanical)	14.30	25.23	29.87	0.063	0.046	0.047	70	66	70	2
Very Low (PAC Burn Only)	14.29	17.23	23.12	0.067	0.065	0.064	72	72	75	4
Very Low (Core Areas)	14.09	17.57	23.46	0.071	0.069	0.068	73	73	76	1
Weighted	**14.86**	**24.71**	**26.65**	**0.61**	**0.34**	**0.40**	**66**	**55**	**63**	

Average[10]										

Table 88 shows a decrease in CBD and an increase in CBH as a direct effect of treatments. This decreases the potential for crown fire initiation (because CBH is higher), less potential for passive crown fire (because of higher CBH and lower CBD), and less potential for active crown fire (lower CC and lower CBD, (Figure 52). Under Alternative C, desired conditions would be met for CBH and CBD. Very Low (PAC Burn Only) and Very Low (Core Areas) do not have desired conditions for canopy characteristics related to fire behavior, but it is worth noting that neither of them would have met desired conditions.



—**Figure 55. Changes in canopy characteristics for Alt. C.**

Figure 55 shows trends for all levels of desired openness. Assumptions are that prescribed fire and mechanical treatments occurred between 2010 and 2020 and no treatments of any kind occurred between 2020 and 2050. In the two least intense treatment types, the initial values (2010) start at the highest (for CBD and CC) and the lowest (CBH). Post-treatment, for those two treatments the increase in canopy cover (CC) from 2010 to 2020 combined with only modest decreases in CBD suggest that conditional Crown fire is still likely in those treatment areas.

Surface fuels: Litter, Duff, and Coarse Woody Debris greater than 3" diameter

Changes to surface fuel loading are direct effects of

[10] Weighted averages for desired openness are based on the number of acres of ponderosa pine proposed for treatment under each alterantive.

proposed treatments, that have indirect effects on fire behavior and effects.

General effects for Alternative C are the same as Alternative B, (see discussion on page 153). Under Alternative C, Forest Plan guidelines for CWD (5 – 7 tons/acre) are met for Very Low (Burn Only), Very Low (PAC Burn Only), and Very Low (Core Areas) in 2020, for a total of approximately 41,000 acres, or 9 percent of the ponderosa pine. For approximately 410,000 acres CWD values range from 2.46 to 2.96, too low to meet desired conditions. Alternative C would leave the treatment area deficit in CWD in some areas although, modeling for this project and research (Waltz et al. 2003) suggest that it would be just a year or two before CWD levels once again met desired conditions (Figure 55). Assumptions include mechanical treatments and prescribed burning occurred between 2010 and 2020 and that no treatments of any kind took place between 2020 and 2050. Assumptions for Table 89 include one mechanical treatment and two prescribed fires between 2010 and 2020, and no addition treatments of any kind – mechanical, wildfire, or prescribed fire – between 2020 and 2050. Shaded cells indicate a condition that does not meet forest plan guidelines of 5-7 tons/acre for CWD.

Historical values were around 5 tons per acre on the high end for CWD, and less than 2.5 tons/acre for duff (Brown et al 2003) so, assuming ~2.5 for litter, all levels of desired openness except the lowest two would be within the historical range of surface fuel loading in 2020, and would exceed it by 2050.

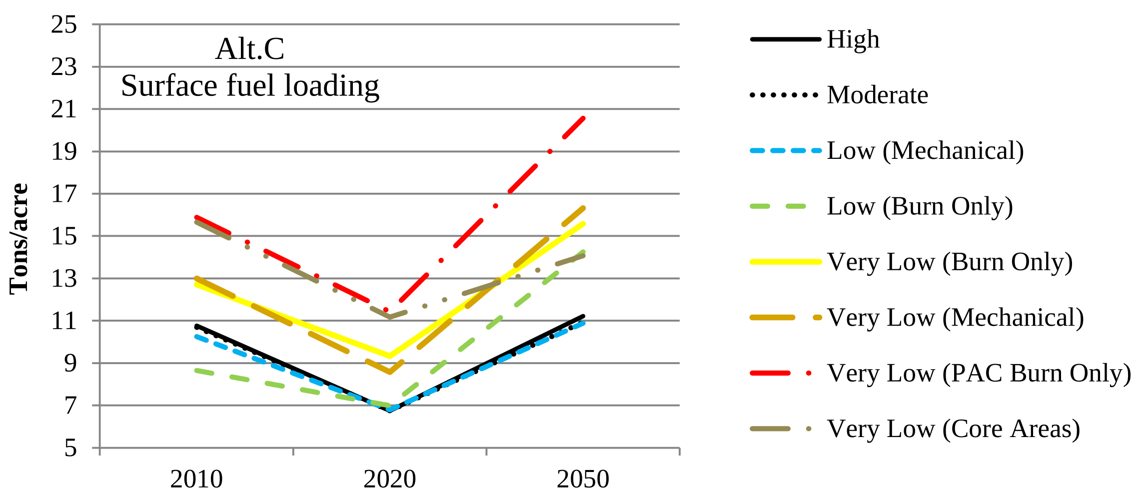


Figure 56. Modeled changes to surface fuel loading (duff + litter + CWD>3")

Except for Very Low (Core Areas), total surface fuel loading exceeds pre-treatment levels by 2050, illustrating the role of fire in regulating surface fuel loading. CWD>3" and Duff both increase from 2010 to 2050, litter decreases. By 2050, all levels of desired openness exceed forest guidelines for CWD>3".

Table 89. Modeled changes to surface fuel loading under Alternative C

Desired openness	CWD>3"			Litter			Duff			CWD>3" + Litter + Duff			Percent of ponderosa pine
	2010	2020	2050	2010	2020	2050	2010	2020	2050	2010	2020	2050	

High	3.91	2.96	5.13	3.48	1.44	2.75	3.38	2.34	2.69	10.76	6.74	10.57	34
Moderate	3.65	2.81	5.24	3.91	1.75	3.41	3.13	2.19	2.63	10.69	6.75	11.28	27
Low (Mechanical)	3.75	2.82	5.57	3.20	1.68	3.06	3.30	2.29	2.69	10.25	6.79	11.33	7
Low (Burn Only)	3.21	2.84	6.29	2.52	1.59	2.62	2.92	2.56	2.91	8.65	6.99	11.82	21
Very Low (Burn Only)	4.71	3.24	7.13	4.43	2.53	5.05	3.58	3.55	4.20	12.71	9.32	16.37	4
Very Low (Mechanical)	4.61	2.46	5.62	4.44	2.00	4.26	3.96	4.11	4.60	13.00	8.57	14.48	2
Very Low (PAC Burn Only)	5.99	3.18	8.36	4.80	2.96	6.10	5.09	5.28	6.03	15.88	11.42	20.49	4
Very Low (Core Areas)	5.85	3.15	8.28	4.98	3.01	6.17	4.83	5.02	5.79	15.66	11.18	20.24	1
Weighted Average[11]	**4.46**	**2.93**	**6.45**	**3.97**	**2.12**	**3.22**	**3.77**	**3.42**	**3.94**	10.7	7.2	11.9	

With duff, litter, and canopy fuels decreased, more sunlight and precipitation would reach the surface, stimulating more vigorous growth of surface vegetation, which would support the low intensity, low severity surface fires to which ponderosa pine is well adapted.

Figure 57 shows the distribution of fuel loading post-treatment (2020), Across most of the treatment area, fuel loading has decreased below 20 tons/acre. There are a few areas that exceed 20, 25, 30, and 35 tons per acre, mostly in RU3 in PACs, a few areas in RU4 and two areas in RU5. Under Alternative C, there would be approximately 809 acres with surface fuel loading greater than 20 tons/acre, and 813 acres in the 15 – 20 tons/acre range. By 2040, there would be 4,120 acres exceeding 20 tons/acre, and 58,217 acres in the 15 – 20 tons/acre range.

[11] Weighted averages for desired openness are based on the number of acres of ponderosa pine proposed for treatment under each alterantive.

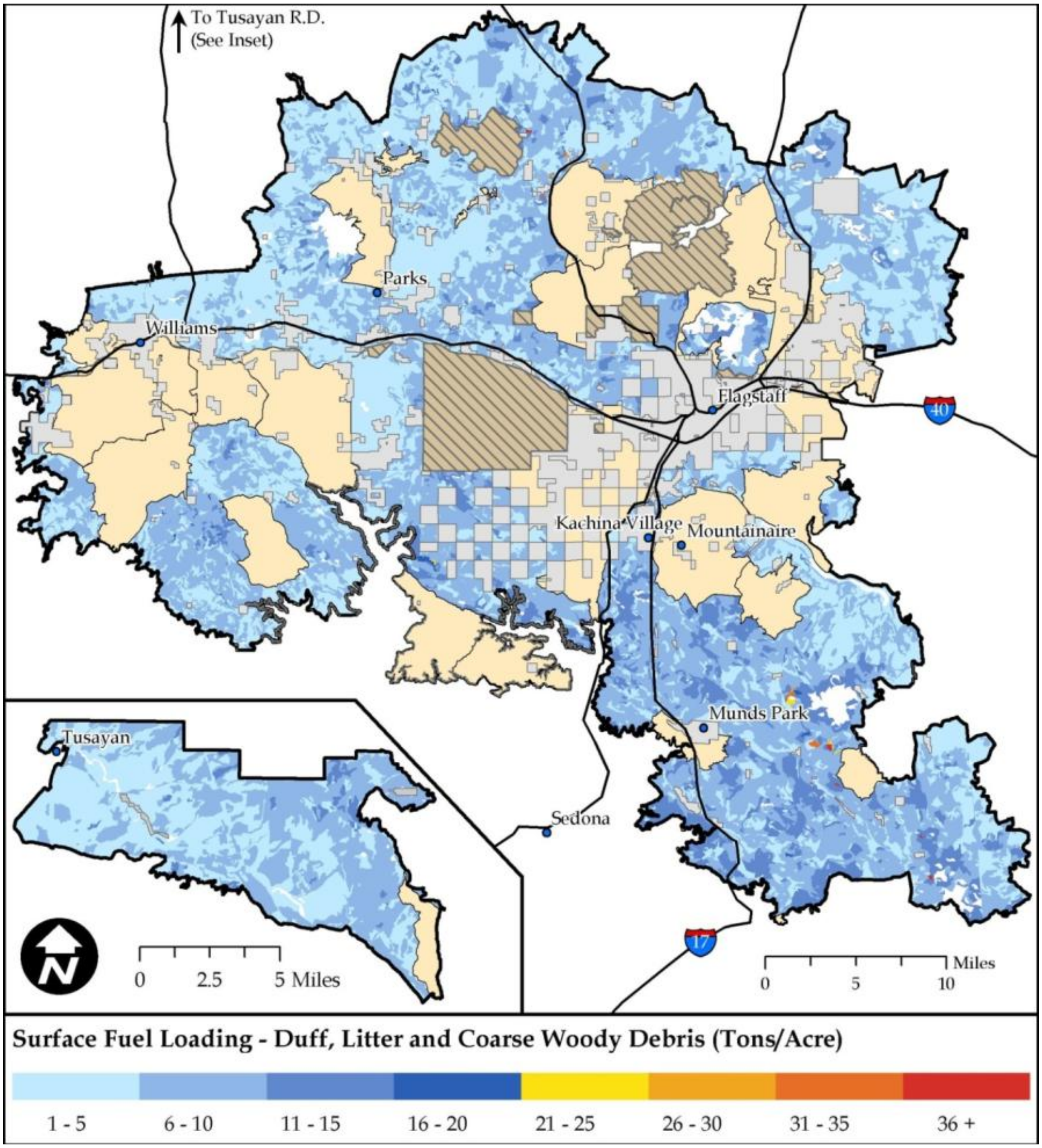


Figure 57. Modeled fuel loading for Alternative C (duff+litter+CWD>3")

Fire Regime/Condition Class

Under Alternative C, Fire Regime/Condition Class (FRCC) would move toward the desired condition of Condition Class 1. Changes in grasslands are more subtle and, with the exception of woody encroachment, not as obvious because the matrix species dominance (grasses, as opposed to forbs) shifts more slowly than pine. Grassland treatments in Alternative C include both mechanical treatments and thinning treatments, moving 3,927 acres (7 percent) of grassland acres out of FRCC3, leaving only 3 percent, and moving 7,293 (13 percent) into FRCC1. Treatments proposed under Alternative C (Table 90) would shift 297,866 acres (59 percent) of the ponderosa pine from FRCC3 to FRCC2, and increase acres of FRCC1 by over 25,000 acres.

Table 90. Fire Regime/Condition Class for Alternative C

Alternative C		2010		2020		2050	
		Acres	Percent	Acres	Percent	Acres	Percent
Ponderosa Pine	FRCC1	70,680	14	95,923	19	80,777	16
	FRCC2	136,311	27	408,934	81	257,477	51
	FRCC3	297,866	59	0	0	166,603	33
Grasslands	FRCC1	10,097	18	17,390	31	19,633	35
	FRCC2	40,389	72	37,023	66	33,657	60
	FRCC3	5,610	10	1,683	3	2,805	5

Fire Return Interval

The effects of Alternative C (Table 91) are identical to those of Alternative B, except that there are no areas that would not move towards a sustainable, resilient fire regime. See discussion on page 162.

As with Alternative B, this should be interpreted with caution, however, because it is the long term cycle of fire return intervals that regulates a system. Two prescribed fires would set the treatment area on a trajectory towards a restored condition, but maintenance fires would continue to be needed to avoid the ecosystem slipping back to an unsustainable condition.

Table 91. Average Fire Return Intervals for Alternative C

Alternative C	# of years averaged	Average annual acres burned	Fire Return Interval over years averaged
Current 10 year average	10 (2001 -2010)	15,000 (2001 -2010)	40
2020	20 (2001- 2020)	59,321 (2001- 2020)	10
2050	40 (2001- 2050)	29,661 (2001- 2050)	20

Air Quality

This alternative would meet the purpose and need, and desired conditions for Air Quality. The effects (indirect) would be almost identical to those in Alternative B, with the exceptions being the additional acres of MSO habitat and grasslands proposed for burning. Most acres in PACs and nest cores would be first entry burns, but all the surface fuel load would not be burned in one entry, so the smoke would be dispersed over time. See discussion on page 159.

Under this alternative, an average of 59,321 acres would need to burn every year, either from wildfire or prescribed fire with a total of 593,211 acres proposed for burning. This alternative differs from Alternative B by treating the PACs with prescribed fire. While this would initially produce a greater volume of smoke, in the long run, it would minimize wildfire emissions and effects, and allow prescribed fire to be used in the future with lower emissions.

Ecological effects of smoke

The ecological effects of smoke would be identical to those under Alternative B, except that they would extend to those 5,288 acres that were not proposed for burning under Alternative B and are under Alternative C, mostly PACs and nest areas.

Stream/spring restoration

Effects on stream/spring restoration would be identical to those in Alternative B. See discussion on page 161.

Roads

Road effects would be identical to those in Alternative B. See discussion on page 161.

Unavoidable Adverse Effects, Irreversible and Irretrievable Commitment of Resources

Unavoidable Adverse Effects, Irreversible and Irretrievable Commitment of Resources would be identical to those in Alternative B. See discussion on page161.

Alternative D

From a fire ecology perspective, the direct and indirect effects of Alternatives D relate to treatments that include either mechanical thinning or prescribed fire, but only one or the other will occur on any one acre. This alternative was developed to address concerns of the effects of emissions from prescribed fires. Alternative D proposes to implement approximately 567,279 acres of restoration activities within the 988,764 acre project area. These treatments include:

- Mechanically cut trees on approximately 388,489 acres. This includes: (1) mechanically treating up to 16-inch dbh within 18 Mexican spotted owl protected activity centers, (2) cutting 99 acres of trees by hand on slopes greater than 40 percent, and, (3) disposing of slash through various methods including chipping, shredding, mastication and removal of biomass off-site
- Utilize prescribed fire-only on approximately 178,790 acres. Up to 40,000 acres of prescribed fire would be implemented annually across the forests and two prescribed fires would occur over the 10-year treatment period. This includes acres available for 'Operational Burn' only. These areas consist of grasslands, Pinyon/Juniper (PJ), oak woodland that are situated within, or adjacent to areas proposed for prescribed fire such that logistics indicate they be included in the burn unit. Two prescribed fires would be implemented over the 10 year period.
- Construct 517 miles of temporary roads for haul access and decommission when treatments are complete (no new permanent roads would be constructed)
- Reconstruct up to 40 miles of existing, open roads for resource and safety concerns (no new permanent roads would be constructed). Of these miles, approximately 30 miles would be improved to allow for haul (primarily widening corners to improve turn radiuses) and about 10 miles of road would be relocated out of stream bottoms. Relocated roads would include rehabilitation of the moved road segment.
- Decommission 770 miles of existing system and unauthorized roads on the Coconino NF
- Decommission 134 miles of unauthorized roads on the Kaibab NF

- Restore 74 springs and construct up to 4 miles of protective fencing
- Restore 39 miles of ephemeral channels
- Construct up to 82 miles of protective (aspen) fencing
- Allocate as old growth 40 percent of ponderosa pine and 77 percent of pinyon-juniper woodland on the Coconino NF, and 35 percent of ponderosa pine and 58 percent of pinyon-juniper on the Kaibab NF

Three non-significant forest plan amendments would be required on the Coconino NF to implement alternative D:

- Amendment 1 would: (1) allow the use of mechanical treatments to improve habitat structure, (2) allow for mechanical treatment up to 16-inch dbh within 18 MSO PACs to improve nesting and roosting habitat and (3) would defer all Mexican spotted owl monitoring to the project's Biological Opinion issued by the US Fish and Wildlife Service.
- Amendment 2 would: 1) add the desired percentage of interspace within uneven-aged stands to facilitate restoration and defines interspace, (2) add the interspace distance between tree groups, (3) add language clarifying where canopy cover is and is not measured, (4) allows 29,017 acres to be managed for an open reference condition (figure 47), which affects canopy cover guidelines for VSS 4 through VSS 6 groups and reserve trees, and (5) add a definition to the forest plan glossary for the terms interspaces, open reference condition, and stands.
- Amendment 3 would allow for managing to achieve a "No Adverse Effect" determination for significant, or potentially significant, inventoried heritage sites.

Two non-significant forest plan amendment would be required on the Kaibab NF to implement the proposed action:

- Amendment 1 would: 1) add the desired percentage of interspace within uneven-aged stands to facilitate restoration and defines interspace, (2) add the interspace distance between tree groups, (3) add language clarifying where canopy cover is and is not measured, (4) allows 27,637 acres to be managed for an open reference condition (figure 47), which affects canopy cover guidelines for VSS 4 through VSS 6 groups and reserve trees, and (5) add a definition to the forest plan glossary for the terms interspaces, open reference condition, and stands.
- Amendment 2 would defer all Mexican spotted owl monitoring to the project's Biological Opinion issued by the US Fish and Wildlife Service.

Alternative D proposes to use a combination of mechanical only treatments and prescribed fire only treatments to meet the purpose and need of the 4FRI and move the treatment area for Alternative D (567,279 acres) toward the desired condition. There would be no acres on which both mechanical and prescribed fire treatments would be implemented.

Operationally, it would be difficult implement fire on all of the 178,753 acres for which it is proposed because of the necessity to lay out burn units in an operationally sound manner. Implementing fire across all the acres proposed for burning would require firelines to be built around burn units that would either necessitate burning acres not analyzed in Alternative D for burning, or blocking additional acres out of burning that are proposed for burning under

Alternative D.

This alternative would meet direction in the Forest Service Manual 5100 (page 9) on USFS use of prescribed fire to meet land and resource management goals and objectives. See Alternative B, pg. 131 for details on Forest Service Manual direction.

Direct and Indirect Effects

Changes to potential fire behavior are the indirect effects of changes to fuel loading and structure. The effects of implementing Alternative D are discussed in the following order.

1. Fire behavior is discussed at the treatment area scale
2. Potential fire behavior is discussed by vegetation type
3. Within Restoration Units and Subunits, fire behavior is broken out by vegetation/habitat types
4. Canopy characteristics and fuel loading and how they affect fire behavior, fire effects and air quality are presented by desired openness

Amendment 1 (Coconino NF): If amendment 1 is implemented, the resulting decreases in CBH, CBD, and CC would have the indirect effect of slightly decreasing crown fire potential for the 18 MSO PACs that would receive mechanical treatments. If amendment 1 is not implemented on the Coconino NF, these 18 PACs would retain the current forest structure that places them at high risk of high severity fire. If prescribed fires was the proposed treatment on acres adjacent to PACs, it is more likely that some firelines would need to be created to avoid burning, producing ground disturbance that would be less likely under the proposed amendment. There would be little effect on emissions, except for a slight decrease in potential emissions in the event of wildfire following mechanical treatments within the PACs.

Amendment 2 (Coconino NF): If amendment 2 is implemented, it would allow 29,054 acres to be managed for an open reference condition. An indirect effect of managing for open conditions would be to have little potential for active crown fire, moving these acres towards the desired conditions. Open conditions would, in the long run, produce fewer emissions because of less litter and debris from trees, and greater herbaceous component to surface fuels, which is a flashier fuel, burning faster and more cleanly quickly than woody fuels. If amendment 2 is not implemented on the Coconino NF, some treatments could be implemented, but would not move these acres as far towards desired conditions as they would be under the amendment.

Amendment 3 (Coconino NF): If amendment 3 is implemented, it would allow fire to be used to meet objectives if it was determined to be the best tool. Additionally, it would allow all significant, or potentially significant inventoried sites that are not considered ‘fire sensitive’ to be included in burn units. If amendment 3 is not implemented, all significant, or potentially significant inventoried sites within burn units, regardless of if they are considered ‘fire sensitive’ or not, would be managed for ‘no effect’.

Amendment 1 (Kaibab NF): If amendment 1 is implemented, the same effects that are described above (Amendment 2 for the Coconino) would apply to the 27,765 acres to be managed for an open reference condition.

Amendment 2 (Kaibab NF): If amendment 3 is implemented, the effects would be minimal, because the Biological Opinion from the US Fish and Wildlife Service is expected to differ only minimally from current direction.

Eliminating prescribed fire on 388,526 acres would eliminate many of the ecological role/s of fire that are necessary and beneficial to healthy forests and watersheds in the 4FRI treatment area. Potential for crown fire would decrease on those acres, and the potential for high severity surface effects would increase or stay the same. Fires that did occur in on the 388,526 acres would be wildfires.

In the short term (<20 years), across the treatment area the potential for undesirable fire behavior and effects would be reduced (indirect effects of proposed treatments) by breaking up the vertical and horizontal canopy fuels (direct effects of proposed treatments). In mechanically treated areas, potential for high severity surface fires would remain the same or increase. In burn only areas, canopy base heights would increase and canopy bulk densities would decrease, decreasing the potential for crown fire, and surface fuel loads of litter and duff would be reduced (all direct effects), and replaced by the light, flashy fuels that would be stimulated by post-treatment conditions (indirect effects), decreasing the potential for high severity surface fire effects (indirect effects). Air quality impacts (indirect effects) could increase some as first and second entry prescribed fires are implemented.

In the long term (>20 years), potential for undesirable fire behavior, as assessed by changes to canopy fuels, would lower than existing condition for approximately 35 percent of the ponderosa pine in the treatment area. Potential for undesirable fire effects, as assessed by changes to canopy fuels and surface fuel loading, would not remain lower than existing condition for any of the ponderosa pine in the treatment area. Air quality impacts (indirect effects) would decrease as the acres are moved in to maintenance mode and fewer emissions per acre are produced by fire.

When analyzed at the scale of the treatment area, Alternative D would move the treatment area towards the desired condition of having potential for less than 10 percent crown fire as modeled under the conditions that produced the Schultz Fire (Table 92). Non-burnable substrates constitute ~2 percent of the treatment area and was not included in the acres shown fire potential fire behavior.

Table 92. Modeled fire type for Alternative D

Fire Type	2010 (percent)	2020 (percent)
Surface fire	64	92
Passive crown fire	9	4
Active crown fire	25	3

A direct effect of treatments proposed under Alternative D is breaking up the horizontal and vertical continuity of canopy fuels are broken up. The indirect effect of this is to decrease the potential for crown fire from 34 percent of the treatment area to 7 percent of the treatment area, with potential for active crown fire decreasing from 25 percent to 3 percent. Non-burnable substrates constitute ~2 percent of the treatment area and was not included in the acres shown fire potential fire behavior. The amount of potential crown fire remaining after proposed treatments would be within the historic ranges of ponderosa pine in this area. As illustrated in Figure 58, post-treatment active crown fire is scattered across all treatment areas, with the most in

Restoration Unit 1 and, in most cases, would occur in MSO and goshawk habitat (Figure 58).

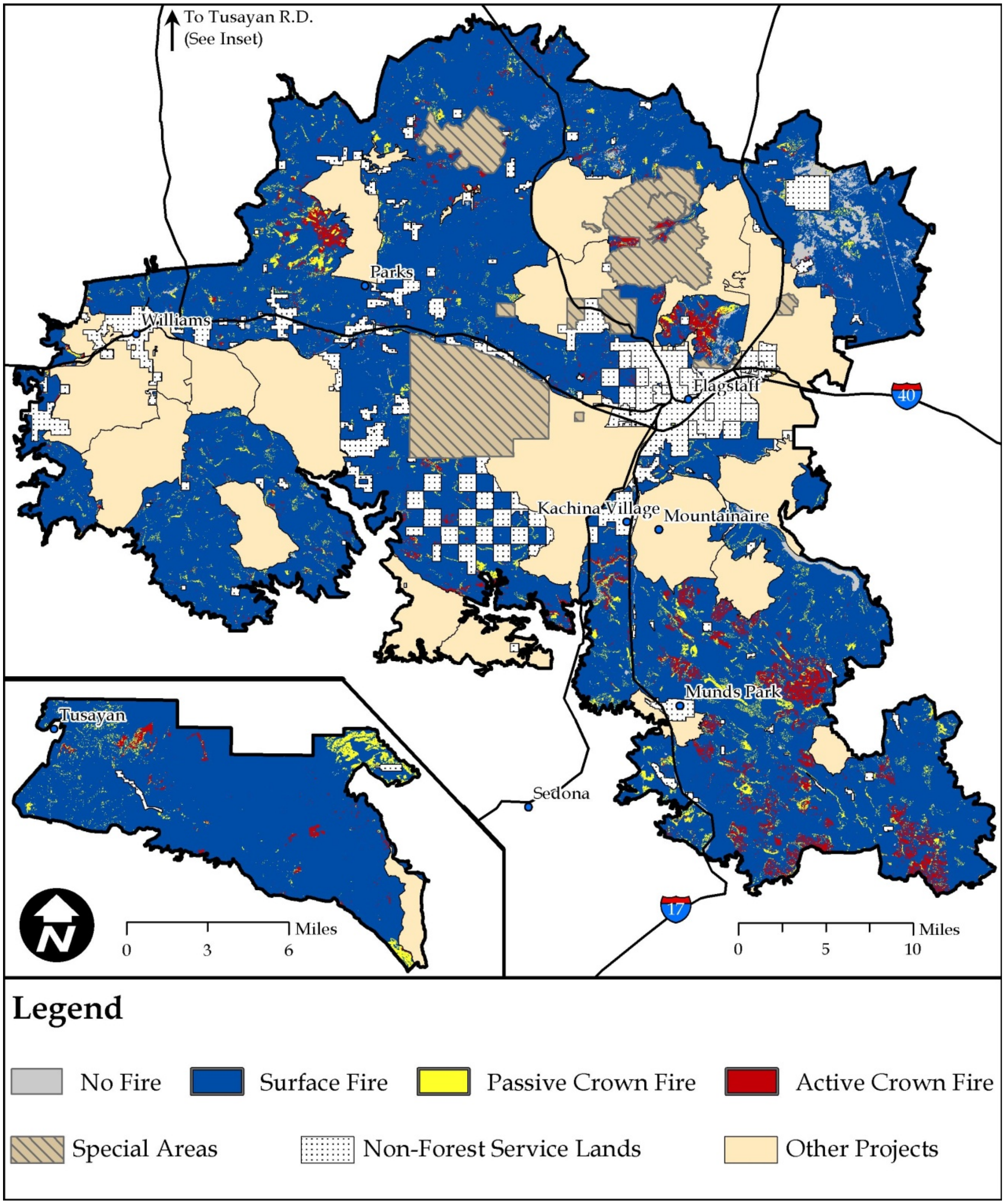


Figure 58. Modeled fire type for Alternative D, 2020

Ponderosa Pine

At the treatment area scale, when considered by vegetation and habitat type, ponderosa pine would meet desired conditions under Alternative D of having potential for crown fire on less than 10 percent of the treatment area (Table 93). When ponderosa pine is broken out by habitat type, there are 16,162 acres that would support crown fire, of which 12,377 acres would be active crown fire. Protected habitat accounts for 70 percent of the active crown fire in ponderosa pine across the treatment area, and 32 percent of all protected habitat. Landscapes outside of PFAs account for an additional 20 percent of all active crown fire in ponderosa pine.

The direct effects of proposed treatments would decrease the horizontal and vertical continuity of canopy fuels with mechanical treatments, allowing sunlight to reach the surface, increasing surface temperatures, and decreasing dead fuel moisture content at the surface. This, combined with increased surface winds with fewer trees blocking the wind, could increase surface fire intensity, flame length, and rate of spread even if surface fuels were the same before and after canopy treatment (Omi and Martinson 2004; Scott, 2003). Therefore, canopy fuel treatments reduce the potential for crown fire at the expense of slightly increased surface fire behavior (fireline intensity, flame length, and rate of spread). However, critical levels of fire behavior (limits of manual or mechanical control) are less likely to be reached in stands treated to withstand crown fires. Although surface intensity may be increased after treatment, a fire that remains on the surface beneath a timber stand is generally more controllable (Scott 2003).

Table 93. Modeled fire type for Alternative D by ponderosa pine habitat type

<table>
<tr><th colspan="2" rowspan="2">Vegetation Type</th><th rowspan="2">Fire Type</th><th colspan="2">Existing Conditions</th><th colspan="2">Alt. D 2020</th></tr>
<tr><th>acres</th><th>percent</th><th>acres</th><th>percent</th></tr>
<tr><td rowspan="18">Ponderosa Pine</td><td rowspan="3">All Pine</td><td>Surface</td><td>313,423</td><td>62</td><td>472,220</td><td>93</td></tr>
<tr><td>Passive crown</td><td>48,523</td><td>10</td><td>17,874</td><td>4</td></tr>
<tr><td>Active crown</td><td>145,113</td><td>29</td><td>16,964</td><td>3</td></tr>
<tr><td rowspan="3">MSO Protected</td><td>Surface</td><td>18,610</td><td>51</td><td>21,399</td><td>58</td></tr>
<tr><td>Passive crown</td><td>3,141</td><td>9</td><td>3,366</td><td>9</td></tr>
<tr><td>Active crown</td><td>14,847</td><td>41</td><td>11,832</td><td>32</td></tr>
<tr><td rowspan="3">MSO Target/ Threshold</td><td>Surface</td><td>4,292</td><td>49</td><td>7,734</td><td>89</td></tr>
<tr><td>Passive crown</td><td>926</td><td>11</td><td>419</td><td>5</td></tr>
<tr><td>Active crown</td><td>3,479</td><td>40</td><td>545</td><td>6</td></tr>
<tr><td rowspan="3">MSO Restricted</td><td>Surface</td><td>35,465</td><td>53</td><td>63,075</td><td>94</td></tr>
<tr><td>Passive crown</td><td>6,608</td><td>10</td><td>3,778</td><td>6</td></tr>
<tr><td>Active crown</td><td>25,187</td><td>37</td><td>407</td><td>1</td></tr>
<tr><td rowspan="3">Goshawk PFA/ dPFA/ Nest Stand</td><td>Surface</td><td>18,737</td><td>62</td><td>28,517</td><td>94</td></tr>
<tr><td>Passive crown</td><td>2,952</td><td>10</td><td>1,238</td><td>4</td></tr>
<tr><td>Active crown</td><td>8,756</td><td>29</td><td>691</td><td>2</td></tr>
<tr><td rowspan="3">Landscapes outside PFAs</td><td>Surface</td><td>236,320</td><td>65</td><td>351,496</td><td>97</td></tr>
<tr><td>Passive crown</td><td>34,896</td><td>10</td><td>9,074</td><td>2</td></tr>
<tr><td>Active crown</td><td>92,844</td><td>26</td><td>3,490</td><td>1</td></tr>
</table>

Mechanical treatments can take the forest a long way towards restoration, removing most of the potential for active crown fire, but ponderosa pine forest structure cannot be restored without fire (Figure 59).

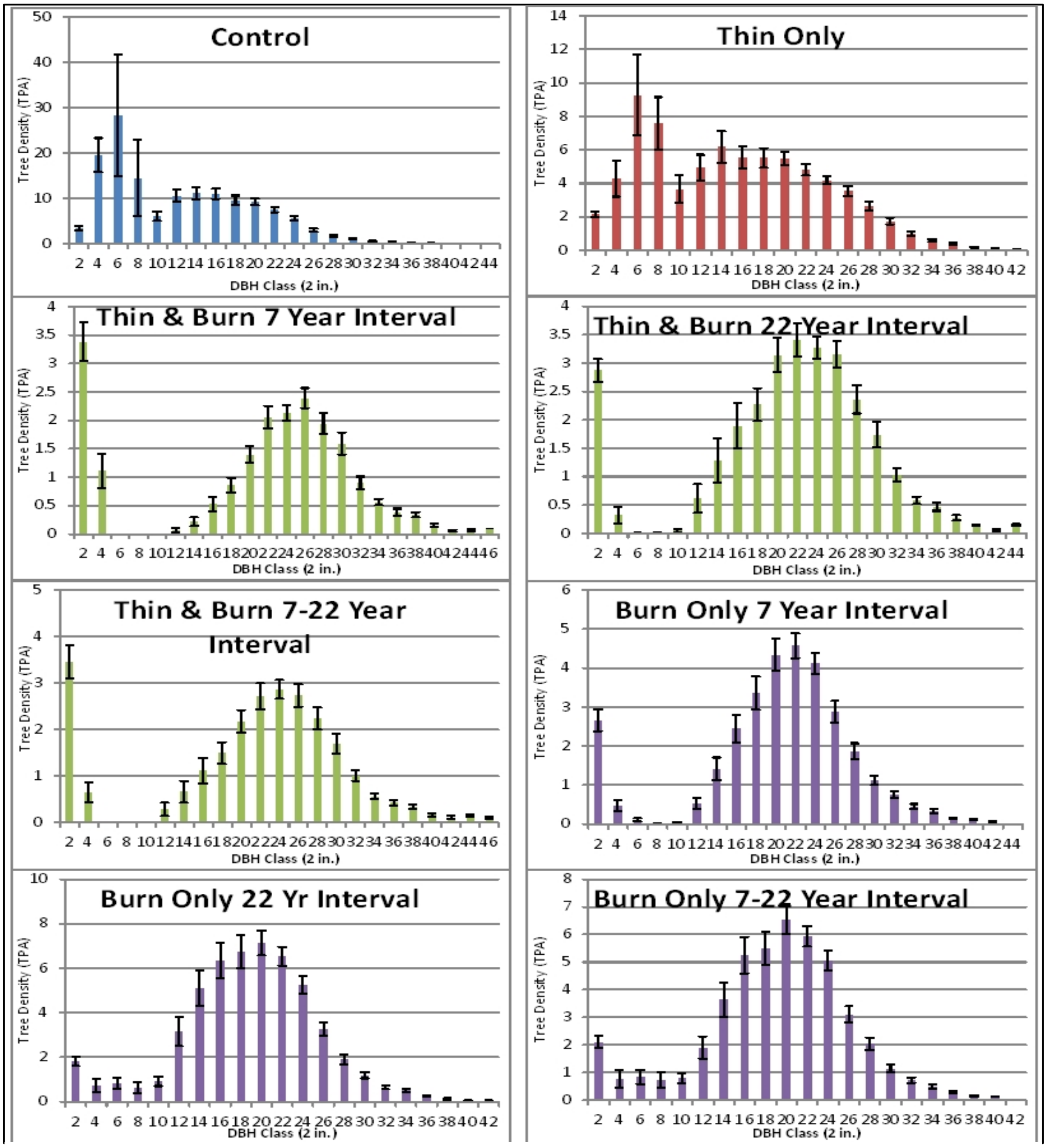


Figure 59. Tree distributions by diameter and trees per acre as modeled with different treatments all include prescribed fire at various intervals (Hall et al. 2011).

For the most part, accumulations of litter, duff, existing dead/down woody debris, and seedlings and small saplings are not addressed by mechanical thinning. In areas where trees are skidded, yarded and/or the surface is disturbed, surface fuels may be moved around, and may even provide temporary firelines if disturbed to the mineral soil, but litter, duff, seedlings or dead/down wood are not removed by thinning operations. Some saplings may be removed, depending on the particulars of the thinning prescription. Thinning adds varying amounts of woody fuels that break off branches and twigs that are left on site from thinning operations (Fulé et al. 2012), even if most of the thinned material is removed from the site, which could increase surface fire intensity. Species that require the smoke or the heat of a fire to germinate or thrive (Abella et al. 2007, Huffman and Moore 2008, Keeley and Fotheringham 2000, Abella 2006, Abella 2009, Keeley and Fotheringham 2002, Schwilk and Zavala 2012) would decline (indirect effect). For those species, in the long run, their survival would depend on the chance of a wildfire burning in those areas at the appropriate time, intensity and frequency (Auld and O'Connell 1991). Another indirect effect of implementing alternative D would be the decline of natural fire patterns, including the groupy/clumpy arrangements that are natural to the ponderosa pine ecosystems in the treatment area because, although mechanical treatments can reset much of the forest structure, they would not address the smallest size classes or surface fuels. In Figure 59 the top two images are no treatment and mechanical treatment-only.

Litter and duff would continue to build up, locking up nutrients, changing soil chemistry, and physically suppressing surface vegetation, decreasing productivity at the surface as well as decreasing species diversity (Moir 1988, Abella et al. 2007, Laughlin et al. 2011). Natural patterns of surface vegetation would continue to deteriorate, as patterns of shrubs and other species adapted to frequent fire continued to shift in response to decreased fire frequencies (Huffman and Moore 2008, Moir 1988).

Pine/Sage

Thinning the pine/sage community in RU6 would allow the sage to expand, which would generally be beneficial to the system. Although little is documented about the dynamics of the system, sage appears to have the capacity to outcompete most other surface vegetation in some places as can be seen in Figure 13 on page 41). Without fire to maintain a shifting mosaic at the surface, it is likely that the woody species (sage and other shrubs) would expand to dominate the surface vegetation until wildfire burned though the area. High severity fire is likely to be lethal to the majority of the sage.

Large/old trees

Throughout the life of this project, direct and indirect effects are likely to result in some large and/or old trees would be damaged or killed by prescribed fire. In this alternative, in areas where prescribed fire would be implemented there would be decreased mortality of old and/or large trees. Over 128,669 acres, prescribed fire would decrease potential fire behavior in the vicinity of old and/or large trees, decreasing the likelihood of lethal damage in the event of a wildfire. Recent research indicates that scorch is one of the primary factors in large and old tree mortality (Jerman et al. 2004), and is influenced by the vertical arrangement of fuels. Old trees, which are more susceptible to dying from fire than younger trees, would have ladder fuels in the immediate vicinity removed before burning whenever possible. Mitigation for trees of particular significance, such as wildlife trees, occupied nest sites, etc., would be completed prior to burning. Ignition techniques or other mitigations would be employed to minimize residence time in deep litter or duff adjacent to old trees whenever possible. Under this alternative, low severity fire would be used in the vicinity of old trees and, to the degree it is practicable, ladder fuels and excessive surface fuel buildups adjacent to old trees would be removed before burning.

Mitigation measures (page 222) are unpredictable, and site specific (Kolb et al. 2007), and some can have negative effects of their own. Raking, for example, can remove fine, live roots in the surface organic layers, which may compound the effects of additional shallow roots being damaged by fire, though it is unlikely to actually kill the tree. Low intensity fire that causes little crown scorch can stimulate resin production in old trees, but may attract bark beetles, increasing tree mortality.

Under Alternative D, 388,526 acres of forested areas would have mechanical treatments. In these areas, potential for active crown fire, and the high severity effects associated with crown fire, would be decreased and would meet desired conditions. When wildfire burned though these acres, surface fuels would have increased (Fulé et al.2012), increasing the surface fie intensity in these areas. Litter and duff cones that accumulate around the base of old and/or large trees can be lethal to large and/or old trees if they burn under wildfire conditions (Egan 2011). These fuels cannot be effectively treated by mechanical methods across the ~600,000 acres proposed for treatment. Old and/or large trees could not be ‘prepped’ for wildfire as they would be for prescribed fire. Across 20 – 45 percent of the area burned with wildfire would be expected to burn with high severity, killing most trees in the area. Based on the current average, and assuming no increase in average annual acres burned with wildfires, by 2020, approximately 64,000 – 144,000 acres within the treatment area could have burned with high severity.

Aspen

Aspen thrives on disturbance, so the 1,229 acres that would receive mechanical treatment would improve as encroaching conifers are removed. The soil disturbance would be likely to stimulate some suckering as well (an indirect effect). It would not be as vigorous as it would if the disturbance was fire, but it would move these acres towards a healthier condition that is more resilient to disturbances such as fire, disease, insects, and drought. There would be no increase in soil temperature or nutrient flush to speed up the growth rate of new sprouts, an adaptation to fire which would help them compete with other surface vegetation that would also increase following treatment.

Those acres that would receive prescribed fire treatments (32 acres) would be expected to sucker vigorously in response to low severity prescribed fire. Dead/down/decadent stems and wood would be partially consumed, and/or topkilled, stimulating vigorous suckering from roots no longer trying to reinvigorate large, decadent stems.

Ungulate grazing would be expected to have an impact on new suckers, so where possible, deterrents would be used. If it was a healthy aspen stand, it is likely to respond by suckering.

Gambel Oak

Gambel oak would benefit from the thinning of ponderosa pine overtopping it. Post-treatment fire modeling shows potential for 2 percent of oak woodland to have crown fire, only 1 percent of which would be active crown fire. Across oak woodland, and pine/oak vegetation, in areas that are thinned but not burned, there would be greater potential for mortality of large and small stems when wildfire did burn across the area because of increased surface fuel loading. Wildfire would be likely to topkill most of the oak, decreasing small stems for a couple of years until suckers matured. At all scales of analysis, desired conditions would be met for fire behavior in oak woodlands (<10 percent crown fire).

Where Gambel oak was treated with prescribed fire, the effects would be identical to Alternatives

B and C. See discussion on page 135.

Grasslands

Effects for grasslands would be almost identical to Alternative B with 135 fewer acres being treated with prescribed fire in Alternative D than in Alternative B. See discussion under Alternative B on page 135. In both cases, prescribed fires in grasslands would be under 'Operational Burn', and would not have restoration objectives associated with them. Treatments proposed for grasslands in Alternative D would move most of the acres towards desired conditions, but would not meet desired conditions at any scale (Table 94 and Table 95).

Table 94. Modeled fire type in grasslands for Alternative D

Grassland RU	Fire Type	Vegetation Type Acres	Existing Condition		2020	
			Acres	Percent	Acres	Percent
1	Surface	8,133	6,151	76	6,164	76
	Passive crown		1,321	16	1,407	17
	Active crown		239	3	140	2
3	Surface	12,775	11,703	92	11,695	92
	Passive crown		683	5	758	6
	Active crown		172	1	105	1
4	Surface	22,599	21,082	93	21,027	93
	Passive crown		753	3	881	4
	Active crown		613	3	540	2
5	Surface	4,595	2,577	56	2,603	57
	Passive crown		225	5	213	5
	Active crown		105	2	91	2
6	Surface	93	89	96	89	97
	Passive crown		3	3	3	3
	Active crown		1	1	1	1

Table 95. Modeled fire type in grasslands for Restoration Unit 1 subunits

Subunit and Vegetation Type	Acres	Alternative D Fire Type		
		Surface	Passive	Active
1-1	10,169	9,564	361	80
Grassland	567	352	167	34
1-2	**8,054**	**7,729**	**235**	**31**
Grassland	1,537	1,338	148	14

1-3	**41,652**	**36,698**	**2,013**	**2,520**
Grassland	3,240	2,396	478	51
1-4	**18,250**	**16,341**	**731**	**1,163**
Grassland	519	384	120	5
1-5	**78,179**	**66,323**	**4,692**	**6,867**
Grassland	2,270	1,694	494	35
3-1	**23,148**	**22,324**	**573**	**184**
Grassland	593	516	53	7
3-2	**32,726**	**31,272**	**911**	**267**
Grassland	9,611	9,251	178	40
3-3	**48,434**	**46,271**	**1,242**	**826**
Grassland	1,353	1,148	173	25
3-4	**9,019**	**7,556**	**544**	**704**
Grassland	99	53	26	6
3-5	**36,392**	**32,336**	**2,647**	**1,175**
Grassland	1,120	728	328	26
4-2	**10,231**	**9,735**	**314**	**82**
Grassland	332	294	9	1
4-3	**67,013**	**63,576**	**1,967**	**1,148**
Grassland	6,951	6,310	367	262
4-4	**81,421**	**77,880**	**2,284**	**1,057**
Grassland	14,988	14,138	473	268
4-5	**6,943**	**6,635**	**97**	**198**
Grassland	327	284	32	9
5-1	**24,172**	**21,656**	**649**	**999**
Grassland	1,299	1,178	83	19
5-2	**51,924**	**46,040**	**774**	**178**
Grassland	3,297	1,425	130	72
6-3	**34,109**	**32,812**	**695**	**570**
Grassland	85	82	3	1
6-4	**3,870**	**2,977**	**886**	**3**
Grassland	7	7	0	0

Pinyon/Juniper (PJ)

Effects for PJ under Alternative D are virtually identical to those in Alternative B, with modeled fire behavior between the alternatives differing by only 16 acres. Effects are discussed under Alternative B under 'Pinyon/Juniper' on page 136.

The only difference may be in the amount of PJ that is burned under 'Operational Burn'. With only 178,753 acres proposed for burning, there would be less PJ to be burned to facilitate burning grasslands and ponderosa pine. There are no desired conditions that specify a desired amount of crown fire for PJ. However, in the 535 acres with fuels reduction objectives, there are 2 percent (10 acres) more acres of crown fire than in Alternatives B and C.

Restoration Units

When analyzed at the scale of the Restoration Unit, Alternative D would meet desired conditions for fire behavior in 4 of the 5 Restoration Units (Table 96). Total crown fire potential would range from 12 percent in RU1 to 4 percent in RU5. The majority of crown fire in RU1 would be in protected habitat, for which there are no desired conditions relating to fire behavior. See discussion below.

Table 96. Modeled fire type by Restoration Unit for Alternative D

	RU	Fire Type Acres			Fire Type Percent		
		Surface	Passive	Active	Surface	Passive	Active
Alternative D (2020)	1	136,654	8,033	10,660	87	5	7
	3	139,760	5,917	3,156	93	4	2
	4	157,826	4,663	2,485	95	3	2
	5	67,696	1,422	1,177	89	2	2
	6	41,154	1,734	599	95	4	1
	Total	543,090	21,770	18,077	92	4	3

Restoration Unit 1

Restoration Unit 1 would be at greater risk of crown fire than the other Restoration units. It is of particular concern because the Lake Mary watershed is a source of water for the city of Flagstaff, and is a popular recreation site. There are adjacency concerns in the area of Mormon Mountain because of heavy fuel loading in mixed conifer, as well as the city of Flagstaff to the northwest. Within RU1, there would be potential for 18,693 (12 percent) acres of crown fire, of which 10,660 (7 percent) would be active crown fire. Alternative D would not meet desired conditions for fire behavior in RU1.

Of the 146,037 acres of pine, 16,860 acres (11 percent) would have potential for crown fire, of which 10,338 acres (7 percent) would be active crown fire (Table 97). Within RU1, Protected habitat accounts for over 92 percent of all active crown fire, and 40 percent of protected habitat is at risk of crown fire, with 31 percent of protected habitat being at risk of active crown fire.

Table 97. Modeled fire type by vegetation and habitat type for Restoration Unit 1

RU 3 Acres: 156,305			Vegetation Type Acres	Alternative D	
Vegetation/Habitat Type		Fire Type		Acres	Percent
Ponderosa Pine	**All Pine**	**Surface**	**146,037**	**128,676**	**88**
		Passive crown		**6,522**	**4**

RU 3 Acres: 156,305			Vegetation Type Acres	Alternative D	
Vegetation/Habitat Type		Fire Type		Acres	Percent
		Active crown		**10,338**	**7**
	MSO Protected	Surface	30,240	18,090	60
		Passive crown		2,597	9
		Active crown		9,500	31
	MSO Target/ Threshold	Surface	4,814	4,199	87
		Passive crown		327	7
		Active crown		276	6
	MSO Restricted	Surface	26,421	24,265	92
		Passive crown		1,976	7
		Active crown		147	1
	Goshawk PFA/ dPFA/ nest stand	Surface	4,670	4,520	97
		Passive crown		87	2
		Active crown		63	1
	Landscapes outside PFAs	Surface	79,892	77,602	97
		Passive crown		1,535	2
		Active crown		351	0
Other Vegetation	Aspen	Surface	420	263	63
		Passive crown		65	15
		Active crown		92	22
	Grassland	Surface	8,133	6,164	76
		Passive crown		1,407	17
		Active crown		140	2
	Juniper Woodland	Surface	286	274	96
		Passive crown		3	1
		Active crown		9	3
	Oak Woodland	Surface	287	260	91
		Passive crown		9	3
		Active crown		18	6
	Pinyon/ Juniper	Surface	1,141	1,017	89
		Passive crown		26	2
		Active crown		64	6

Aspen occupy 420 acres in RU1. There would be crown fire potential on 157 acres (37 percent). In those areas that burn with moderate to high severity, fire would probably top-kill most aspen stems but, in most cases, the clone would respond by vigorous sprouting. Alternative D proposes one prescribed fire in 32 acres of aspen. This would be low to moderate severity fire, benefiting the aspen by consuming accumulations of litter and some of the CWD. Following fire, the decreased surface albedo, decreased shade, and the flush of nutrients would stimulate vigorous sprouting. For 388 acres, mechanical treatment would decrease potential for crown fire by 7 percent from existing conditions. In these areas, there would be sprouting, though not as vigorous as in areas that were burned.

Grasslands would benefit from wildfire or prescribed fire because, where fuels are herbaceous, the intensity at it which it could burn, even under extreme conditions, would benefit the system. Where there would be potential for crown fire in grasslands (1,547 acres, or 19 percent), the fire would decrease woody encroachment. In the 140 acres (2 percent) of grasslands with potential for active crown fire, there would be potential for undesirable fire effects such as high burn severity (detrimental soil effects), including killing the existing seed bank and potentially giving invasive plant species a foothold. The decrease in potential crown fire by 5 percent indicates a decrease in ponderosa pine, most likely pine that was young enough to have low canopy base heights. Although the grasslands would mostly benefit from wildfires occurring following proposed treatments, Alternative D would not meet desired conditions for fire behavior in grasslands in RU1.

Oak woodlands in Restoration Unit 1 would have the potential for 27 acres (9 percent) of crown fire in oak woodlands, of which 18 acres (6 percent) would be active crown fire. In the short run it would increase sprouting and small-diameter stems. It is also possible that there would be some mortality of large oak in the prescribed burns, particularly initial entry though, in the long run, it would decrease the risk to large oak.

Pinyon/Juniper woodlands crown fire potential in Restoration Unit 1 would decrease to 102 acres (down from 266 in the existing condition). PJ in RU1 is Operational Burning, but would benefit from the prescribed fires that would be implemented.

Subunits

Subunit 1-1 includes Walnut Canyon, is adjacent to Flagstaff and the Pulliam Airport. Following treatments, there is potential for 3 percent (308 acres) of crown fire (Table 98). There would be potential for crown fire on 441 acres, of which 80 acres would be active crown fire. Some of the crown fire would be near, or adjacent to the Country Club area in southeastern Flagstaff, as well as adjacent to or close to Pulliam Airport. Approximately 65 percent of the grassland area in subunit 1-1 would have potential for crown fire. Subunit 1-3 includes the Lake Mary watershed, a source watershed for the town of Flagstaff. Following treatments proposed in Alternative D, 16 percent of it (4,533 acres) would have potential for crown fire, 11 percent of which would be active crown fire. The majority of the active crown fire in Subunit 1-3 is on the south and west sides of the Subunit, furthest away from the lakes and in PACs. Subunit 1-5 has over 35 PACs, which account for the majority of the crown fire in this subunit. Almost all of the active crown fire is in PACs, with passive crown fire scattered throughout the units. Alternative D would meet desired behavior for in subunits 1-1, and 1-22, but not in subunits 1-3 (16 percent), 1-4 (14 percent), or 1-5 (21 percent).

Table 98. Modeled fire type in Restoration Unit 1 subunits by vegetation type for 2020

Vegetation	Alternative D 2020

Type by Sub Unit	Total acres	Surface Fire (acres)	Passive crown (acres)	Active crown (acres)	Surface (percent)	Passive crown (percent)	Active crown (percent)
1-1	**10,169**	**9,564**	**361**	**80**	**94**	**4**	**4**
Ponderosa Pine	8,914	8,579	182	36	96	2	2
Grassland	567	352	167	34	62	29	36
Oak Woodland	173	173	0	0	100	0	0
Pinyon-Juniper	515	460	12	10	89	2	4
1-2	**8,054**	**7,729**	**235**	**31**	**96**	**3**	**3**
Ponderosa Pine	6,517	6,391	87	17	98	1	2
Grassland	1,537	1,338	148	14	87	10	11
1-3	**41,652**	**36,698**	**2,013**	**2,520**	**88**	**5**	**11**
Ponderosa Pine	38,324	34,266	1,520	2,430	89	4	10
Aspen	88	36	14	38	41	16	59
Grassland	3,240	2,396	478	51	74	15	16
1-4	**18,250**	**16,341**	**731**	**1,163**	**90**	**4**	**10**
Ponderosa Pine	17,285	15,548	596	1,135	90	3	10
Grassland	519	384	120	5	74	23	24
Oak Woodland	83	56	9	18	68	11	32
Pinyon-Juniper	363	352	7	5	97	2	3
1-5	**78,179**	**66,323**	**4,692**	**6,867**	**85**	**6**	**15**
Ponderosa Pine	74,996	63,892	4,137	6,719	85	6	14
Aspen	332	227	51	54	68	15	32
Grassland	2,270	1,694	494	35	75	22	23
Juniper Woodland	286	274	3	9	96	1	4
Oak Woodland	32	31	0	0	99	1	1
Pinyon-Juniper	262	205	7	50	78	3	22

Restoration Unit 3

Winds on the Mogollon Rim are generally out of the southwest, so this RU has a high strategic importance in regards to fire movement. Adjacency concerns for fire behavior include Interstates 40 and 17 which are adjacent to RU3 to the north and east, respectively, so that smoke from wildfires would have good potential to impact travel, as well as the communities of Flagstaff, Belmont, Parks, Williams, and Kachina Village. Additional concerns include Oak Creek, Oak Creek Canyon, and Sycamore Canyon. Under Alternative D, there would be potential for 9,353 (6 percent) acres of crown fire, of which 3,156 (2 percent) would be active crown fire. Alternative D (Table 99) would meet desired conditions for fire behavior in RU3. Most of the crown fire is scattered, with more concentrated (though not always contiguous) areas following treatment type boundaries, or drainages and slopes.

When evaluated at the vegetation/habitat type scale, RU3 would meet desired conditions for ponderosa pine with 75 percent of the pine having potential for crown fire, of which 2 percent (2,279 acres) would be active crown fire. Protected habitat accounts for approximately 68 percent of the active crown fire in the ponderosa pine vegetation type.

Table 99. Modeled fire type for Restoration Unit 3 for 2020

RU 3 acres (149,718)			Vegetation type acres	Alternative D 2020	
Vegetation Type		Fire Type		Acres	Percent
Ponderosa Pine	All Pine	Surface	129,225	120,479	93
		Passive crown		5,072	4
		Active crown		3,029	2
	MSO Protected	Surface	4,507	2,279	51
		Passive crown		592	13
		Active crown		1,552	34
	MSO Target/ Threshold	Surface	3,899	3,535	91
		Passive crown		92	2
		Active crown		268	7
	MSO Restricted	Surface	38,748	36,673	95
		Passive crown		1,759	5
		Active crown		239	1
	Goshawk PFA/ dPFA/ Nest Stand	Surface	5,452	4,815	88
		Passive crown		395	7
		Active crown		239	4
	Landscapes outside PFAs	Surface	76,619	73,177	96
		Passive crown		2,233	3
		Active crown		731	1
Other Vegetation	Aspen	Surface	201	156	77
		Passive crown		46	23
		Active crown		0	0
	Grassland	Surface	12,775	11,695	92
		Passive crown		758	6
		Active crown		105	1
	Juniper Woodland	Surface	1,851	1,838	99
		Passive crown		5	0
		Active crown		3	0
	Oak Woodland	Surface	1,633	1,617	99

RU 3 acres (149,718)			Vegetation type acres	Alternative D 2020	
Vegetation Type		Fire Type		Acres	Percent
		Passive crown		4	0
		Active crown		2	0
	Pinyon/ Juniper	Surface	4,033	3,975	99
		Passive crown		34	1
		Active crown		17	0

Aspen occupy 201 acres in RU1. 46 acres (23 percent) would have potential for crown fire under wildfire conditions, all of which would be passive crown fire. In those areas that burn with moderate to high severity, fire would probably top-kill most aspen stems but, in most cases, the clone would respond by vigorous sprouting. In those areas that burned with low severity (wildfire and prescribed fire) aspen would benefit as the fire consumed accumulations of litter and some CWD. Following fire, the decreased surface albedo, decreased shade, and the flush of nutrients would stimulate vigorous sprouting. For those areas with only mechanical treatment, there would be sprouting, though not as vigorous as in areas that were burned.

Grasslands would benefit from wildfire or prescribed fire because, where fuels are herbaceous, the intensity at it which it could burn, even under extreme conditions, would benefit the system. Where there would be potential for crown fire in grasslands (863 acres, or 7 percent), the fire would decrease woody encroachment. Table 99 displays fire behavior by vegetation types. In the 105 acres (1 percent) of grasslands with potential for active crown fire, there would be potential for undesirable fire effects such as high burn severity (detrimental soil effects), including killing the existing seed bank and potentially giving invasive plant species a foothold. Although the grasslands would mostly benefit from wildfires occurring following proposed treatments, Alternative D would not meet desired conditions for fire behavior in grasslands in RU1.

Oak woodlands would have no potential for crown fire under Alternative D. Fires that burned through them would stimulate sprouting and small-diameter stems. It is also possible that there would be some mortality of large oak in the prescribed burns, particularly initial entry though, in the long run, it would decrease the risk to large oak.

Pinyon/Juniper crown fire potential would decrease to 59 acres (down from 266 in the existing condition). PJ in RU1 is Operational Burning, but would benefit from the prescribed fires that would be implemented.

Subunits

Subunit 3-5 has all, or parts of approximately 11 PACs accounting for most of the active crown fire. There is potential for small areas of crown fire on slopes >30 percent in Subunits 3-5 (on the edge of the rim), and 3-4 (Kelly Canyon). When evaluated at the Subunit scale, RUs 3-1, 3-2, and 3-3 meet desired conditions for fire behavior under Alternative D. Subunits 3-4 (20 percent) and 3-5 (18 percent) would not (Table 100).

Table 100. Modeled fire type in Restoration Unit 3 subunits by vegetation type for 2020

Vegetation Type by Sub-Unit	Total acres	Alternative D 2020					
		Surface Fire Acres	Passive Crown Fire Acres	Active Crown Fire Acres	Surface Fire Percent	Passive Crown Fire Percent	Active Crown Fire Percent
3-1	**23,148**	**22,324**	**573**	**184**	**96**	**2**	**3**
Ponderosa Pine	18,805	18,097	491	173	96	3	4
Aspen	91	70	21	0	76	23	23
Grassland	593	516	53	7	87	9	10
Juniper Woodland	907	902	3	1	99	0	0
Oak Woodland	845	840	2	2	99	0	0
Pinyon-Juniper	1,908	1,899	3	1	100	0	0
3-2	**32,726**	**31,272**	**911**	**267**	**96**	**3**	**4**
Ponderosa Pine	22,885	21,807	717	227	95	3	4
Aspen	59	42	16	0	72	28	28
Grassland	9,611	9,251	178	40	96	2	2
Oak Woodland	172	172	0	0	100	0	0
3-3	**48,434**	**46,271**	**1,242**	**826**	**96**	**3**	**4**
Ponderosa Pine	44,426	42,510	1,049	794	96	2	4
Aspen	50	42	8	0	84	16	16
Grassland	1,353	1,148	173	25	85	13	15
Juniper Woodland	873	866	2	2	99	0	0
Oak Woodland	232	222	1	1	96	0	1
Pinyon-Juniper	1,500	1,483	10	3	99	1	1
3-4	**9,019**	**7,556**	**544**	**704**	**84**	**6**	**14**
Ponderosa Pine	8,920	7,503	518	698	84	6	14
Grassland	99	53	26	6	54	26	32
Oak Woodland	0	0	0	0	100	0	0
3-5	**36,392**	**32,336**	**2,647**	**1,175**	**89**	**7**	**11**
Ponderosa Pine	34,190	30,562	2,297	1,137	89	7	10
Aspen	2	2	0	0	100	0	0
Grassland	1,120	728	328	26	65	29	32
Juniper Woodland	70	70	0	0	100	0	0
Oak Woodland	384	383	1	0	100	0	0
Pinyon-Juniper	626	592	21	13	95	3	5

Restoration Unit 4

Located west and north of Flagstaff, and north of Williams and I-10, RU4 has been impacted by some large fires, including the Hockderffer (2004, 16,000 acres) and Pumpkin (2000, 8,700 acres) fires. There are adjacency concerns with Kendrick and Sitgreaves mountains because of steep slopes and potential for high severity fire effects uphill from the treatment area. Within RU4, there would be potential for 7,148 acres (5 percent) of crown fire, of which 2,485 (2 percent) would be active crown fire. Alternative D would meet desired conditions for fire behavior in RU4. When evaluated at the vegetation/habitat type scale, ponderosa pine would meet desired conditions; with 4 percent (5,651 acres) having potential for crown fire of which 1,927 (1 percent) would be active crown fire (Table 101).

Table 101. Modeled fire type for Restoration Unit 4 under Alternative D, 2020

RU 4 acres: 165,607			Vegetation Type Acres	Alternative D 2020	
Vegetation Type		Fire Type		Acres	Percent
Ponderosa Pine	All Pine	Surface	134,301	128,205	95
		Passive crown		3,724	3
		Active crown		1,927	1
	MSO Protected	Surface	558	350	63
		Passive crown		33	6
		Active crown		176	31
	MSO Restricted	Surface	1,575	1,540	98
		Passive crown		10	1
		Active crown		18	1
	Goshawk PFA/ dPFA/ Nest Stand	Surface	13,484	12,569	93
		Passive crown		567	4
		Active crown		344	3
	Landscapes outside PFAs	Surface	118,683	113,748	96
		Passive crown		3,114	3
		Active crown		1,388	1
Other Vegetation	Aspen	Surface	499	462	93
		Passive crown		26	5
		Active crown		8	2
	Grassland	Surface	22,599	21,027	93
		Passive crown		881	4
		Active crown		540	2
	Juniper Woodland	Surface	118	115	98
		Passive crown		0	0
		Active crown		0	0
	Oak Woodland	Surface	926	918	99

RU 4 acres: 165,607			Vegetation Type Acres	Alternative D 2020	
Vegetation Type		Fire Type		Acres	Percent
		Passive crown		4	0
		Active crown		2	0
	Pinyon/ Juniper	Surface	7,165	7,098	99
		Passive crown		29	0
		Active crown		7	0

Aspen occupy 499 acres of aspen in RU4. There would be potential for crown fire on 34 acres (7 percent), of which 8 acres would be active crown fire. Decreased conifer encroachment would help decrease crown fire potential so that the passive crown fire that did occur would be less likely to topkill entire clones, both stimulating sprouting and allowing the survival of some large stems.

Grassland acres in Restoration Unit 4 include Government Prairie, a grassland area of ~20,000 acres, as well as other scattered grasslands units. These grassland areas would be included as Operational Burn. Potential crown fire would be 6 percent (1,421 acres), of which 540 acres (2 percent) would be active crown fire, across all the grasslands in RU4 following Operational Burns. With the exception of the active crown fire, grasslands would benefit from any fire that does occur because it would decrease woody encroachment, stimulate decadent grasses, shrubs, and forbs, and provide a disturbance to which they are well adapted.

Pinyon/Juniper woodlands would have only 36 acres of potential crown fire, of which only 7 acres would be active crown fire. As with grasslands, these areas would be Operational Burn and, post-treatment, would include potential for 7,213 acres of surface fire.

Oak woodlands would support just 2 acres of modeled crown fire out of a total of 926 acres in the Restoration Unit. This would meet desired conditions for <10 percent crown fire potential in oak woodlands.

Subunits

At the subunit level (Table 102) SU 4-5, though the smallest SU in the project (6,943 acres), is adjacent to the city of Flagstaff, and has some steep topography, so that the second order (indirect) fire effects of any high severity fires have good potential to impact neighborhoods and schools. Under Alternative D, Subunit 4-5 would have potential for 295 acres of crown fire, of which 198 acres would be active crown fire. There is a section (1 mile by 1 mile) immediately west of north flagstaff with scattered active crown fire a little over a mile southwest from a residential area, with forested non-federal land between. The majority of crown fire in RU4 is in Subunit 4-3, on the northwest and north side of the peaks, and west of Sitgreaves. All Subunits in RU4 would meet desired conditions for fire behavior, though there are multiple areas with contiguous passive crown fire that are greater than 30 acres, and some of active crown fire that are close to 30 acres.

Table 102. Modeled fire type in Restoration Unit 4 subunits under Alternative D, 2020

		Alternative D 2020					
	Total acres	Surface Fire (acres)	Passive crown (acres)	Active crown (acres)	Surface (percent)	Passive crown (percent)	Active crown (percent)
4-2	**10,231**	**9,735**	**314**	**82**	**95**	**3**	**4**
Ponderosa Pine	7,381	6,971	296	74	94	4	5
Aspen	1	1	0	0	67	0	0
Grassland	332	294	9	1	89	3	3
Juniper Woodland	8	8	0	0	97	1	3
Oak Woodland	567	559	4	2	99	1	1
Pinyon-Juniper	1,941	1,902	6	4	98	0	1
4-3	**67,013**	**63,576**	**1,967**	**1,148**	**95**	**3**	**5**
Ponderosa Pine	55,311	52,552	1,577	878	95	3	4
Aspen	232	220	3	6	95	1	4
Grassland	6,951	6,310	367	262	91	5	9
Juniper Woodland	31	31	0	0	100	0	0
Oak Woodland	325	325	0	0	100	0	0
Pinyon-Juniper	4,162	4,137	20	2	99	0	1
4-4	**81,421**	**77,880**	**2,284**	**1,057**	**96**	**3**	**4**
Ponderosa Pine	65,003	62,339	1,789	787	96	3	4
Aspen	255	234	19	1	92	8	8
Grassland	14,988	14,138	473	268	94	3	5
Juniper Woodland	78	76	0	0	97	0	0
Oak Woodland	35	35	0	0	100	0	0
Pinyon-Juniper	1,062	1,059	3	0	100	0	0
4-5	**6,943**	**6,635**	**97**	**198**	**96**	**1**	**4**
Ponderosa Pine	6,605	6,344	62	188	96	1	4
Aspen	11	7	4	0	63	35	37
Grassland	327	284	32	9	87	10	12

Restoration Unit 5

Restoration Unit 5 includes parts of the area burned in the Schultz fire (2010, ~17,000 acres) and the Radio Fire (1977, 2,600). Adjacency concerns include housing developments, including Doney Park, and the city of Flagstaff, which would be mostly downslope from any fire occurring in parts of this RU. Within RU5, there would be potential for 2,599 acres (4 percent) of crown fire, of which 1,177 acres (2 percent) would be active crown fire. Alternative D would meet desired conditions for fire behavior in RU5. RU5 has areas of cinder substrate northeast of Flagstaff, mostly in and around the Doney Park area, and north. These areas, though they have little fuel, have been reported to attract lightning, increasing the potential for lightning starts in the vicinity.

When evaluated at the vegetation/habitat type scale (Table 103), ponderosa pine meets desired conditions, with 4 percent (2,215 acres) of the pine having potential for crown fire, of which 2 percent (1,073 acres) would be active crown fire. Within the pine, over 56 percent of the active crown fire is accounted for by protected habitat, of which 52 percent (749 acres) has potential for crown fire.

Table 103. Modeled fire type by vegetation and habitat for Restoration Unit 5, 2020

RU 5 76,096 acres			Veg Type acres	Alternative D 2020	
Vegetation Type		Fire Type		Acres	Percent
Ponderosa Pine	All Pine	Surface	61,730	55,717	90
		Passive crown		1,152	2
		Active crown		1,073	2
	Protected	Surface	1,452	681	47
		Passive crown		144	10
		Active crown		605	42
	Restricted	Surface	634	597	94
		Passive crown		33	5
		Active crown		2	0
	PFA/ dPFA/ Nest Stand	Surface	2,944	2,624	89
		Passive crown		132	4
		Active crown		42	1
	Landscapes outside of PFAs	Surface	56,700	51,815	91
		Passive crown		843	1
		Active crown		424	1
Other Vegetation	Aspen	Surface	403	345	86
		Passive crown		50	12
		Active crown		2	1
	Grassland	Surface	4,595	2,603	57
		Passive crown		213	5
		Active crown		91	2
	Juniper Woodland	Surface	74	74	100
		Passive crown		0	0
		Active crown		0	0
	Oak Woodland	Surface	523	497	95
		Passive crown		1	0

RU 5 76,096 acres		Veg Type acres	Alternative D 2020	
Vegetation Type	Fire Type		Acres	Percent
	Active crown		6	1
Pinyon/ Juniper	Surface	8,771	8,459	96
	Passive crown		7	0
	Active crown		5	0

Aspen occupy 403 acres of aspen in RU5, 64 acres (13 percent) would have potential for crown fire, of which 50 acres (12 percent) would be passive crown fire. Decreased conifer encroachment would help decrease crown fire potential so that the passive crown fire that did occur would be less likely to topkill entire clones, both stimulating sprouting and allowing the survival of some large stems.

Grassland effects, under Alternative D, would differ from Alternative B by just one acre, so the effects were considered identical. See discussion under Alternative B on page 146.

Pinyon/Juniper effects, under Alternative D, would differ from Alternative B by 2 acres and were considered identical. (See discussion under Alternative B in ‘Restoration Unit 5’ on page 146).

Oak woodland effects to fire behavior under Alternative D differ from those in Alternative B by 6 acres, and were considered nearly identical. (See discussion on under Alternative B in ‘Restoration Unit 5’ page 146). Under Alternative D, there would be potential for 7 acres of crown fire, 6 acres of which would be active crown fire.

Subunits

Both Subunits in RU5 would meet desired conditions for fire behavior, though Subunit 5-1 would be right at the desired behavior with potential for 10 percent (1,648 acres) of the area to burn with crown fire (Table 104). Subunit 5-1, includes portions of three PACs, all of which would support extensive areas of active crown fire, the largest contiguous area would be around 150 acres, of which, approximately 30 acres is above and adjacent to Schultz Pass road and on slopes greater than 30 percent. The other two both have areas of contiguous active crown fire >20 percent, some of which is on slopes greater than 30 percent. Subunit 5-2 includes much of the youngest, most sparsely vegetated cinder cones, as well as areas that were affected by the second order (indirect) fire effects resulting from the Schultz Fire.

Table 104. Modeled fire type in Restoration Unit 5 subunits under Alternative D, 2020

Vegetation Type by Sub-unit	Total acres	Alternative D 2020					
		Surface (acres)	Passive crown (acres)	Active crown (acres)	Surface (percent)	Passive crown (percent)	Active crown (percent)
5-1	24,172	21,656	649	999	90	3	7
Ponderosa Pine	20,674	18,373	512	972	89	2	7

Aspen	392	337	49	2	86	12	13
Grassland	1,299	1,178	83	19	91	6	8
Oak Woodland	232	223	1	6	96	0	3
Pinyon-Juniper	1,574	1,545	4	0	98	0	0
5-2	51,924	46,040	774	178	89	1	2
Ponderosa Pine	41,055	37,344	639	101	91	2	2
Aspen	10	9	2	0	85	15	15
Grassland	3,297	1,425	130	72	43	4	6
Juniper Woodland	74	74	0	0	100	0	0
Oak Woodland	291	274	0	0	94	0	0
Pinyon-Juniper	7,196	6,914	3	5	96	0	0

Restoration Unit 6

Restoration Unit 6 is the smallest of the RUs, and lies immediately south of and adjacent to Grand Canyon National Park. The town of Tusayan is in the northwest corner, and concerns about hazardous wildland fuels to the east of Tusayan. It is the driest of all the RUs, and has had more recent fire than most of the rest of the proposed treatment area (see map, Figure 28). Modeled post-treatment fire behavior (Table 105) shows 5 percent (2,333 acres) of crown fire, of which 599 acres (1 percent) would be active crown fire. Although there would only be potential for 5 percent of RU6 to burn with crown fire, there would be two areas of contiguous crown fire of over 50 acres. That would exceed the desired condition of <30 contiguous acres of active crown fire. For this reason, Alternative D would not meet desired conditions for fire behavior in RU6. When considered at the scale of vegetation/habitat type, the ponderosa pine would meet desired conditions for fire behavior, with 4 percent (2,003 acres) having potential for crown fire.

Table 105. Fire type by vegetation type for Restoration Unit 6

RU 6 acres: 43,529			Acres of Veg type in RU	Existing Condition		Alterative D 2020	
	Vegetation Type	Fire Type		Acres	Percent	Acres	Percent
Ponderosa Pine	All Pine	Surface	41,188	33,675	82	39,143	95
		Passive crown		2,224	5	1,405	3
		Active crown		5,247	13	598	1
	Goshawk PFA/ dPFA/ Nest Stand	Surface	4,050	3,502	86	3,988	98
		Passive		111	3	56	1
		Active		433	11	3	0
	Landscapes outside PFAs	Surface	37,138	30,173	81	35,155	95
		Passive		2,113	6	1,349	4
		Active		4,814	13	595	2
Vegeta	Grassland	Surface	93	89	96	89	97
		Passive		3	3	3	3

		Active		1	1	1	1
	Juniper Woodland	Surface	13	10	78	11	84
		Passive		3	22	2	16
		Active		0	0	0	0
	Oak Woodland	Surface	30	9	29	29	98
		Passive		21	69	1	2
		Active		1	2	0	0
	Pinyon/ Juniper	Surface	2,206	1,468	67	1,882	85
		Passive		511	23	324	15
		Active		227	10	0	0

Grassland effects under Restoration Unit 6, would be identical to those of Alternative B. See Alternative B discussion under 'Restoration Unit 6' on page 150.

Pinyon/Juniper treatment acres occupy 2,219 acres. The effects of Alternative D on fire behavior in Pinyon/Juniper in RU6 differ from those of Alternative D by 10 acres, and were considered identical. See Alternative B discussion on page 150. Under Alternative D, there would be 10 more acres of passive crown fire. Active crown fire acres would be the same.

Oak woodlands would have the same effects under Alternative D as under Alternative B. See Alternative B discussion under 'Restoration Unit 6' on page 150.

Subunits

As indicated in Table 106, Subunits 6-2 would meet desired conditions for fire behavior under Alternative D, of less than 10 percent crown fire in ponderosa pine. Subunit 6-3 meets desired conditions for less than 10 percent crown fire, but there are two areas of >30 acres of contiguous crown fire, one of which is mostly active crown fire. For that reason, Subunit 6-3 would not meet desired conditions for fire behavior. In Subunit 6-4, there is diverse vegetation in most of the stands showing potential for passive crown fire, including juniper and Gambel oak. Figure 29 shows the structure of the area, with multiple ladder fuels, but open areas between clumps of vegetation, with ponderosa pine as the dominant species. This structure easily promotes passive crown fire, which is responsible for much of the crown fire potential in Subunit 6-4, the majority of which is in Pinyon/Juniper. This does not meet desired conditions for fire behavior.

Table 106. Modeled fire type in Restoration Unit 6 subunits by vegetation type for 2020

RU 6 Subunits	Total acres	Alternative D 2020 Fire Type					
		Surface (acres)	Passive crown (acres)	Active crown (acres)	Surface (percent)	Passive crown (percent)	Active crown (percent)
6-2	**5,551**	**5,365**	**153**	**25**	**97**	**3**	**3**
Ponderosa Pine	5,069	4,893	143	25	97	3	3
Pinyon-Juniper	483	473	10	0	98	2	2

6-3	**34,109**	**32,812**	**695**	**570**	**96**	**2**	**4**
Ponderosa Pine	32,635	31,455	579	569	96	2	4
Grassland	85	82	3	1	96	3	4
Juniper Woodland	13	11	2	0	84	16	16
Pinyon-Juniper	1,375	1,264	111	0	92	8	8
6-4	**3,870**	**2,977**	**886**	**3**	**77**	**23**	**23**
Ponderosa Pine	3,484	2,795	682	3	80	20	20
Grassland	7	7	0	0	100	0	0
Oak Woodland	30	29	1	0	98	2	2
Pinyon-Juniper	348	145	203	0	42	58	58

Surface fuels and canopy characteristics affecting fire behavior and effects

Canopy characteristics and surface fuel loading are discussed in this section by desired openness. As described on page 9, desired openness is an indication of the relative desired post treatment interspace/tree group condition.

Relationships between surface fuels and canopy characteristics affecting fire behavior and effects are discussed on page 155. Surface fuel loading may produce desirable or undesirable fire effects, depending on the initial loading and the conditions under which it burns (see page 71).

In Alternative D, there would be no treatment on ~20,000 acres labeled 'None (PACs)', or ~5,000 acres labeled 'None (PACs)'.

Canopy characteristics affecting fire behavior

Changes to canopy cover (CC), canopy base height (CBH), and canopy bulk density (CBD) are important indicators of potential fire behavior that can display changes that are not always apparent in the fire behavior data. The following figures and tables are classified by treatment type, based on their relative ability to attain a mosaic of interspaces and tree groups (McCusker 2012). Across the landscape, a mosaic at all scales would be well adapted to fire for southwestern ponderosa pine, and would be maintainable by fire alone should that be desired. Immediately post-treatment (2020), all action alternatives show movement towards desired condition significant enough to have met desired conditions for fire behavior in ponderosa pine (see sections above).

Acres that are the most at risk regarding canopy fuel structure that supports crown fire are in PACs and Core Areas. When CBH and CBD are averaged over all pine vegetation, they meet desired conditions, with an average CBH of 23 feet, and an average CBD of 0.043 kg/m^3. Under Alternative D, post treatment condition differ by as much as 10 feet, between None (core areas), and High. CBH reaches and maintains desired condition for 95 percent of the ponderosa pine vegetation (excluding PACs and Core Areas which do not have desired conditions for CBH or CBD) though 2050. CBD reaches desired conditions in 95 percent of the ponderosa pine, and maintains desired conditions though 2050 for 89 percent of the ponderosa pine. In Table 107, shaded cells indicate a condition that does not meet desired conditions. Note: desired conditions for CBH and CBD do not apply to PACs or Core Areas.

Table 107. Modeled canopy characteristics under Alternative D

Desired openness	CBH (feet)			CBD (kg/m3)			CC (%)			Percent of ponderosa pine
	2010	2020	2050	2010	2020	2050	2010	2020	2050	
High	15.18	25.83	26.81	0.067	0.031	0.041	68	55	64	35
Moderate	14.77	22.22	23.50	0.061	0.035	0.045	66	58	66	27
Low (Mechanical)	16.13	23.22	25.46	0.060	0.042	0.048	66	61	68	6
Low (Burn Only)	13.98	20.06	24.48	0.046	0.036	0.037	58	53	60	20
Very Low (Burn Only)	15.95	23.45	29.05	0.062	0.049	0.050	69	66	71	4
Very Low (Mechanical)	14.30	21.24	27.00	0.063	0.053	0.052	70	68	72	2
None (PAC Burn Only)	14.29	15.99	21.78	0.067	0.067	0.066	72	73	76	4
None (Core Areas)	14.09	15.88	22.24	0.071	0.071	0.070	73	74	76	1
Weighted Average[12]	**14.84**	**22.79**	**25.18**	**0.061**	**0.037**	**0.043**	**66**	**58**	**65**	

Canopy Cover (CC) decreases with completion of treatments for all but the two lowest intensity treatments (in Alternative D 'None (PACs)' and 'None (core areas)' are not treated) in which it increases (figure 60). CC stays below pretreatment levels for high and moderate. In this alternative, the lowest two levels of desired openness support canopy characteristics most likely to support crown fire. When CBH is high, if CBD and CC are high enough, it is possible for conditional crown fire to occur, as crown fire moves into a stand from the canopy of an adjacent stand. Crown fire only needs one 'ladder' location to initiate active crown fire. Only in the two highest levels of desired openness does CC stay below pre-treatment levels by 2050. Assumptions are that thinning and two prescribed burns occurred between 2010 and 2020, and no mechanical treatments, wildfire, or prescribed fire occurred between 2020 and 2050.

Surface fuels: Litter, Duff, and Coarse Woody Debris greater than 3" diameter

Changes to surface fuel loading are direct effects of proposed treatments, that have indirect effects on fire behavior and effects. Litter, duff, and Coarse Woody Debris greater than 3" diameter (CWD>3") contribute to multiple characteristics of a fire regime, including, but not limited to: flammability, surfaced fire intensity, scorch height, flame length, and surface fire effects. They contribute more than other fuels to emissions. Surface fuels can cause high severity effects to soil, and to surface biota (roots, seeds, forbs, and other species adapted to low severity fire), as well as producing troublesome emissions. Mechanical thinning alone can contribute significantly to decreasing the potential for crown fire by breaking up vertical and horizontal

[12] Weighted averages for desired openness are based on the number of acres of ponderosa pine proposed for treatment under each alterantive.

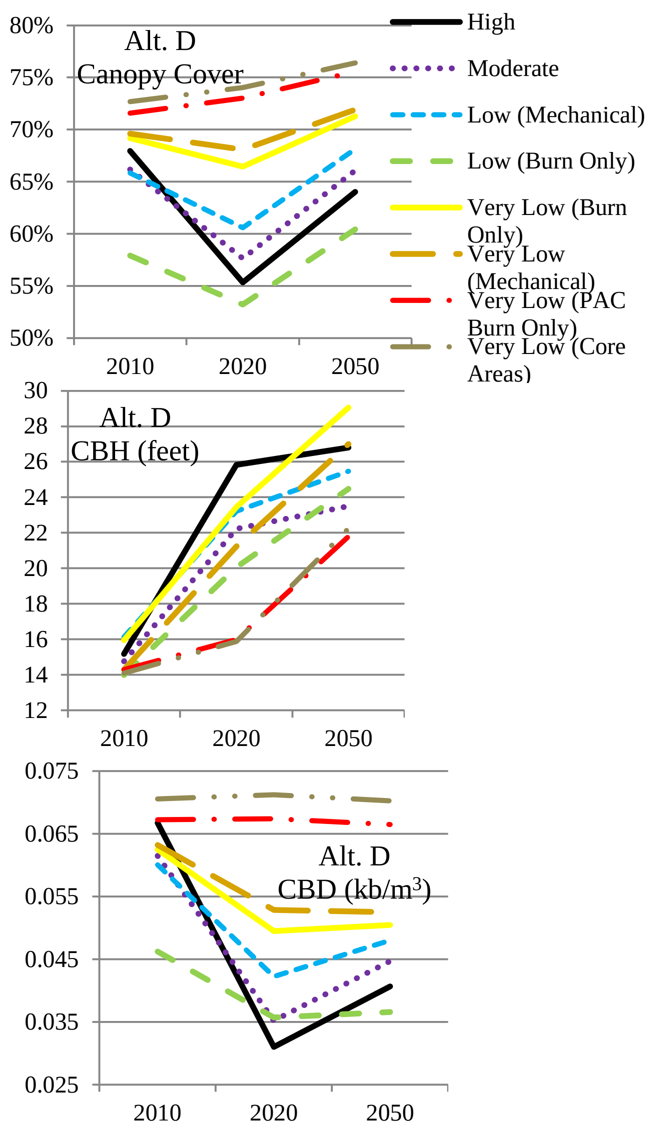


Figure 60. Canopy characteristics for Alt. D

canopy fuel continuity, but does not decrease surface fuel loading (Fulé et al. 2012). General effects are similar in areas that are not burned (see discussion in Alternative B under 'Litter, Duff, and Coarse Woody Debris greater than 3 inches Diameter' on page 153.

Under Alternative D, only 'Low (Burn Only), and 'Very Low (Burn Only) would actually include prescribed fire, but the names are kept the same as they indicate the intensity of mechanical treatments that are implemented. As can be seen in figure 61, surface fuel loading increases where there are mechanical treatments and, where there is prescribed fire, surface fuel loading decreases, or there is only a very slight increase. Using 20 tons/acre as the upper end of what might be considered a range of recommended fuel loading, All treated areas (the lowest two receive no treatment under this alternative) would remain below 20. Historical values were around 5 tons per acre on the high end for CWD, and less than 2.5 tons/acre for duff (Brown et al. 2003), none of these treatments decrease to levels that would indicate values within historic ranges (figure 61 also includes litter).

Table 108 displays modeled changes in surface fuel loading under alternative D. Assumptions are that one mechanical treatment and two prescribed burns occur between 2010 and 2020, and that there were no additional mechanical treatments, wildfires, or prescribed fires between 2020 and 2050. Shaded cells indicate a condition that does not meet forest plan guidelines of 5-7 tons/acre for CWD.

Table 108. Modeled changes in surface fuel loading under Alternative D

Desired openness	CWD>3"			Litter			Duff			CWD>3" + Litter + Duff			Percent of ponderosa pine
	2010	2020	2050	2010	2020	2050	2010	2020	2050	2010	2020	2050	
High	3.95	6.52	7.27	3.48	2.68	3.33	3.39	3.56	3.99	10.82	12.76	14.6	35
Moderate	3.66	5.84	6.89	3.93	3.40	4.20	3.14	3.33	3.89	10.72	12.57	14.98	27
Low	3.58	5.41	6.87	3.22	3.13	3.82	3.20	3.36	3.88	9.99	11.9	14.57	6

(Mechanical)													
Low (Burn Only)	3.16	2.78	6.19	2.48	1.57	2.59	2.90	2.54	2.89	8.54	6.90	11.67	20
Very Low (Burn Only)	4.71	5.47	9.22	4.43	3.99	5.10	3.58	3.59	4.32	12.71	13.06	18.64	4
Very Low (Mechanical)	4.61	6.33	9.06	4.44	4.03	4.53	3.96	4.17	4.81	13.00	14.53	18.41	2
None (PACs)	5.99	7.72	12.46	4.80	5.57	6.15	5.09	5.35	6.24	15.88	18.64	24.84	4
None (Core Areas)	5.85	7.66	12.42	4.98	5.66	6.21	4.83	5.09	5.99	15.66	18.41	24.62	1
Weighted Average[13]	**4.44**	**5.97**	**8.80**	**3.97**	**3.75**	**4.49**	**3.76**	**3.87**	**4.50**	10.7	11.8	14.9	

Figure 62 shows the post-treatment spatial distribution of surface fuel loading. Shaded colors represent areas where surface fuel loading exceeds 20 tons/acre. The majority of those areas are in PACs or PFA in RU1 and RU3. Under Alternative D, in 2020 there would be approximately 3,507 acres with surface fuel loading greater than 20 tons/acre and 75,932 acres in the 15 – 20 tons/acre range. By 2040, there would be 19,396 acres exceeding 20 tons/acre, and 155,370 acres in the 15 – 20 tons/acre range. Assumptions are the same as for Table 108. Shaded cells indicate a condition that does not meet forest plan guidelines of 5-7 tons/acre for CWD.

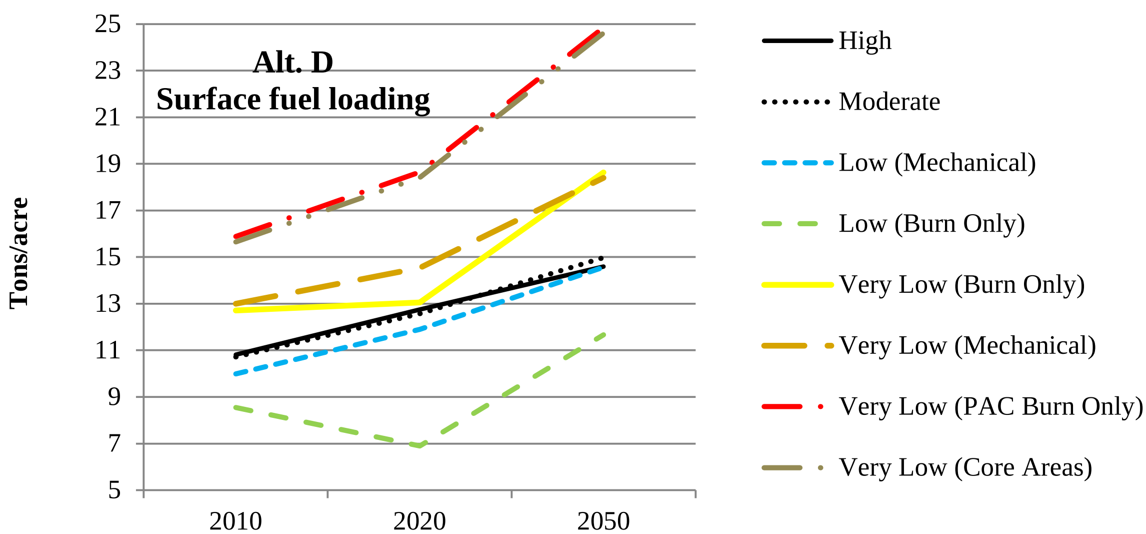


Figure 61. Modeled changes in fuel loading under Alternative D (duff + litter + CWD>3")

[13] Weighted averages for desired openness are based on the number of acres of ponderosa pine proposed for treatment under each alterantive.

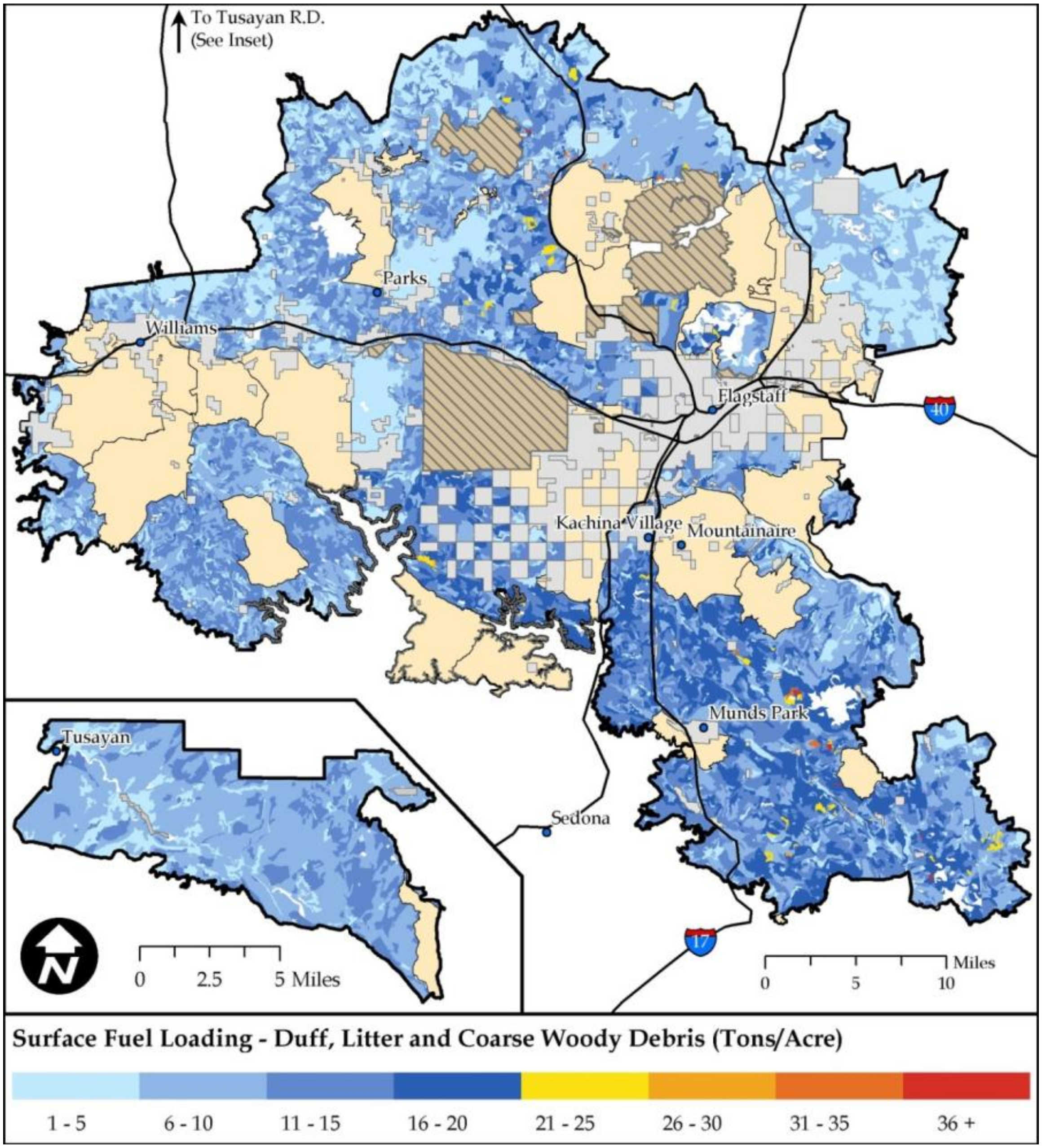


Figure 62. Surface fuel loading under Alternative D

Fire Regime/Condition Class

In ponderosa pine, Fire Regime/Condition Class (FRCC) for Alternative D shows a decrease in FRCC3 acres from the existing condition to 2020 (Table 109). From 2020 to 2050, FRCC3 acres increase again, but remain below the starting point (Existing Condition). From Existing Condition though 2020, acres in FRCC1 decrease from 14 percent to 8 percent and, by 2050, have decreased to 5 percent. Overall, for ponderosa pine post treatment, both in 2020 and 2050, there are fewer acres in FRCC1 and FRCC3, but more acres in FRCC2.

The assessment for grasslands was conservative because there is little documented evidence of fire regimes of the grasslands in the project area. However, the general deterioration of the stability would be expected because so many acres have been encroached upon by trees that are too big to kill with fire. Under alternative D, grasslands would move away from desired condition, with acres of FRCC1 decreasing from Existing condition to 2020, and again from 2020 to 2050. Acres in FRCC3 move the opposite direction, increasing from existing condition to 2020, and increasing again from 2020 to 2050.

Under Alternative D, the treatment area would move ponderosa pine toward the desired condition for FRCC in terms of moving acres from FRCC3 (least desirable) towards FRCC1 (most desirable), while grasslands would move further away from desired condition. One of the variables that is important to determining FRCC is the fire return interval. Across 70 percent of the treatment area, there would be no fire. As the fire return interval gets longer, canopies close up and encroachment and ladder fuels make progress so, with no treatments of any kind modeled from 2020 to 2050, there would be a continual shift towards FRCC3.

Table 109. Fire Regime/Condition Class under Alternative D

Alternative D		Existing Condition		2020		2050	
		Acres	Percent	Acres	Percent	Acres	Percent
Ponderosa Pine	FRCC1	70,680	14	40,389	8	25,243	5
	FRCC2	136,311	27	413,983	82	227,186	45
	FRCC3	297,866	59	50,486	10	252,428	50
Grasslands	FRCC1	10,097	18	8,414	15	2,805	5
	FRCC2	40,389	72	41,510	74	44,876	80
	FRCC3	5,610	10	6,170	11	8,414	15

Fire Return Interval

Fire return intervals (FRI), as described on page 26, are a characteristic of a fire regime, and a coarse measure of the health of a system. This analysis uses running averages of acres treated b planned and unplanned fire. In reality, there would be wide fluctuations in the number of acres treated each year which would depend on weather, resource availability, public tolerance, funding, and logistics. See discussion in Alternative B under ‘Fire Return Interval’ on page 162.

Under Alternative D, the use of either fire or mechanical treatments is absolute (there are no areas that include both, it can be assumed that, for areas that receive only mechanical treatments, the FRI would be the same as for Alternative A (no treatment) and, for areas that would receive burning, the FRI would be similar to Alternative B.

Post treatment (2020), in burn only areas (178,753 acres, or 30 percent of the treatment area), the FRI would be approximately 10 years, on a trajectory towards the desired condition. In areas that would receive only mechanical treatments, the FRI would be 80 years, departing further from desired conditions of being sustainable and resilient.

By 2050, FRI in burn only areas would be approximately 20 years, departing from the trajectory it was on immediately post-treatment. In areas with only mechanical treatments, the FRI would be 160 years, highly departed from what would be a sustainable, resilient condition.

Table 110 shows the estimated fire return intervals for the proposed treatment area under different alternatives over forty years. Alternatives B and C are within the desired FRI.

Table 110. Fire Return Intervals under Alternative D

Alternative D	# of years averaged (years)	Average annual acres burned	Fire Return Interval over years averaged
Current 10 year average	10 (2001 -2010)	15,000 (2001 -2010)	40
2020 (burn only) 2020 (mechanical only)	20 (2001- 2020)	17,875 (2001- 2020)	10 (burn only) 80 (mechanical only)
2050 (burn only) 2020 (mechanical only)	40 (2001- 2050)	8,938 (2001- 2050)	20 (burn only) 160 (mechanical only)

Emissions/Air Quality

This alternative would meet desired conditions for air quality. Under this alternative, 17,875 acres would need to burn each year to meet a 10 year fire return interval.

There is an inverse relationship between short term and long term smoke impacts to communities. Alternatives that reduce fire treatment also reduce short term smoke impacts, which are indirect effects from prescribed fire. However, alternatives that increase short term smoke impacts would likely reduce longer term impacts because the potential for undesirable wildfire behavior and effects is reduced, including the potential tons/acre of emissions. Uncharacteristic wildfires produce more concentrated and toxic smoke impacts.

Alternative D proposes to treat 388,526 with mechanical thinning treatments only. However, at some point, these acres (as with most acres within the treatment areas) are likely to burn with wildfire. Under those circumstances, there would be with little warning, little control over the smoke, and a great deal more smoke that if prescribed fire was used. Figure 63 shows emissions potential in pounds/acre that would be expected from areas that began with similar fuel loading, but were given different treatments before burning under conditions that would produce extreme fire behavior (details in Appendix F). Columns 2 and 4 represent restoration treatments that include removal of the most flammable surface fuels with prescribed fire – duff, litter and CWD. Column 1 represents no treatment, and column 3 represents a treatment that only removes the large fuels and canopy fuels (mechanical thinning), and in which surface fuel loading has increased. The error bars show that they are statistically identical. This chart shows only surface fuel emissions, because canopy fuels are only a minor component of most prescribed fire but, when they burn in wildfire, they generally burn up in a short period during the passage of the flaming front.

Alternative D proposes to thin but not burn 70 percent of the treatment area. That means that approximately 388,526 acres would produce emissions more like column three, and 178,753 (burn only) would be in column two. Emissions from prescribed fires would be still less, though they would occur cyclically.

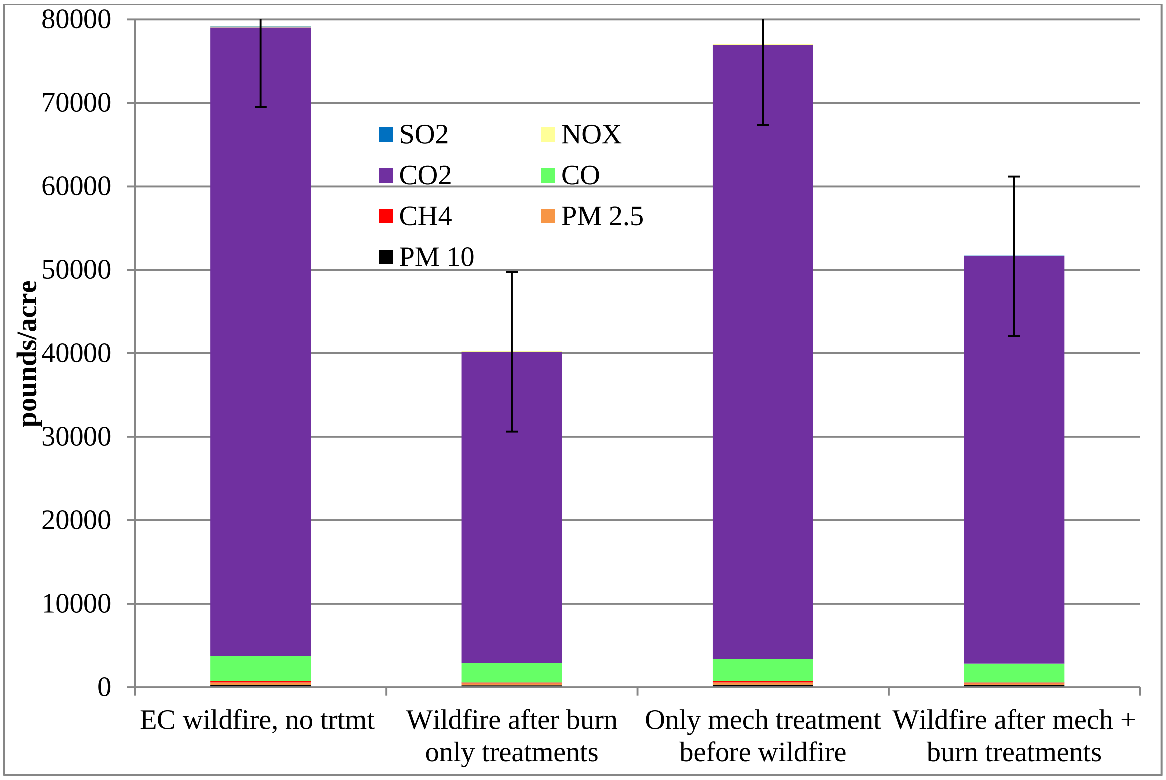


Figure 63. Emissions from surface fuels burning in wildfires after various treatments

Ecological effects of smoke

From an ecological perspective, smoke effects are important to the germination of many native plants (Abella 2006; Abella et al. 2007; Abella 2009; Keeley and Fotheringham 2002; Schwilk and Zavala 2012), and may be a natural control for mistletoe and other tree infections (Parmeter and Uhrenholdt 1975; Zimmerman et al. 1987). This Alternative would significantly decrease the area over which smoke could maintain its ecological roles.

Stream/spring restoration

Effects on stream/spring restoration would be identical to those in Alternative B. See discussion on page 161.

Roads

Road effects would be identical to those in Alternative B. See discussion on page 161.

Unavoidable Adverse Effects, Irreversible and Irretrievable Commitment of Resources

Unavoidable Adverse Effects, Irreversible and Irretrievable Commitment of Resources would be almost identical to those in Alternative B. See discussion on page161.

Climate Change

Based on current projections, the primary regional-level effects of climate change that are expected to affect fire regimes in the Southwest include:

- warmer temperatures
- decreasing precipitation
- decreased water availability with increased demand
- increased extreme disturbance events, such as insect outbreaks or widespread drought (Williams et al. 2010).

Changes in key climate variables affect the seasonality of hydrologic regimes and the length of the fire season. In the west, fire season has increased by 78 days since the mid-1980s (Westerling et al. 2006). Disturbance, such as uncharacteristically severe fire, facilitates the introduction and spread of invasive species, which increase extinction risks for native species and disrupt ecosystem processes and functions. Native species' constitute the fuels that exist in the historic fire regimes, so effects to native species affect fire regimes. These effects challenge the objectives of: reducing risk to communities and natural resources from uncharacteristically severe wildfires; reducing adverse impacts from invasive species; and restoring and maintaining healthy watersheds and diverse habitats. The changing climate is already altering species ranges and has the potential to alter ecosystem structure in the future.

Carbon sequestration is an important dynamic of climate change that has been and continues to be affected by current and past forest management. Fire suppression practices have changed the dynamics of fire in ponderosa pine forests across the southwest, resulting in greater fuel-loads and increased risk of uncharacteristic fire. Although current conditions, with dense forest stands can sequester more carbon than open forests, shrublands, or grasslands, it is not a stable state. These forests are prone to increasingly large, high severity wildfires, which release a pulse of carbon emissions, shifting carbon storage from live trees to standing dead trees and woody debris (North et al. 2009). Kolb et al. (2007) have shown that biomass and carbon may fail to recover; the Horseshoe Fire was still a net carbon source fifteen years after the fire (Figure 65). Savage & Mast (2005) showed that these conditions can persist for decades.

High severity fire in ponderosa pine forests releases large quantities of CO_2 to the atmosphere (Figure 65). The emissions below are associated with ponderosa within an existing, healthy fire regime. Far more carbon is stored in the healthy ponderosa pine forest than the area recovering from a high severity fire. Figure 66 displays modeled emissions from a VSS4 stand with no mechanical treatment prior to burning.

Both thinning and prescribed burning would help to mitigate the negative impacts of stand replacing fire in dry, dense forests, by consuming less biomass and releasing less carbon into the atmosphere (Finkeral and Evans 2008, Wiedinmyer and Hurteau 2010). They found that while the treatment initially produced a 30 percent reduction in the carbon held in trees, it significantly reduced the threat of an active crown fire, which they predicted would kill all the trees and release 3.7 tons of carbon per acre in any untreated areas. Such findings are especially important when one considers that climate change is expected to make the conditions for uncharacteristic fire and insect outbreaks even more prevalent in the western United States. Thinning, prescribed burning, or allowing wildfires that produce only low to moderate severity effects reduces on-site carbon stocks and releases carbon into the atmosphere at a lower rate than high severity fire.

Fuel treatments (e.g. thinning, prescribed fire) as identified in the proposed action, promote low-density stand structures, characterized by larger, fire resistant trees. This strategy should afford for greater carbon storage in southwestern fire adapted ecosystems over time (North et al. 2009;

Hurteau and North 2009). Although fire-excluded forests contain higher carbon stocks, this benefit is outweighed in the long term by the loss that would result from uncharacteristic stand replacing fires (Hurteau et al.2011) exacerbated by a changing climate and denser forests if left untreated. Woods et al. (2012) found that, although burn frequency affected the rate and total amount of carbon storage in a ponderosa pine forest, both 20 year and 10 year fire return intervals produced forests that were net carbon sinks, while the no action alternative forest became a net carbon source (Figure 67).

Figure 64. Top - Fifteen years after the Horseshoe Fire (photo from November 2011); Bottom – healthy ponderosa pine forest

Figure 67 displays carbon storage per acre comparing a no action 'baseline' scenario with 10 and 20 year fire return intervals in a ponderosa pine forest of northern Arizona (adapted from Woods et al. 2012).

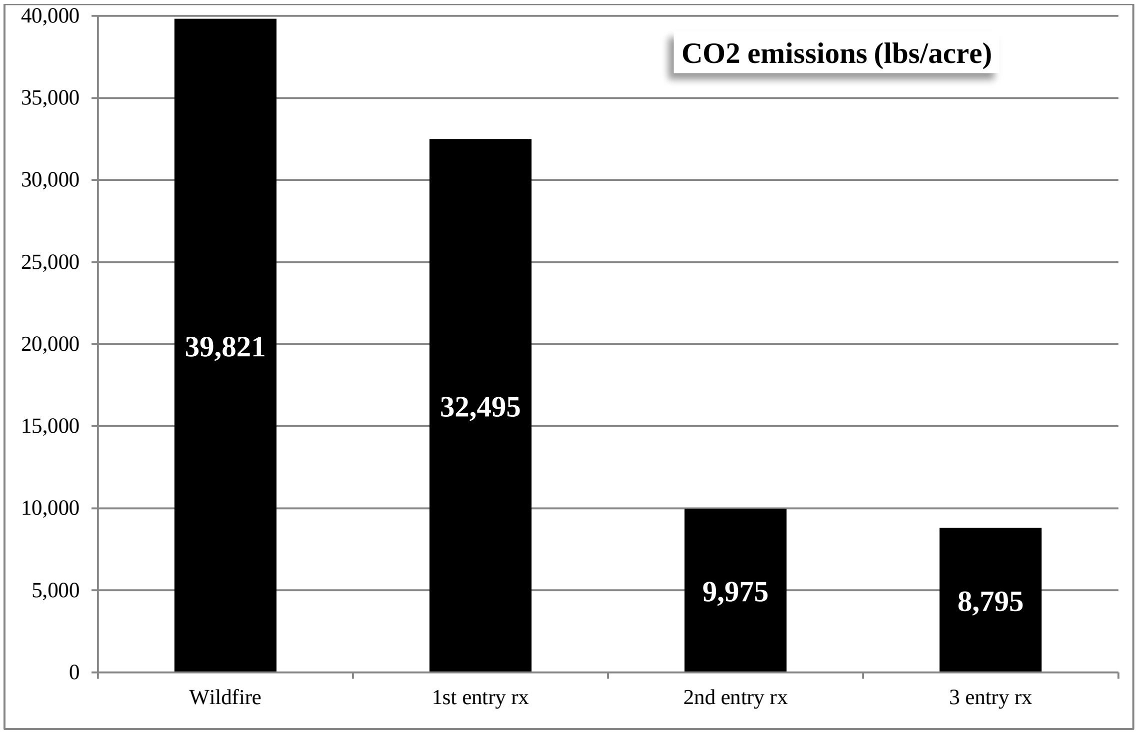


Figure 65. Modeled Co2 emissions from a typical stand with no mechanical treatment prior to burning

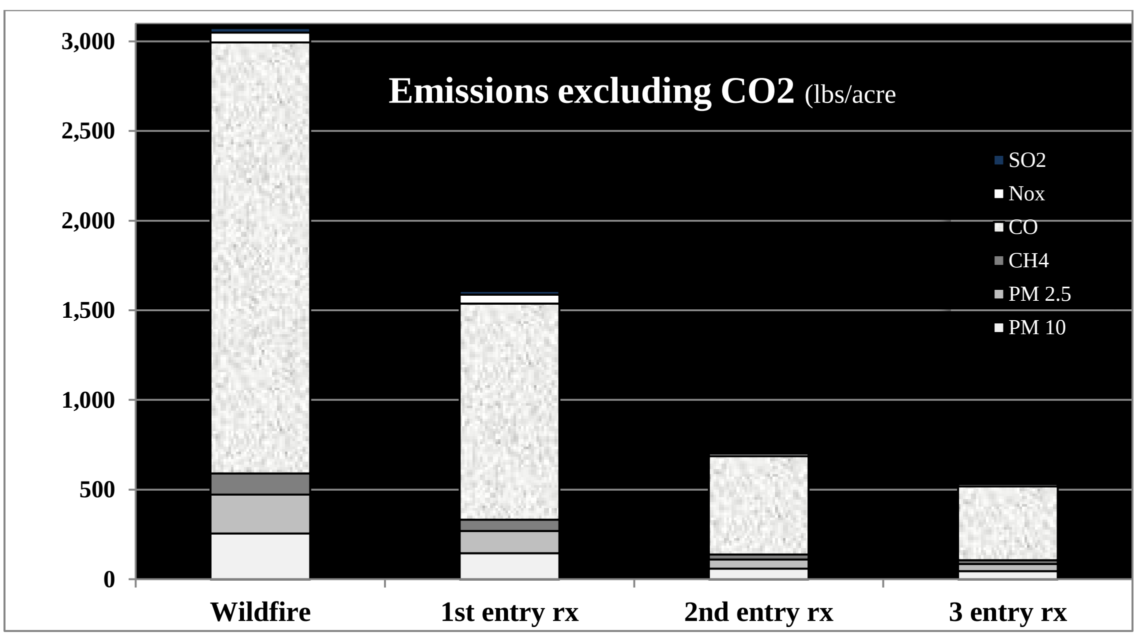


Figure 66. Modeled emissions from a typical stand with no mechanical treatment prior to burning

In the long term (e.g.100 years) the action alternatives would create more resilient forests, less prone to stand replacing events and subsequently able to store more carbon by an increased availability of live (vs. Dead) trees, longer lived wood products (in the form of large trees), and energy products created from resulting slash which are used in place of fuels (North and Hurteau 2011, Sorenson et al. 2011, Woods et al. 2012). Not all forest products sequester carbon equally. For example, products with longer on average lifespans (e.g. houses), have a greater potential to store carbon than short lived products such as fence posts. In addition, biomass products created from slash can be used in place of fossil fuels greatly reducing carbon emissions into the atmosphere (Ryan et al.2010). Wood products which substitute standard building materials such as steel and concrete produce far less greenhouse gas emissions during their production while simultaneously sequestering carbon (Ryan et al.2010). Thoughtful incorporation of carbon effects in landscape scale planning should help implementation of 4FRI actions improve the ability of the project area to store carbon in a stable condition.

Thinning and burning, as proposed at various levels in all action alternatives would:

- temporarily lower the amount of biomass in the forest and, thus, the amount of carbon the forest sequesters over the **short term**
- reduce the amount of competition for water and nutrients, allowing the remaining trees to grow larger and, subsequently, sequester more carbon over the *long term*
- works with the ecology of the ponderosa pine system to restore a condition in which carbon is stored in its most stable form within the vegetation and soil
- softens the effects of uncharacteristic disturbances (e.g. wildfires, insects, disease), allowing natural disturbances (e.g. Low-severity surface fires) to play their essential roles

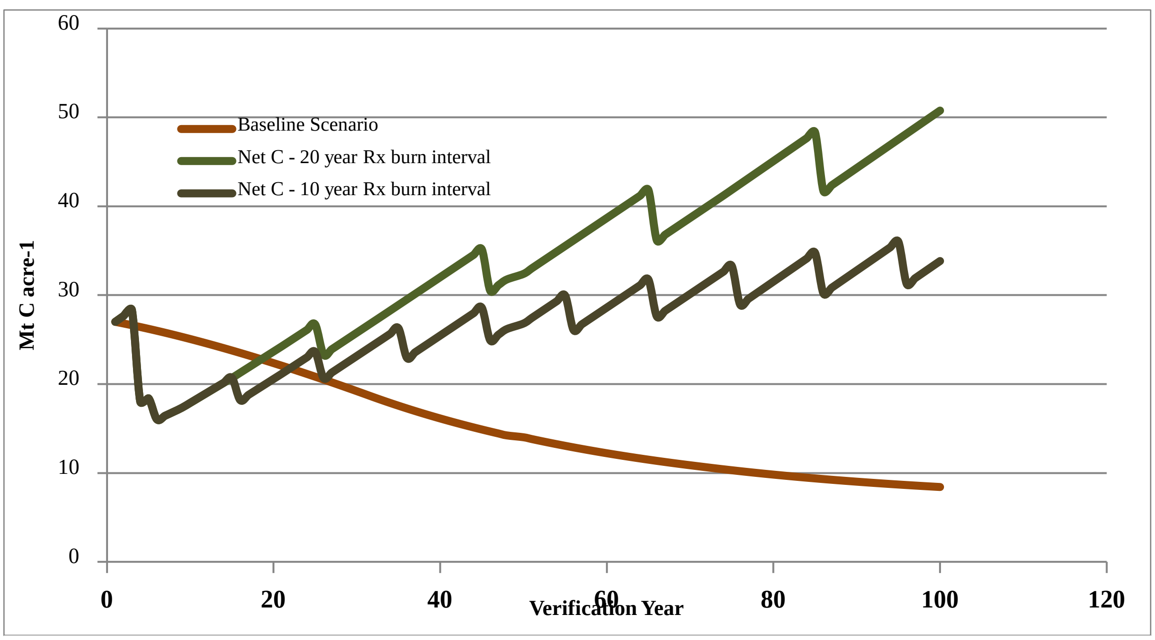


Figure 67. Carbon storage per acre comparing a no action baseline scenario with 10 and 20 year fire return intervals

Cumulative Effects – All alternatives

Spatially, cumulative effects of projects and wildfires are considered within the 988,764 acre project area, the South Rim of the Grand Canyon National Park, and the Coconino NF. The treatment areas in RU6 and the four contiguous restoration units to the south of RU6 (1, 3, 4, and 5) are separated by over 23 miles, so projects and wildfires affecting Restoration Unit 6 (RU6) or the Southern EIS area (SEIS) are discussed separately. For the SEIS, the effects of wildfires and other project are considered for ~15 miles south and west of the Project area because prevailing winds during fire season generally have a western, southwestern, or southerly component to them, so fires burning in those areas have potential to burn into the project area (Figure 68). Some of the smallest fires shown were not included in this analysis, nor are the fires from 2010 (such as the Schultz Fire), though they are included in the acres. All fires included occurred from 2001 through 2010 and are at least 100 acres.

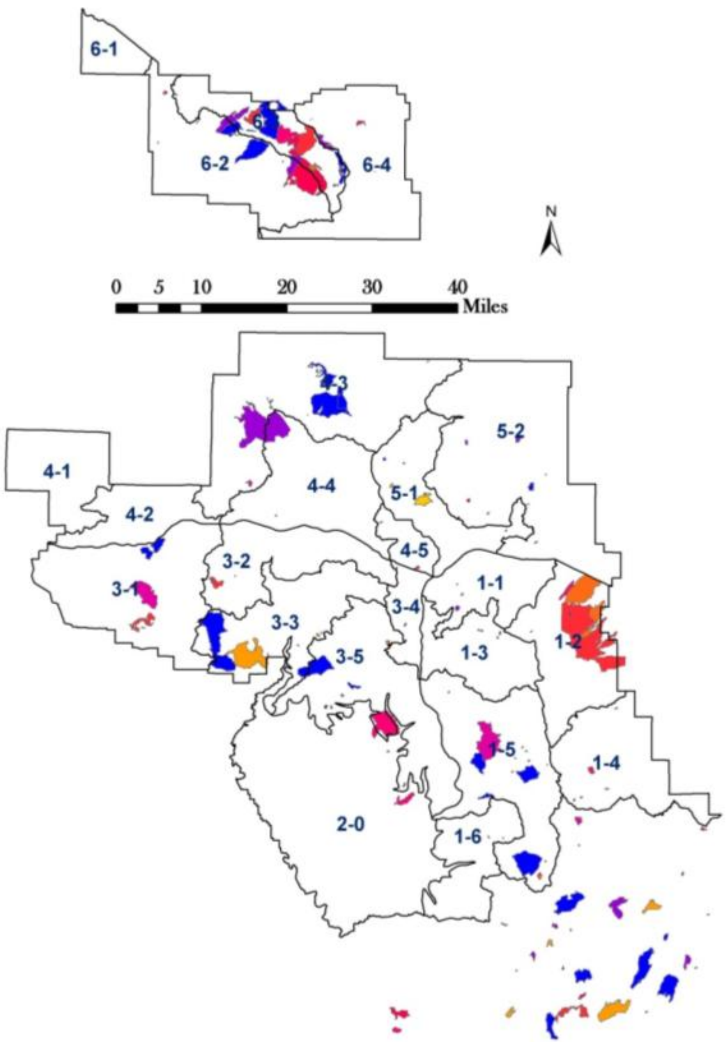


Figure 68. Wildfires used for cumulative effects analysis with Restoration Units and Subunits

The effects of past treatments and wildfires within the area shown in Figure 68 could affect if and how wildfires burn into the treatment area. Vegetation/fuels in treated/burned areas are more likely to produce surface fires, which are easier to manage and are likely to produce effects that are beneficial to the ecosystems.

Cumulative effects include the effects of wildfire and vegetation management activities (mechanical treatments, prescribed fire and road decommissioning) on fire behavior and fire effects, including air quality. The time frame considered is approximately 10 years in the future at which time the majority of the actions proposed will have been completed and fire effects from prescribed fire and the effects of treatment on potential wildfire behavior should be measurable. Assumptions include that approximately 33 percent of acres burned in wildfires managed primarily for suppression and less than 1 percent of acres burned in prescribed fire, or fires specifically managed as Wildfire Use (prior to 2009) are high severity unless more specific data are available.

For the Environmental Consequences and Affected Environment analyses, canopy characteristics and surface fuel loading were evaluated for assessing movement towards desired conditions because they are indicators of potential fire behavior and effects and are used for modeling potential fire behavior. Fire Regime/Condition Class and Fire Return Interval were also used as coarse indicators of the departure of the treatment area from desired conditions, but estimating fire return intervals (needed to calculate FRCC) for a single project would not be a good comparison with what was calculated for the entire 4FRI treatment area because of the difference in scale. Specific data are not available for most other projects. However, the intent of considering canopy characteristics and surface fuel loading was to evaluate potential fire behavior and effects. For projects included in this cumulative effects analysis, the treatments and the project objectives were considered as they relate to fire behavior and fire effects.

Cumulative Effects –Past Vegetation Management Activities and Wildfires

Restoration Unit 6 (RU6)

Vegetation treatments and wildfires near, adjacent to, and within the project area have contributed to shaping the existing vegetation conditions for the treatment area with prescribed fire and/or mechanical treatments. There are eight projects which were completed near, adjacent to, or within the project area in RU6 that have affected potential fire behavior and effects in the treatment area (Table 111). An additional 3 projects were considered, but eliminated from analysis because of incomplete data.

Table 111. Estimated acres of vegetation management activities within the EIS analysis area of RU6

Restoration Unit 6		Acres	
Project Name	**Year***	**Thinning**	**Broadcast burn**
Hull		876	876
Long Jim	2005	913	1175
Scott	2001	721	9,434
Ten X	2004	1,780	700
Topeka	2004	1,100	1,100

Restoration Unit 6		Acres	
Project Name	**Year***	**Thinning**	**Broadcast burn**
Tusayan East	2002	2,600	2,600
Tusayan South	2000	1,970	1,970
Tusayan South/Boggy Tank	2000	0	2,948
Upper Basin Burn Project***	2000	0	1884
Grand Canyon NP prescribed fires (South Rim)	2001 - 2010		18,970
	Total	**9,960**	**41,657**
****Footprint acres =**			**42,737**

*Grassland acres were counted only if the objectives specifically mention 'grassland' and acres of 'grasslands' treated could be estimated from the available information.

**'Footprint acres' includes only the largest footprint of a project. For example, for the Russell Project, there would be 8,000 burned, 5,000 of those acres would also be thinned. The footprint of the project would be the 8,000 acres.

Within RU6, near, adjacent to, or within the treatment area, there are approximately 42,737 acres on which projects were completed within the last 10 years that included mechanical thinning and/or prescribed burning and have, or may, affect potential fire behavior and effects within the treatment area. The Scott and Hull projects totaled a little over 10,000 acres in one block in the eastern and northeastern part of the treatment area within RU6. Both projects included thinning and prescribed fire, and decreased the potential rate of spread and potential for crown fire for areas downwind, adjacent, or upslope. The Scott project was pre-commercial thinning in 2001. On the west side, there are approximately 10,000 acres of vegetation projects which surround the airport and the town of Tusayan to the east and north, as well as being adjacent to the Grand Canyon Railroad and less than four miles from Grand Canyon Village. Objectives of these projects include fuels reduction, maintenance burning, recreating historic stand conditions in PJ (mixed severity), and reducing the risk of stand replacement fire and the rate of spread, intensity, and severity of wildfires that do occur. In general, all of these projects would decrease the potential for stand replacement fire in ponderosa pine, as well as the potential rate of spread, increasing the decision space for how to manage wildfires that occurred in the vicinity. For the action alternatives (B, C, and D), these actions have the potential to increase the size and burn windows for proposed prescribed fires.

Many of the wildfires that burned within RU6 in the last 10 years were managed primarily for resource objectives (as opposed to being managed primarily for suppression), and produced primarily low severity effects (Table 112). Data from the Rapid Assessment of Vegetation Condition After Wildfire database (RAVG) showed that the Miller fire (managed primarily for suppression) burned with only 3 percent (89 acres) high severity. The X-Fire, burned with almost 70 percent high severity, but little of it was in ponderosa pine and, for some of the area it burned in, high severity fire is part of the natural fire regime. Using the RAVG numbers, and assuming 33 percent high severity for those that were managed primarily for suppression, and 0.01 high severity for those managed primarily for resource benefit, there would have been approximately 983 acres that burned at high severity in RU6, in the last 10 years. In these high severity areas, there was some mortality of large and old trees. There is wide variability in the severity of wildfire effects, depending on the condition of the forests when they burn, and environmental conditions at the time of the burn.

Table 112. Wildfires in Restoration Unit 6

Restoration Unit 6		
Fire Name	**Year**	**Acres**
Antelope*	2003	244
Horse*	2003	153
Camp 36*	2004	3,052
Transfer*	2004	1,058
Mudersbach*	2005	7,260
North*	2005	1,315
West*	2006	1,925
Bar*	2006	193
Newt*	2008	770
Twenty-two*	2008	1,255
X	2008	2,030
Anderson*	2009	1,238
Indian	2009	619
Miller	2009	3,160
Rae	2009	1,392
Ruby	2009	4,107
Scott	2010	458
Tank	2010	945
Wash	2010	197
Grand Canyon NP (south rim)*	2001 – 2010	647
Grand Canyon NP (south rim)	2001 - 2010	684
Total Acres	**32,702**	

*Managed primarily for resource objectives as opposed to being managed primarily for suppression.

All of the projects listed in Table 111 have decreased the potential for active crown fire and crown fire initiation on acres thinned (9,960), and the potential for crown fire initiation, and high severity effects from surface fire on approximately 41,657 acres of prescribed fire, and approximately 31,443 acres of wildfire. The combined effects of these projects and the wildfires that have burned in and near the SEIS have created a mosaic of stand conditions across parts of the EIS analysis area. These treatments and wildfires moved parts of the area proposed for treatment towards desired conditions for all alternatives.

Across the project area other projects have affected vegetation in similar ways to those described under the alternatives, though there are some variations in treatments, particularly older fuels treatments. Past mechanical and prescribed fire treatments decreased the potential for crown fire by breaking up the vertical and horizontal continuity of canopy fuels. Prescribed fire and low severity wildfires further decreased the potential for crown fire, by removing additional ladder fuels, decreasing canopy bulk density, and raising canopy base height. Maintenance burning and wildfires decreased surface fuel loading in most areas burned, decreasing the potential fire intensity for subsequent fires. Overall, the combined effects of past treatments and wildfires have decreased the potential size and severity of wildfires in areas within and adjacent to the proposed treatment areas.

Where wildfires and treatments as described above are close to, or adjacent to treatments proposed in the action alternatives (B, C, and D), they would augment the moderating effect the change in fuel structure would have on wildfires moving though the area by increasing the acres where active crown fire would not be supported. These areas may also augment the potential size and locations of burn units for the action alternatives because the moderated fire behavior in burned and/or thinned areas would allow prescribed fire to be implemented with broader burn windows and higher intensity fire while still meeting control and resource objectives.

Air Quality

Past treatments and wildfires in the last 10 years have decreased the potential emissions by removing canopy fuels, mostly from thinning on 9,960 acres, but some from wildfire and prescribed fire. Low severity fire would have consumed surface fuels, further decreasing potential for emissions on approximately 30,000 acres. Where wildfires burned with high severity (~1,259 acres in and adjacent to the project area), fine canopy fuels (needles and small twigs) were consumed leaving tree stems and branches, some of which have fallen and are now Coarse Woody Debris which have the potential to smolder for days, or weeks. From 2001 through 2010, Grand Canyon National Park implemented prescribed fire on almost 40,000 acres within the Colorado River Airshed. Approximately 19,000 acres were on the South Rim (Grand Canyon National Park), while the Tusayan Ranger District (Kaibab National Forest) completed ~136,000 acres of prescribed burning. The completion of this many acres contributes, for RU6, to a widespread lowering of potential ignitions per acre from both wildfire and prescribed fire for all alternatives, increasing the number of acres that could be burned while meeting desired conditions for Air Quality.

Southern EIS Area (SEIS)

There are over forty projects which were completed near, adjacent to, or within the SEIS (Table 113) that would have potential to affect fire behavior and effects in the treatment area for all alternatives. An additional seven projects were considered, but eliminated from analysis because of incomplete data. Two others (Blue Ridge and Fossil Creek) were not included because their location makes it unlikely they would affect, or be affected by proposed treatments.

Table 113. Vegetation activities within the EIS Analysis area of the SEIS

SEIS: 2001 - 2010 non-grassland treatments	Acres*	Acres	
Project	Year	Thinning	Broadcast burn
APS Power line	2007	167	0
APS Hazard Tree Removal	2003	0	315

SEIS: 2001 - 2010 non-grassland treatments	Acres*	Acres	
Project	**Year**	**Thinning**	**Broadcast burn**
Arboretum WUI	2000	602	602
Bald Mesa WUI	2005	457	4,451
Bill Williams Cap	2009	10	1
Blue Ridge 69kV	2005	50	1,300
Blue Ridge WJI	2001	7,500	10,549
City	2005	8,667	12,400
Clover High (385 acres all within the 'City' project)	2004	385	0
Dogtown	2004	6,029	6,029
East Clear Creek	2006	83	14,500
Eastside	2006	5,619	19,977
Elden	2006	193	0
Elk Park	2007	1,800	3,500
Flag Tank	2007	22	36
Frenchy	2003	6,529	6,529
Government Mountain/Coleman	2005	75	0
IMAX	2002	1,595	6,358
Kachina Village	2003	3,801	2,147
Kendrick	2005	2,835	2,835
Lake Mary	2005	1,845	1,400
Moqui Antelope Habitat Improvement	2006	2,990	2,990
Mormon Lake	2005	2,388	2,388
Munds Park	2009	990	2,950
Pineaire	2004	602	645
Potato Hill	2003	637	0
Rocky Park	2001	5,451	7,800
Skunk Canyon	2005	0	831
Spring Valley Urban/Wildland Interface	2002	8,165	7,900
Twin	2005	1,400	1,400
Valley	2005	0	10,245
Victorine UI	2006	1,756	8,407
Williams High Risk	2001	756	756
Woody Ridge	2004	7,987	11,184
	Total =	**81,386**	**150,425**
****Footprint Acres =**	**154,255**	**Treatment Type**	

SEIS: 2001 - 2010 non-grassland treatments	Acres*	Acres	
Project	Year	Thinning	Broadcast burn
SEIS - 2001 - 2010 grassland* vegetation treatments	**Acres**		
Project	**Year**	**Thinning**	**Broadcast burn**
Anderson Mesa	2003	0	800
Apache Maid Grassland Restoration	2004	54,528	0
Dogtown	2004	480	480
Eastside	2006	220	220
Garland Prairie	2005	500	0
IDA Grassland	2008	1,800	1,800
Lake Mary	2005	1,845	1,845
Rocky Park	2001	200	200
Slate Mountain	2010	2,250	0
South Williams Prescribed Burn #51	2005	0	290
Spring Valley Urban/Wildland Interface	2002	135	135
Twin	2005	1,400	1,400
	Total =	**63,358**	**7,970**
****Footprint Acres =**	**64,448**		

*Grassland acres were counted only if the objectives specifically mention 'grassland' and acres of 'grasslands' treated can be estimated from the available information.

*There is some overlap in the total acres

**'Footprint acres' includes only the largest footprint of a project. For example, for the Russell Project there would be 5,000 acres thinned and 8,000 burned. The footprint of the project would be the 8,000 acres.

Within the SEIS there are approximately 150,255 acres of forest and savanna, and 64,448 acres of grasslands on which projects have been implemented within the last 10 years that included mechanical thinning and/or prescribed burning and have affected, or could affect potential fire behavior and effects in the proposed treatment area.

Within and adjacent to the southeastern part of the project area, including parts of RU1, there is an almost continuous block of 8 project implemented between 2001 and 2010 that lower chance of active crown fire or high severity surface fire effects than in areas that have not been treated. In forested habitat, these projects range from 14,500 acres of prescribed fire and 1,800 acres of thinning, to 54,000 acres of thinning and 800 acre of prescribed fire in grasslands. In RU3 and RU1, adjacent to I-17, a series of treatments from south of Kachina Village and north to the lower slopes on the southwest side of Mt. Humphries were treated between 2000 and 2004. The northernmost of these treatments includes some experimental treatments (Fort Valley) that were not full treatments. These areas have grown back somewhat and, though there are still few ladder fuels in much of the area because of thinning, canopies have grown, allowing potential for undesirable fire behavior and effects. More recent treatments south of Munds Park (Rocky Park, 2009) decreased the potential for crown fire initiation. Fuels projects north and south of I-40, surround the communities of Williams, and mitigate potential effects to Bellemont and Parks. North of I-40 and west of the Peaks, scattered large projects up to 4,500 acres break up fuels on a landscape level, though there are large areas untreated between the projects. East of the peaks, north and south of I-40 is a large fuels reduction project with almost 8,000 acres of mechanical treatments, and over 20,000 acres of prescribed fire.

These large treatments across the project area would slow down the rate of spread for large fires (Finney et al. 2006), particularly in those areas that were treated with a restoration focus. Thinning along power lines creates a linear feature that helps protect the power lines in the event of a wildfire, and limits the number of starts caused by power lines (Figure 69). Developed two track roads in the thinned areas could be used as firelines for low intensity burns, facilitating subsequent prescribed fire treatments.

Figure 69. Powerline corridor in Restoration Unit 1 (April 2011)

Wildfires from 2001 to 2010 burned approximately 151,782 acres within the Southern portion of the project area. Several of the wildfires that burned within the SEIS in the last 10 years were managed primarily for resource objectives (as opposed to being managed primarily for suppression), and produced primarily low severity effects (Table 114). Data from the Rapid Assessment of Vegetation Condition After Wildfire database (RAVG) showed that the Eagle Rock fire (managed primarily for suppression) burned with only 48 percent (1,661 acres) high severity; the Schultz Fire burned with almost 56 percent (7,886 acres) high severity; the Taylor fire burned with 23 percent (794 acres) high severity, and the Birdie fire burned with 7 percent (387 acres) high severity. Using those numbers and, for the rest of the fires, assuming 66 percent low severity for the rest that were managed primarily for suppression, and 99 percent low severity for those managed primarily for resource benefit, there would have been approximately 46,607 acres (~31) that burned at high severity between 2001 and 2010. There is wide variability in the severity of wildfire effects, depending on the condition of the forests when they burn, and environmental conditions at the time of the burn. In general, severity ranges from 20 percent to 45 percent of acres burned in wildfires managed primarily for suppression, depending on the conditions at the time of the burn.

Table 114. Wildfires in the southern EIS analysis area from 2001 - 2010

SEIS					
Fire Name	**Year**	**Acres**	**Project or wildfire**	**Year**	**Acres**
Leroux	2001	1,200	Oak*	2008	473
Fry	2003	179	Oh	2008	180
Lizard	2003	5,270	Poor Farm	2008	140
Mormon	2003	2,725	Yeager	2008	470
Bargaman	2007	320	Bear	2009	350
Birdie	2007	5,016	Bow	2009	2,940
Gov. Prairie	2001	751	Brady	2009	4,000
Five Mile	2002	376	Cinder Hills	2009	256
Packrat	2002	2,800	Cross	2009	7,718
Springer	2002	874	Independence	2009	1,370
Tram	2002	197	July 4TH Complex	2009	3,084
Trick	2002	5,550	Point	2009	1,295
Jacket	2004	17,219	Raptor	2009	1,922
Morgan	2004	670	Rattle Ridge	2009	403
Webber	2004	1,400	Real	2009	1,545
Wildsteer	2004	1,220	Red	2009	2,203
Bull Run	2005	885	Reservoir	2009	156
Tater	2005	150	Taylor	2009	3,545
Brins	2006	4,317	Tucker	2009	2,600
February	2006	150	Twin	2009	908
Kennedy	2006	191	Wildhorse	2009	13,790
Knife	2006	560	89 Mesa	2010	523
La Barranca	2006	800	Bravo	2010	3,254
Pomeroy*	2006	260	Eagle Rock	2010	3,474
Sawmill	2006	300	Hardy	2010	3,026
Towel	2006	237	Hobble	2010	2,395
Woody	2006	106	Juniper	2010	470
Dutch*	2007	3,148	Ranger	2010	2,200
Radio*	2007	175	Schultz	2010	15,075
Black	2008	225	Tag	2010	355
Late	2008	140	Tuba	2010	363
Lost Eden	2008	1,500	Weir	2010	1,600

SEIS					
Fire Name	**Year**	**Acres**	**Project or wildfire**	**Year**	**Acres**
Marteen*	2008	10,789	**Total =**		**151,782**

*Managed primarily for resource objectives as opposed to being managed primarily for suppression.

The combined effects of the projects listed in Table 113 have decreased the potential for active crown fire and crown fire initiation on approximately 145,000 acres of mechanical treatments, and the potential for crown fire initiation, and high severity effects from surface fire on ~134,244 acres of prescribed fire, and ~151,782 acres of wildfire. This is true for all alternatives. As with RU6, the combined effects of these projects and the wildfires that have burned in and near the SEIS have created a mosaic of stand conditions across much of the treatment area, and adjacent areas, decreasing the potential for undesirable fire behavior and effects. The scattered large blocks of treatments with decreased fire behavior potential would slow down a large wildfire and decrease the severity of its effects.

Air Quality

As with RU6, past treatments and wildfires in the last 10 years have decreased the current potential for emissions in areas that burned with low to moderate severity. The cumulative effects of prescribed fires in on the Coconino, Kaibab, and Prescott National Forests over the last 12 years has resulted in one exceedence of NAAQS on one monitor for one day for $PM_{2.5}$ in Flagstaff in 2007. Past treatments and wildfires in the last 10 years have decreased the potential emissions by removing canopy fuels, mostly from thinning on approximately 63,000 acres, and by increased canopy base height from wildfire and prescribed fire. Low severity fire would have consumed surface fuels, further decreasing potential for emissions on approximately 151,000 acres. In some areas of high severity fire, canopy fuels were consumed leaving tree stems and branches which have the potential to smolder for days, or weeks.

Cumulative Effects – Current and Foreseeable Vegetation Management Activities

Restoration Unit 6 (RU6)

Table 115 lists approximate acres of seven projects within RU6 that are implementing mechanical and prescribed fire treatments (as of 2011) or are foreseeable and likely to impact fire behavior and effects within the proposed treatment area for all alternatives. The estimated annual acres of prescribed fire and low severity fire from the South Rim of Grand Canyon National Park are included (3,000 acres), based on trends and averages of the last 10 years. The effects are similar to what was described under RU6 in the previous section, ‘Past Vegetation Management Activities and Wildfires’ (page 228), though the locations of some projects are different, as are the acres. On the eastern side of the treatment area in RU6, there are acres adjacent to, and overlapping past treatments, as well as an additional 3,000 acres east of the treatment area. Large areas that can moderate fire behavior can be effective at slowing down wildfires, decreasing the potential for undesirable effects and behavior. An additional treatment west of the Tusayan Airport will help protect the airport and the town of Tusayan for a period of time by extending the treated area further around the airport, as well as further mitigation fire behavior adjacent to the Grand Canyon railroad and the potential for a fast moving wildfire to burn into the park.

Table 115. Current and foreseeable vegetation management activities in Restoration Unit 6

Restoration Unit 6		Acres	
Project Name	**Year**	**Thinning**	**Broadcast burn**
10X Pre-Commercial	Current	0	700
Airport Fuels	Current	2,961	2,961
Long Jim	Current	0	1,175
Russell	Current	5,000	8,000
Tusayan East	Current	0	2,600
Upper Basin Veg Management* (w/grassland acres)	2012	3,000	0
Grand Canyon NP fire (estimated wildfire and rx)	2012 - 2020		3,000
	Total	7,961	18,436
		****Footprint acres =**	**18,436**

*Grassland acres were counted only if the objectives specifically mention 'grassland' and acres of 'grassland' treated can be estimated from the available information.

**'Footprint acres' includes only the largest footprint of a project. For example, for the Russell Project, there would be 5,000 acres thinned and 8,000 burned. The footprint of the project would be the 8,000 acres.

Air Quality

Prescribed fires implemented for the projects listed in Table 115 will comply with the regulations and requirements of the Arizona Department of Environmental Quality (ADEQ), as will prescribed fires within Grand Canyon National Park. There are ~18,436 acres of prescribed burns planned in RU6, and Grand Canyon National Park by 2020. There is potential for both the Colorado River Airshed and the Little Colorado River Airshed to be impacted by fires occurring within RU6 and Grand Canyon National Park. It is likely that similar burn windows will be needed for many of the fires in the park and parts of RU6.

Southern EIS Area (SEIS)

There are approximately 207,000 acres of mechanical treatments and 240,000 acres of prescribed fire ongoing or planned within the SEIS that could impact fire behavior and effects within the proposed treatment area for all alternatives (Table 116). Surrounding the community of Flagstaff is a block of projects which include over 35,000 acres of mechanical treatments and almost 55,000 acres of prescribed fire. In addition to past projects surrounding the community of Williams, an additional ~17,700 acres of mechanical treatments and ~32,000 acres of prescribed fire are being implemented and planned. Adjacent to the southern border of RU1, ~34,000 acres are being planned for both prescribed fire and mechanical treatments. These ongoing projects will augment the effectiveness of past projects designed to minimize the potential for high severity fire near and/or in Williams and surrounding homes. Ongoing maintenance thinning along power lines creates linear features that help protect the power lines in the event of wildfire, and limits the number of starts caused by power lines (see Figure 69). Developed two track roads in the thinned areas could be used as firelines for low intensity burns. In higher intensity burns, there may be thick smoke that can create a path for electricity to arc from the power lines to something nearby.

Table 116. Current and foreseeable vegetation management activities in the SEIS

SEIS - Current & Foreseeable Projects (forested)		Acres	
Project	Year	Thinning	Broadcast burn
A-1 Mountain	2012	0	8,274
Arboretum	Current	0	602
Aspen Restoration Project	2012	402	402
Bill Williams Mtn Restoration	2012	11,650	15,200
Blue Ridge Fire Risk	Current	50	50
Camp Navajo (entire project is within DOD AZ ARNG)	2012	968	1,498
Community Tank	2011	185	185
City	2005	600	600
Clint's Well Forest Restoration	2012	12,733	16,509
Community Tank	2011	865	865
DOD AZ ARNG	2012	17,049	17,049
Dogtown	Current	1,700	1,700
Eastside	2006	7,819	20,197
East Clear Creek	Current	1,562	4,700
Elk Park Fuels	Current	4,700	6,400
Frenchy Vegetation/Fuels Management	2003	2,790	6,529
GFFP	2012	535	535
Grapevine Canyon Wind Project; ROW & Switchyard	2012	2,212	0
Hart Prairie	Current	9,815	9,815
Jack Smith/Schultz Fuel Reduction & Forest Health	2007	2,000	2,000
Kachina Village Forest Health Project	2003	3,801	2,147
Long Valley Experimental	2012	953	706
Mahan-Landmark	2012	33,747	33,747
Marshall	2012	7,120	2,580
McCracken	2012	15,262	17,337
Mormon Lake	Current	0	2,388
Mountainaire HFRA Project	2006	13,363	15,109
Munds Park	Current	0	2,950
Skunk Canyon Prescribed Fire Fuel Reduction	2006	0	831
Slate Mountain	2010	2,250	0
South Williams Prescribed Burn #51	Current	0	290
Tornado Rehab	2011	18,756	0

SEIS - Current & Foreseeable Projects (forested)		Acres	
Project	**Year**	**Thinning**	**Broadcast burn**
Turkey/Barney	2012	17,835	17,835
Twin	Current	0	1,400
Upper Beaver Creek	2010	1,562	4,700
Western Area Power Admin	2012	4,584	0
Wing Mtn.	2012	9,561	22,327
Woody Ridge	Current	0	11,184
Wupatki, Sunset Crater and Walnut Canyon NM	Current	1,104	2,956
Total =		**204,368**	**242,617**
*****Footprint Acres =**		**286,375**	
SEIS - Current & Foreseeable Vegetation Projects (grasslands*)		**Acres**	
Project or wildfire	**Year**	**Thinning**	**Broadcast burn**
Marshall	2012	3,680	3,680
Wing Mtn.	2012	629	629
	Total =	**4,309**	**4,309**
	****Footprint Acres =**	**4,309**	

***Grassland acres were counted only if the objectives specifically mention 'grassland' and acres of 'grassland' treated can be estimated from the available information.**

****'Footprint acres' includes only the largest footprint of a project. For example, for the Russell Project, there would be 5,000 acres thinned and 8,000 burned. The footprint of the project would be the 8,000 acres.**

Across the project area other projects have affected vegetation in similar ways to those described under the action alternatives, though there are some variations in treatments. Current, ongoing, and reasonably foreseeable management activities including mechanical and prescribed fire treatments would decrease the potential for crown fire by breaking up the vertical and horizontal continuity of canopy fuels. Overall, for the action alternatives, the combined effects of current, ongoing, and reasonably foreseeable management activities would augment the effects of proposed treatments to decrease the potential size and severity of wildfires. These areas also may augment the potential size and increase the flexibility of locating burn units, because the moderated fire behavior in burned and/or thinned areas would allow prescribed fire to be implemented with broader burn windows and higher intensity fire while still meeting control and resource objectives.

Air Quality

Emissions from 244,000 acres of prescribed fire will be managed in compliance with regulations and requirements of the Arizona Department of Environmental Quality (ADEQ). There is potential for air quality impacts to the Peaks and Sycamore Canyon Wilderness areas, the Colorado River Airshed, the Little Colorado River Airshed, and the Verde River Airshed from fires occurring in the SEIS.

Cumulative Effects – Alternative A

Alternative A would continue to maintain RU6 with potential for high severity fire effects, though the effects would be mitigated to some degree by past wildfires and projects, and current, and reasonably foreseeable projects. Alternative A would not contribute to improving the structure, composition, and patterns within the area proposed for treatment. Within the EIS area, there would be some improvement from the projects listed above (Table 116). It would not put the ponderosa pine forests, or the vegetative communities that are cohorts of ponderosa pine on trajectories towards being resilient and sustainable. The treatment area would continue to become less adapted to fire, increasing the potential for undesirable fire behavior and effects when wildfires do occur.

Air Quality

Air quality would be unaffected by prescribed fire from the treatment area, but would be affected by prescribed fires from projects listed in Table 115 and Table 116. Emissions from 244,000 acres of prescribed fire from current, ongoing, and reasonably foreseeable projects will be managed in compliance with regulations and requirements of the Arizona Department of Environmental Quality (ADEQ). Wildfires occurring in the untreated areas would produce more emissions in areas that were not treated than in areas that were treated, and could augment the effects of prescribed fires (from current and foreseeable projects) on air quality. Areas with potential for impact would be the Colorado River Airshed, the Little Colorado River Watershed, and the Verde River Watershed. Class 1 airsheds that could be affected include Grand Canyon National Park, Sycamore Canyon Wilderness Area.

Cumulative Effects – Alternatives B & C

Treatments proposed in Alternative B would move 509,195 more acres toward desired conditions for fire behavior and effects across the project area. When considered with past wildfires, and past, current, ongoing, and reasonably foreseeable management activities, would augment the effects of proposed treatments on large (project area), mid (restoration unit), and small (subunit) scales, creating mosaics at all scales of potential fire behavior and effects, dominated by low severity fire. The proposed treatments would fill in most of the acres between past, current, ongoing, and foreseeable management activities, creating a more cohesive restored landscape across the project area.

Treatments proposed in Alternative C would move 562,380 more acres toward desired conditions for fire behavior and effects across the project area. Most of the effects would be identical to Alternative B, with the exception of PACS and grasslands that would be treated, further augmenting the cumulative effects of the proposed actions and past wildfires, and past, current, ongoing, and reasonably foreseeable management activities.

Air Quality

All prescribed fires would be implemented in compliance with ADEQ regulations and requirements as well as forest plan direction to meet legal standards and provide for public safety. Emissions from prescribed fires proposed in Alternatives B and C would utilize many of the same burn windows that the ~244,000 acres of current, ongoing, and reasonably foreseeable projects would use. However, the increased acres of prescribed fire would allow more flexibility, and may make it possible to burn more acres at once with the same impacts. Areas with potential for impact would be the Colorado River Airshed, the Little Colorado River Watershed, and the Verde River Watershed. Class 1 airsheds that could be affected include Grand Canyon National Park, Sycamore Canyon Wilderness Area. As more acres are treated, there will be broader burn windows, potentially resulting in more days of prescribed fire and days of air quality impacts.

Cumulative Effects – Alternative D

Treatments proposed in Alternative D would move 489,029 more acres toward desired conditions for fire behavior and effects across the project area. The proposed treatments would fill in most of the acres between past, current, ongoing, and foreseeable projects, creating a more cohesive restored landscape across the project area. 388,526 acres would not move as far toward desired conditions, and some areas would retain potential for crown fire and high severity surface fire as surface fuel loading increased following thinning, increasing the potential intensity of surface fires.

Air Quality

Restoration Unit 6 (RU6) is adjacent to the Grand Canyon National Park, one of the most heavily visited national parks in the United States, as well as being a Class 1 airshed. Burn windows for the burns proposed in the action alternatives would be the similar to those for the current, ongoing, and reasonably foreseeable future actions. The potential for undesirable air quality impacts from prescribed fire would be the same as other alternatives because all prescribed fires are regulated by the same laws regarding allowed emissions. Areas with potential for impact would be the Colorado River Airshed, the Little Colorado River Watershed, and the Verde River Watershed. Class 1 airsheds that could be affected include Grand Canyon National Park, Sycamore Canyon Wilderness Area. In most of the area that was thinned and not burned (388,526 acres), there would be potential for greater wildfire emissions from increased surface fuel loading. When combined with emissions from current, ongoing, and reasonably foreseeable management actions, there would be potential for greater air quality impacts when wildfires burned in these areas than in areas that had been previously treated with low severity fire. That could result in fewer acres of desirable fire (because NAAQs are already too close to the limit for another permit to be issued for prescribed fire or to allow a wildfire to be managed for something other than full suppression).

Cumulative effects - Climate change – All Alternatives

Climate change is expected to result in extreme weather conditions, with periods of drought and higher temperatures, making conditions for uncharacteristic fire and insect outbreaks even more prevalent in the western United States. As a part of current, ongoing, and reasonably foreseeable management actions, there would be up to ~244,000 acres of prescribed fire and ~210,000 acres of mechanical project area. Thinning, prescribed burning, or allowing wildfires that produce only low to moderate severity effects reduces on-site carbon stocks and releases carbon into the atmosphere at a lower rate than high severity fire.

Summary of Alternatives

This report analyzed the effectiveness of four alternatives for modifying composition, pattern, and structure to restore healthy ecological functions and reset the current trajectory of the treatment areas towards sustainability and resilience is what is primarily addressed in this report. Fire is a necessary component in achieving this need for change. The major vegetative community that is driving this need for change is ponderosa pine, but also affected are, aspen, grasslands, pinyon/juniper and oak. Restoring the historic fire regime plays direct and indirect roles in achieving or maintaining the desired condition for all these vegetation communities. All action alternatives move the 4FRI proposed treatment area toward desired conditions.

There are minimal differences between Alternatives B and C There are more substantial differences between Alternative D and Alternatives B/C. This can most easily be seen in estimates of the distribution of FRCC acres (Figure 70).

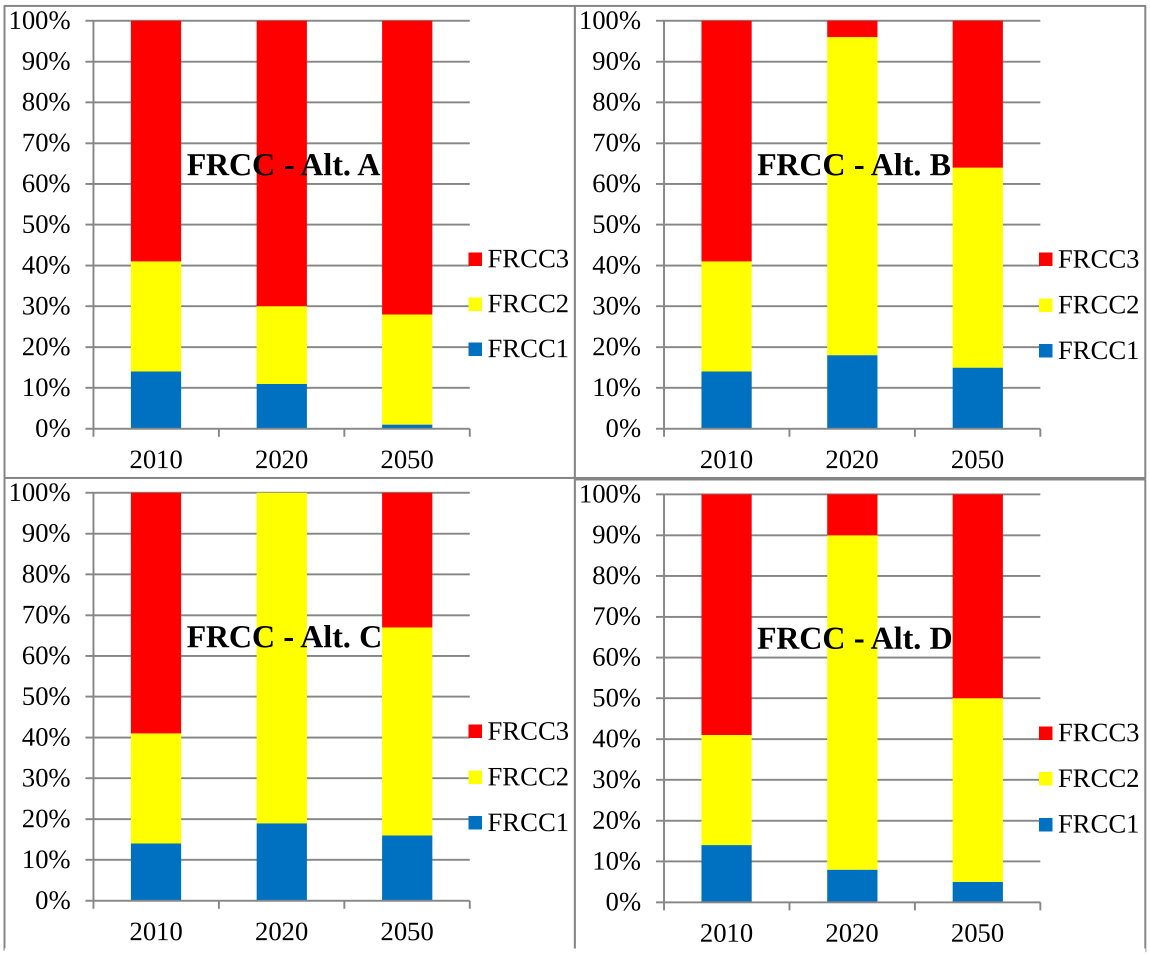


Figure 70. Percent acres in Fire Regime/Condition Classes by Alternatives over time

As shown in Table 117, among the action alternatives, Alternative C produces the most acres of surface fire, followed by Alternative B, then Alternative D, then Alternative A. Passive crown fire is less of a concern than active but, when other variables are close, it is worth considering passive crown fire in the context of both severity and its potential to become active crown fire if burning conditions were worse. Passive crown fire does not produce the same magnitude of negative effects as active crown fire because those areas that are burned with high severity are smaller, discontinuous and, in an ecological context, can help maintain forest structure and spatial patterns across the landscape. At the Restoration Unit scale shown below, both Alternatives B and C meet desired conditions for all RUs. Alternative D meets desires conditions for all RUs except RU1 (shaded cells in Table 117) for which 12% of the acres would remain at risk of crown fire.

Table 117. Modeled fire types for existing condition and alternatives by restoration unit

	RU	Surface Fire Acres	Passive Crown Fire Acres	Active Crown Fire Acres	Surface Fire Percent	Passive Crown Fire Percent	Active Crown Fire Percent
Existing Condition	RU 1	156,305	17,513	48,845	57	11	31
	RU 3	149,718	13,644	48,868	61	9	30
	RU 4	165,607	11,941	42,496	67	7	25
	RU 5	76,096	7,674	15,464	70	10	12
	RU 6	43,529	2,761	8,010	81	6	13
	Total	**380,043**	**53,533**	**170,655**	**64**	**9**	**25**
Alt. A (2020)	RU 1	90,633	18,251	46,463	58	12	30
	RU 3	92,532	14,219	42,082	62	9	28
	RU 4	111,840	11,850	41,285	68	7	25
	RU 5	52,931	7,265	10,100	70	10	13
	RU 6	37,121	2,766	3,600	85	6	8
	Total	**385,056**	**54,351**	**143,530**	**65**	**9**	**24**
Alt. B (2020)	RU 1	142,723	6,110	6,514	91	4	4
	RU 3	140,055	6,636	2,142	94	4	1
	RU 4	160,389	3,444	1,141	97	2	1
	RU 5	68,331	1,127	837	90	1	1
	RU 6	41,459	1,921	107	94	4	0
	Total	**552,958**	**19,238**	**10,741**	**94**	**3**	**2**
Alt. C (2020)	RU 1	145,200	4,607	5,540	93	3	4
	RU 3	141,029	5,890	1,914	94	4	1
	RU 4	161,469	2,939	566	98	2	0
	RU 5	68,708	894	693	90	1	1
	RU 6	41,463	1,918	106	95	4	0
	Total	**557,868**	**16,249**	**8,820**	**94**	**3**	**1**
Alt. D (2020)	RU 1	136,654	8,033	10,660	87	5	7
	RU 3	139,760	5,917	3,156	93	4	2
	RU 4	157,826	4,663	2,485	95	3	2
	RU 5	67,696	1,422	1,177	89	2	2
	RU 6	41,154	1,734	599	95	4	1
	Total	**543,090**	**21,770**	**18,077**	**92**	**4**	**3**

Alternative A: As the no action alternative, this would maintain and regress the ecosystem toward less and less sustainable and unstable characteristics. Canopies will continue to close and provide more and more contiguous fuel across the landscape (Figure 71) while overall canopy fuels (canopy bulk density, canopy base height) decrease, setting up forests for conditional crown fire (Figure 72 and Figure 73). Alternative A would maintain 34 percent of the area with potential for high severity fire effects from crown fire, while Alternatives B, C, and D reduce this potential to 5 percent and 4 percent and 7 percent respectively. As canopies close up, surface fuel loading will increase so that, when wildfires do burn, more area is subject to high severity surface fire. These canopy fuel changes have detrimental effects on understory vegetation, increasingly suppress the production of forbs, grasses and shrubs. Over time it can be expected that most ponderosa pine forests will have little to no understory with only minimal light penetrating the canopy. Grasslands and savannas would continue to shrink as woody encroachment continued unchecked. Aspen would continue to decline as conifer encroachment continued, and the lack of disturbance continued to result in decreasing regeneration. The combination of abundant and contiguous canopy fuels, the lack of understory vegetation, and an already high and increasing surface fuel load, would combine with high potential for high severity fire, maintaining the area in a Fire Regime/Condition Class of 3 into the foreseeable future.

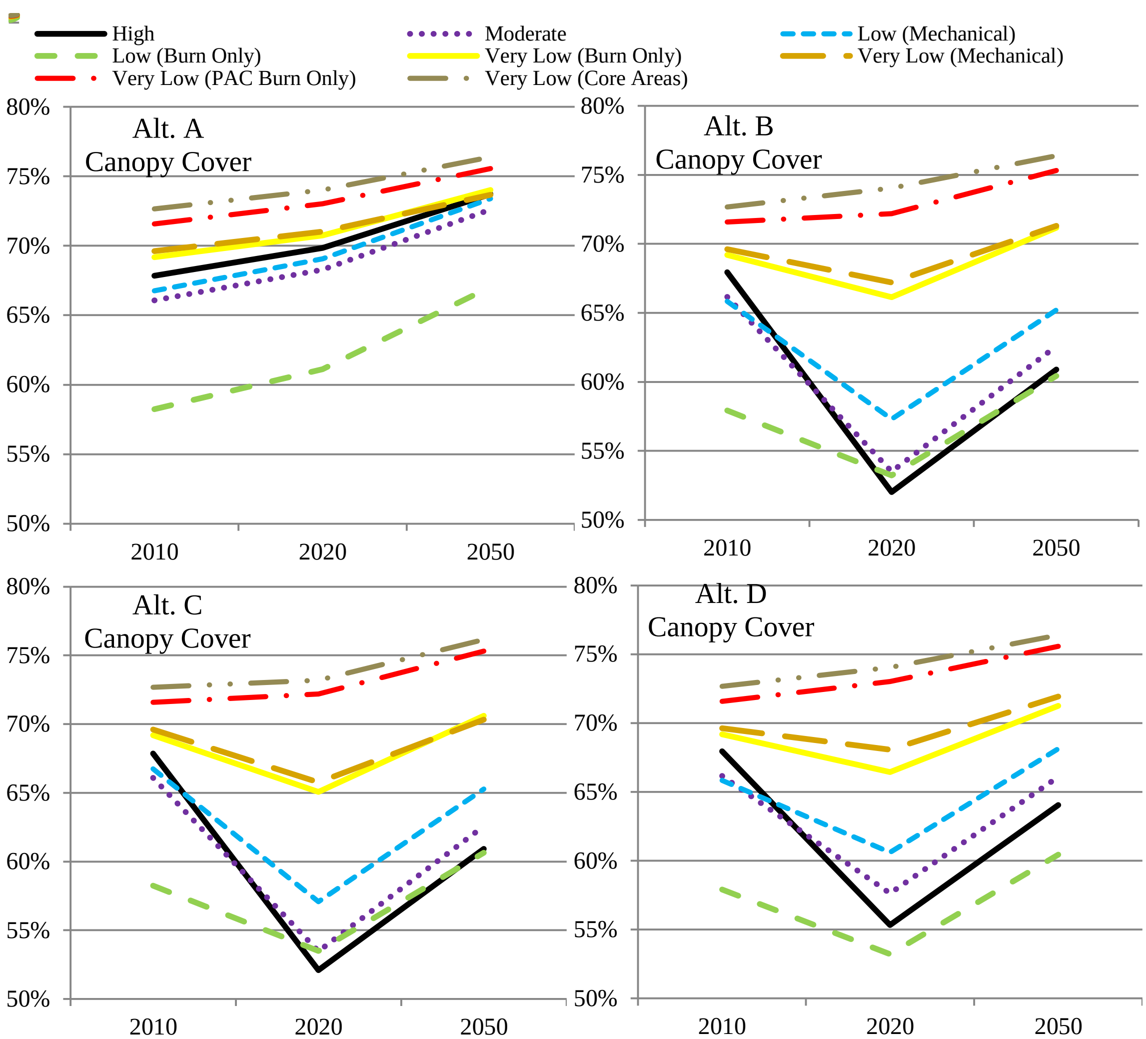


Figure 71. Comparison between alternatives of modeled changes in canopy cover

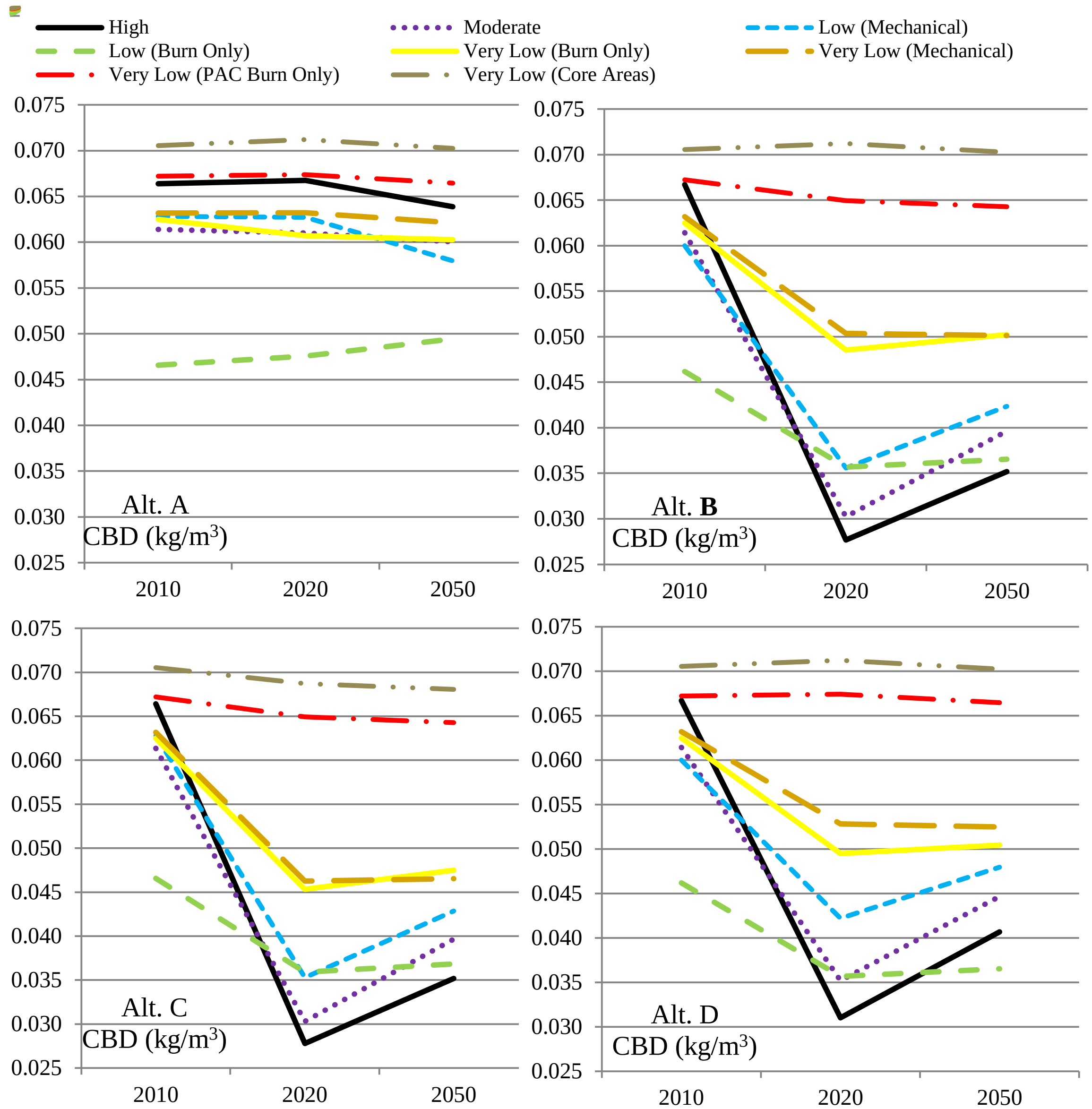


Figure 72. Comparison of effects to Crown Bulk Density between all alternatives

Alternatives B and C and D: all begin to restore the area by moving acres away from Fire Regime/Condition Class 3 (Figure 70). Alternatives B and C move the most acres the furthest towards restoration. In the case of crown fire, the differences between B and C and D are minimal on the scale of the project. However, there are a large number of small differences between them and they combine to indicate that C is would move the most acres the furthest towards desired conditions. B would be second, and D would be third. Alternatives B, C, and D would all increase fine surface fuels and species diversity in the form of understory vegetation. Much of the species diversity in ponderosa pine forests is contained in understory vegetation (Moore et al. 1999). Understory vegetation can be >10 times higher in restored openings than under even sparse ponderosa pine cover (Clary 1975), and is important in supporting fire spread similar to that under which southwestern forests evolved. Canopy characteristics directly affect the amount of sun that reaches the surface. All action alternatives decrease Canopy Cover and Canopy Bulk Density and increase Canopy Base Height, with the most change occurring in Alternative C, the

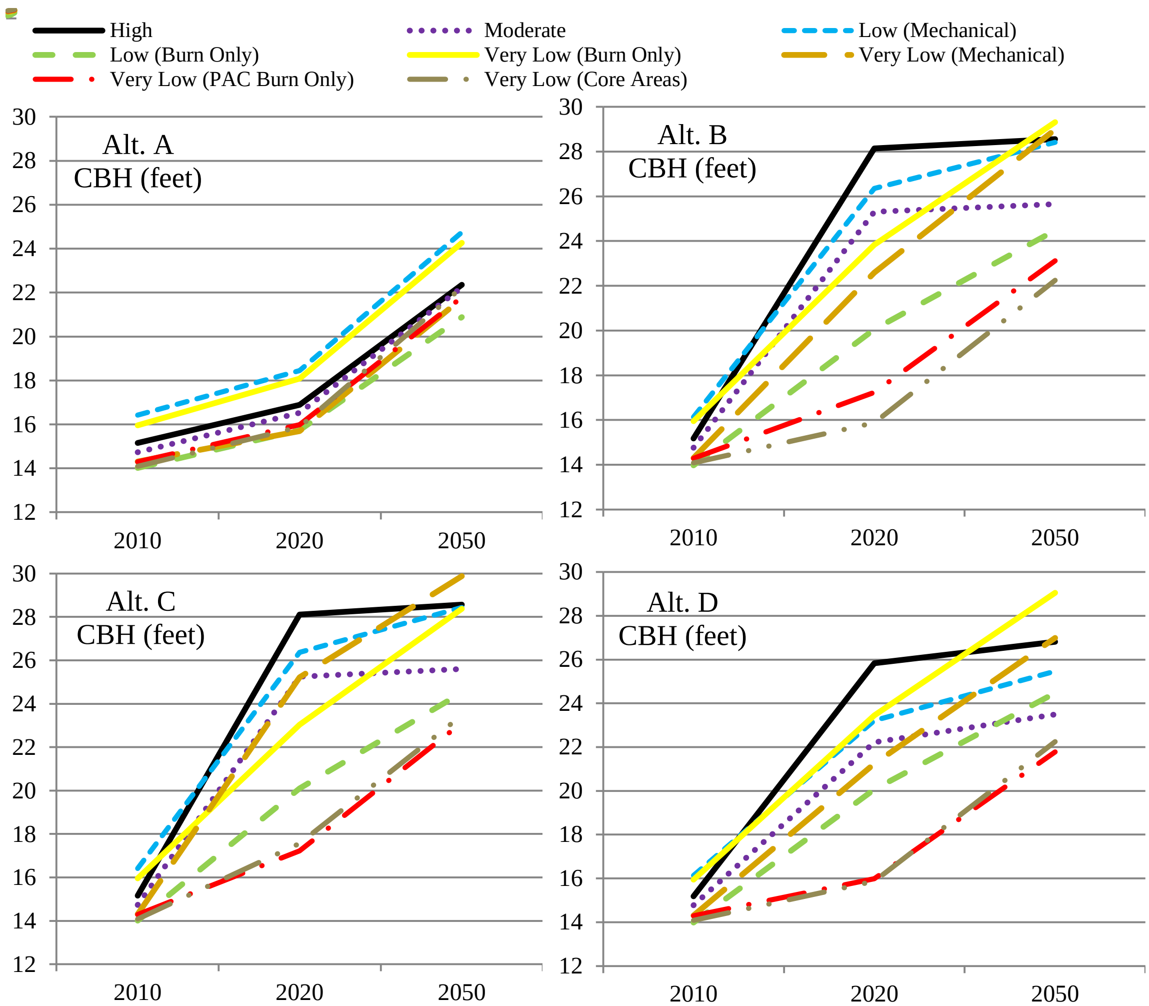


Figure 73. Comparison of effects to Canopy Base Heights between all alternatives

second most change in Alternative B, and the least in Alternative D (Figure 72 and Figure 73). In ponderosa pine systems, surface vegetation is necessary for maintaining fire regimes that are sustainable over time. More fine, herbaceous surface fuels would increase surface fire rates of spread, compared with fine surface fuel loading composed of litter and duff which are more compact and produce slower fires that can put more heat into the soil (Figure 75 and Figure 75). There are no desired conditions for total surface fuel loading, but 20 tons/acres is a reasonable recommendation for average maximum surface fuel loading for the area of this analysis (Brown et al. 2003, Passovoy and Fulé 2006, Graham et al. 1994). Historic levels were estimated to be less than 10 tons/acre for CWD alone. As shown in Figure 74 and Figure 75, Alternatives B and C move the most acres towards the lower levels of surface fuel loading.

Figure 75 shows the differences in fuel loading for the Existing Condition and all alternatives as modeled for 2020. Alternatives B and C would have the lowest percent of acres with fuel loading that exceeds 20 tons/acre, or at the 15 – 20 tons/acre level.

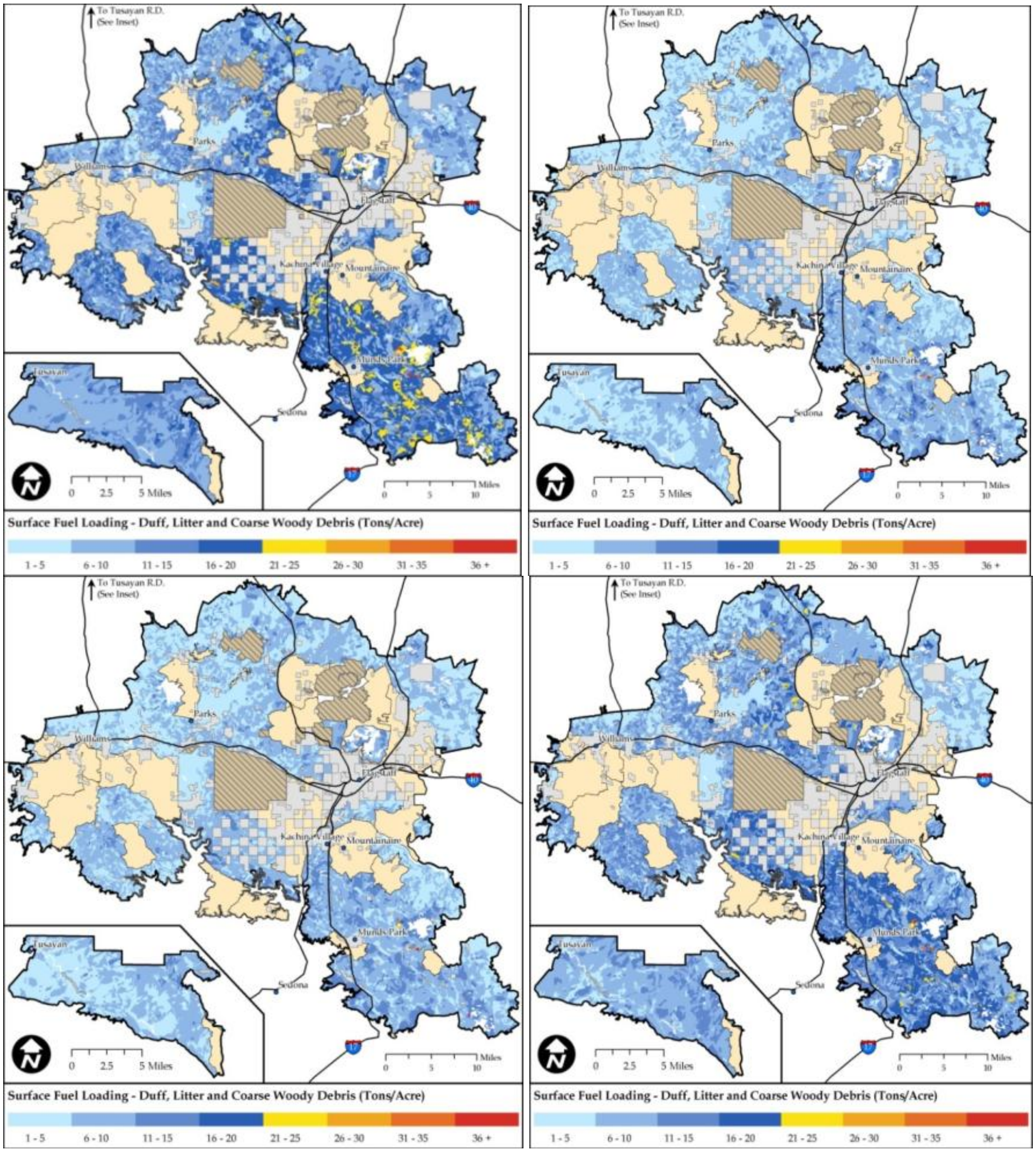


Figure 74. Surface fuel loading by alternative

The amount of biomass consumed during a wildfire is less easily mitigated than a wildfire, and the more biomass is consumed by fire the more smoke will be produced. When comparing alternatives, the action alternatives propose prescribed burning which will have an impact on surrounding communities but in a controllable manner. The outcome of these alternatives would also reduce the amount of biomass available to fire during wildfire which would reduce the impact of smoke from such a wildfire. Alternative A does not propose any prescribed burning, however, it would continue to maintain large amounts of biomass available to fire in the event of a wildfire which will have direct and most likely uncontrollable impacts on recreation and surrounding communities from emissions, as well as longer lasting fire effects.

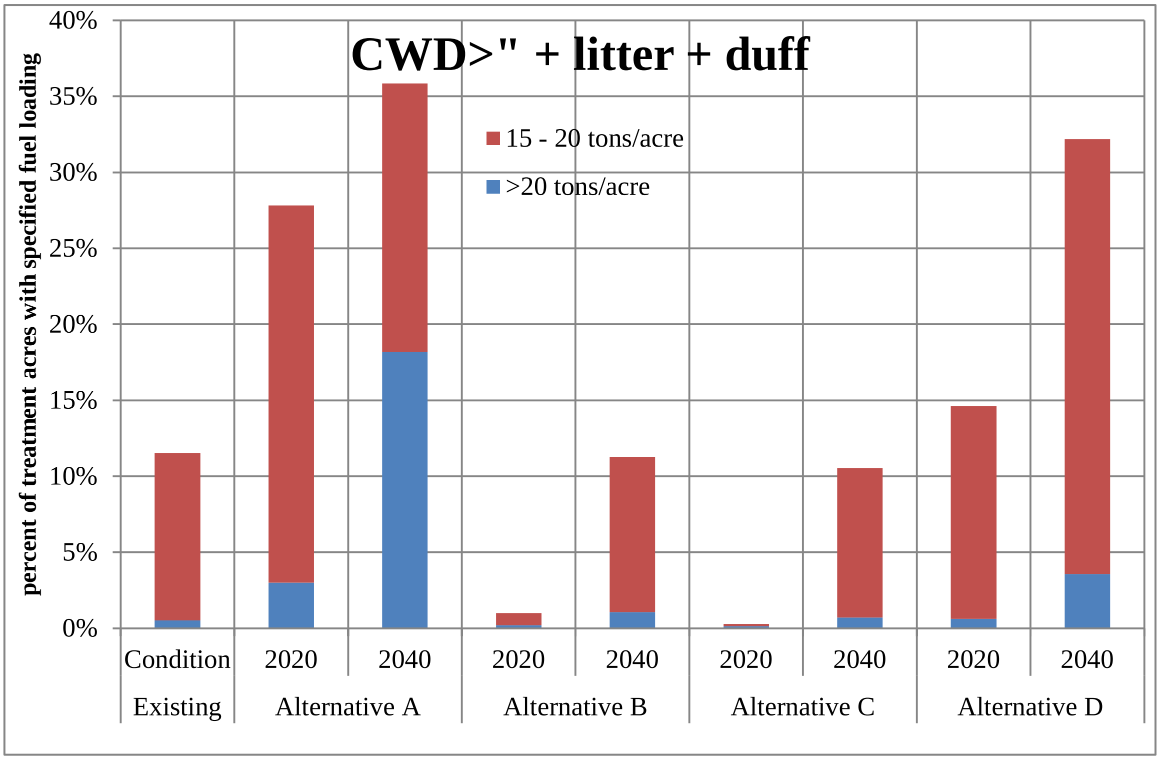


Figure 75. Percent of treatment acres at specified levels of fuel loading for each alternative

Examining cumulative effects from smoke on air quality differs from the evaluation of cumulative effects for many other resources because of the transient nature of air quality impacts from smoke. It is a relatively simple exercise to estimate the total tons per acres of emissions, but there is no calculation that correlates total annual emissions to total concentrations of emissions. As discussed earlier, air quality impacts are measured as concentrations of emissions, whether it's in µg/m3 for National Ambient Air Quality Standards (NAAQS), or in deciviews measuring visibility in Class I Areas. Cumulative effects are not the total emissions produced in a day or a year, but rather the concentration of all fire emissions in a given airshed at a given time. For NAAQS these concentrations have a varying time weighted period depending on the pollutant. For PM10 and PM2.5, they are measured as a 24 hour average, and as an annual arithmetic mean (Kleindienst 2012). The area of analysis discussed for air quality includes the EIS analysis area, as well as the Colorado River Airshed, the Little Colorado River Airshed, and the Verde River Airshed. The season for broadcast burning is approximately April through October, pile burning is most often done in the winter months, and wildfires generally occur from April through October.

The three action alternatives propose prescribed burning at different levels. The variables that determine what the concentration of smoke is at specific locations for a given prescribed burn are too many for a spatially explicit evaluation on the scale of this project a year (or more) in advance of implementing a burn. Burn Plans, tiered to the NEPA document for which they are implementing, include spatial specific modeling that specify what effects are expected where, and to help determine what conditions will produce the desired results to minimize impacts from emissions. It is reasonable to assume there is a correlation between the amount of smoke produced in a fire, and the potential for that smoke to produce undesirable impacts.

Monitoring

Monitoring would be a critical component in the success of the 4FRI. Fulé and Laughlin (2007) stated: "Ecological restoration can be criticized because future climate conditions will not be like those of the past (Millar & Wolfenden 1999). However, the issue is not whether future climates will be unchanging, they will not, but rather whether native forest ecosystems can persist under future conditions. Climate change, whether through gradual changes or greater extremes that affect disturbance severity, may create novel thresholds beyond which a species or ecosystem type cannot survive (Malcolm et al. 2002). But unless or until such a point is reached, **the most relevant question for assessing restoration is sustainability"**(Clewell 2000).

When choosing what to monitor, there should be a balance of the measures used to 1) evaluate the post-treatment condition of the treatment area and the treated areas in regards to potential fire behavior and potential fire effects and; 2) those that can provide information about the sustainability of management actions based on current and expected fire effects. Questions to be answered by monitoring include:

- How many acres (or percent of the landscape or vegetation type) burned with desired/undesired fire behavior and effects? If monitoring data show treated areas do not meet desired conditions, there would need to be a re-evaluation of treatments to determine what changes are needed. Evaluation could be based on such things as burn severity (fire effects on soil), mortality of desirable species (in particular, large and/or old ponderosa pine, and large gambel oak), the response of surface vegetation for several years following treatments and/or wildfire.

- Were there any exceedences? This would be automatic feedback from ADEQ monitors to track this. If there are exceedences, there would need to be a re-evaluation of treatments to determine what changes are needed.

- Were the logistics and operations implementable at the desired spatial and temporal scales? If, after 5 years of implementation, the necessary acres are not being treated with prescribed fire and/or the trend in average acres burned indicates they will not be, there would need to be a re-evaluation of limitations to determine what changes would be needed to meet objectives for prescribed fire.

Adaptive Management

All alternatives assume the use of adaptive management principles. Forest Service decisions are made as part of an on-going process, including planning, implementing projects, and monitoring and evaluation. All Forests' Land Management Plans identify monitoring programs. Monitoring the results of actions would provide a flow of information that may indicate the need to change a course of action or amend either the land management plans, the 4FRI EIS, or both. Scientific findings and the needs of society may also indicate the need to adapt resource management to new information. Forest Supervisors annually evaluate monitoring information displayed in evaluation reports through a management review and determine if any changes are needed in management actions or the documents themselves. In general, annual evaluations of the monitoring information consider the following questions:

- What are the effects of resource management activities on the health and condition of the land in regards to potential fire behavior and effects?
- To what degree are resource management activities maintaining or making progress toward the desired conditions and objectives for the plan?
- What changes are needed to account for unanticipated changes in conditions?

Recommended adaptive management actions for transportation, springs and roads was reviewed. None of the recommended management actions would conflict with desired conditions and proposed actions for Fire Ecology/Fuels/Air Quality.

Appendix A: Direction from the Coconino and Kaibab National Forests' LRMPs

Forest-wide Direction

Fire Management Planning and Analysis (Coconino NF Forest Plan, pp. 92-96)

Protection (Coconino NF Forest Plan, p. 93)

- Continue fire management analysis and planning for activities such as pre-suppression, detection, suppression, prevention, and fuel treatment.
- Coordinate fuel treatment plans with other resources with input provided by other resource specialists.
- Manage smoke from prescribed fires to meet legal standards and to provide for public safety.

Fire Prevention (Coconino NF Forest Plan, pp. 93-94)

- Work with homeowners associations and homeowners in the Urban Interface to plan and implement measures to reduce wildfire threats to life and property such as: Treating vegetation and fuels near homes.
- Commercial Timber Lands - This zone consists of the remainder of the commercial timber land. Prescribed fire using both planned and unplanned ignitions is used to accomplish fuel treatment and resource management objectives.
- PJ and Desert Grasslands - This zone consists of grassland, desert shrub, pinyon/juniper, some unsuitable and noncommercial timber land other than designated wildernesses. Prescribed fire using planned and unplanned ignitions is used to accomplish fuel treatment and other resource management objectives.

Fire Suppression (Coconino NF Forest Plan, pp. 93-94)

- Urban Interface - This zone is the urban interface and an area up to 10 miles long in a southwesterly direction from urban areas. Prescribed fire, using planned ignitions, is used to accomplish fuel treatment and resource management objectives (CNF Forest Plan, p. 93)
- Prescribed fires are monitored to assure that they remain in prescription (p. 94)

Fuel Treatment (Coconino NF Forest Plan, p. 96)

- The first priority for fuel treatments is to allow and reasonably assist the public to remove available and accessible firewood. Aggressively enlist media support to inform the public about available firewood prior to fuel treatments. Firewood areas are well signed to direct people to them. Road maintenance and management are coordinated to provide access. Burning is generally deferred 2 years to allow for firewood removal.
- Plan fuel treatments on an area basis. Fuel treatment objectives are met on the area as a

whole and not necessarily on each acre. Plan fuel treatments that have the least impact on the site, meet resource management needs, are cost effective, and meet fuel treatment objectives.

- Snags and downed logs that are necessary to meet wildlife management objectives for the area are identified and fire lined to protect them. They are also monitored during burning to protect them. T&E and sensitive species are also protected by lining and monitoring. Any unburned islands inside the perimeter of the fire of one-quarter to 2 acres are left unless they are a threat to the management of the fire or prevent achievement of the fuel treatment objectives.

- Suppress fires that threaten habitat of threatened and endangered, or sensitive species.

- Limit the treatment of natural fuels to areas where fuel buildups are a threat to life, property, adjacent to old-growth areas, or specifically identified high resource values.

- Maintain existing fuelbreaks and construct additional fuelbreaks that are necessary for protecting life and property.

- Annually review the smoke management implementation schedule and update as needed. Include a quality assurance section in the plan during the first year of the Plan implementation.

- Fuel treatment projects include pretreating fuels to meet specified air quality standards and mop-up to control residual smoke, whenever necessary.

- Prescriptions for the use of prescribed fire for any purpose include measures to minimize smoke production when projects will impact smoke sensitive areas.

- Monitor and document the effects on smoke sensitive areas of smoke from prescribed burning during the burning season. The purpose is to prevent smoke intrusions. Adjust the burning program as needed based upon the monitoring.

- The initial monitoring will be by aerial observation, photography from observation points, and ground observations. Monitoring may be daily or less frequent depending upon the amount of burning and atmospheric conditions.

- Evaluate potential for smoke intrusions on airports, highways, and roads.

- Employ appropriate measures to provide for public safety by keeping smoke off of these types of facilities to the degree possible. Keep smoke warning signs posted on roads. If an intrusion occurs take cooperative action with appropriate law enforcement personnel to provide for public safety.

Management Area (MA) Direction:

Management Area 3

- Manage to make firewood available from major species within this MA (p.118)

- Plan fuel treatments on an area basis. Fuel treatments will be designed to meet objectives on the area as a whole, not on every acre. (p.96)

- Plan fuel treatments that have the least impact on the site, meet resource management needs, are cost effective, and meet fuel treatment objectives (p.96).
- Snags and downed logs that are necessary to meet wildlife management objectives for the area are identified and fire lined to protect them. They are also monitored during burning to protect them. T&E and sensitive species are also protected by lining and monitoring. Any unburned islands inside the perimeter of the fire of one-quarter to 2 acres are left unless they are a threat to the management of the fire or prevent achievement of the fuel treatment objectives (p.96)
- Snags and downed logs that are necessary to meet wildlife management objectives for the area are identified and fire lined to protect them. They are also monitored during burning to protect them. T&E and sensitive species are also protected by lining and monitoring ((p.96).
- Any unburned islands inside the perimeter of the fire of one-quarter to 2 acres are left unless they are a threat to the management of the fire or prevent achievement of the fuel treatment objectives (p.96)
- Maintain existing fuelbreaks and construct additional fuelbreaks that are necessary for protecting life and property. (p.96)
- Annually review the smoke management implementation schedule and update as needed. Include a quality assurance section in the plan during the first year of the Plan implementation. (p.96)
- Fuel treatment projects include pretreating fuels to meet specified air quality standards and mop-up to control residual smoke, whenever necessary.(p.96)
- Prescriptions for the use of prescribed fire for any purpose include measures to minimize smoke production when projects will impact smoke sensitive areas. (p.96)
- Monitor and document the effects on smoke sensitive areas of smoke from prescribed burning during the burning season. The purpose is to prevent smoke intrusions. Adjust the burning program as needed based upon the monitoring. The initial monitoring will be by aerial observation, photography from observation points, and ground observations. Monitoring may be daily or less frequent depending upon the amount of burning and atmospheric conditions. (p.96)
- Evaluate potential for smoke intrusions on airports, highways, and roads. Employ appropriate measures to provide for public safety by keeping smoke off of these types of facilities to the degree possible. Keep smoke warning signs posted on roads. If an intrusion occurs take cooperative action with appropriate law enforcement personnel to provide for public safety.

Management Area 4

Protection Standards and Guidelines for fire management planning and analysis are the same as for MA 3.

Management Area 5

- Protection Prescribed fire using planned and unplanned ignitions is used to meet resource objectives. Suppression objective is to hold fires to 100 acres or less (p.144).

Management Area 6

- Use prescribed fire as a tool to help meet desired resource objectives (p.145)
- Prescribed fire using planned and unplanned ignitions is used to accomplish resource objectives except no provision for unplanned ignitions in areas included in urban interface (p.147).

Management Area 7 p.148-155

- Fire occurrence is low and potential for large fires is low. Ground fuels are less than 5 tons per acre except in stands that have been harvested for firewood
- Use prescribed fire to help achieve resource objectives.
- Where slash suitable for firewood is piled for burning, there is at least 2 years free-use firewood salvage before burning piles.
- An average of three unburned piles per acre are left on areas with piled slash to provide cover for birds and small animals or leave lopped and scattered slash on 30 of treatment area.
- Prescribed fire using planned and unplanned ignitions is used to accomplish resource objectives except no provision for unplanned ignitions in areas included in urban interface.
- Emphasize using slash for firewood.   Unless there are documented resource or protection needs, leave slash for at least 2 years before disposal. Clearly identify free-use firewood areas to assist the public in removing wood residues and thereby reducing future slash disposal costs.   Provide easy to follow maps and signing for designated firewood areas.

Management Area 9 – p.161

Prescribed fire using planned and unplanned ignitions is used to accomplish resource objectives except no provision for unplanned ignitions in areas included in urban interface.

Management Area 10

Control invasion of undesirable plant species when necessary to improve and protect wildlife habitat values. Prescribed burning will be one specific practice used, especially where needed to improve wildlife habitat (p.164)

Management Area 12

No direction

Management Area 13

Prescribed fire using planned and unplanned ignitions is used to accomplish resource objectives except there is no provision for unplanned ignitions in areas included in the urban interface (p.182).

Management Area 14

Use prescribed fire and mechanical methods to achieve fire management goals (p.184).

Identify locations of high fuel buildup and potential National Forest/urban interface wildfire problems (p.184)

Management Area 15

Prescribed fire using planned ignitions is used as a management tool where it is needed to accomplish resource objectives (p.190).

Management Area 18

Prescribed fires from planned ignitions are used to accomplish fuel treatment and other resource management objectives (p.199)

Management Area 20 – p. 206-5

Slash work may include piling, lop and scatter, pile burning, broadcast burning, chipping and hauling.

Prescribed fire using planned ignitions is used as a management tool where such use is compatible with other resources.

Slash for fuelwood may be emphasized where practical depending on access from forest roads and whether or not there is a need to more quickly dispose of slash to meet visual quality or fire risk management needs.

Management Area 28 (p.206-54)

Use prescribed fire to rejuvenate wildlife browse/forage areas.

FLEA

Management activities, such as thinning and prescribed fire, result over the long-term, in alterations that appear natural to most visitors (p.206-70)

The risk of and potential for destructive crown wildfire is reduced, especially in the Urban/Rural Influence Zone (U/RIZ) and the Wildland Urban Interface (1U) as depicted on the Fire Management Analysis Zones map.

Guideline: Reduce crown canopy and ladder fuels where needed to reduce risk of stand replacing crown fires.

Watershed Goals/Objectives (pp.206-77): Natural vegetative and fuels composition area restored so as to reduce susceptibility to large scale watershed disturbances, such as large catastrophic wildfire. Guideline: Implement actions to restore a natural vegetative and fuels composition, and ensure that soil condition objectives are met on a landscape scale to reduce susceptibility of large-scale watershed disturbances, such as a large catastrophic fire or insect/disease outbreak.

Coordination with the City of Flagstaff and Coconino County Guidelines: Continue coordination related to fire suppression and fire risk reduction (p.206-79).

Management Area 31 (p.206-88)

As stated in Management Area 10, maintain and improve grasslands, including removing encroaching pinyon/juniper and re-introducing fire. Maintain or improve watershed conditions throughout the MA.

Management Area 32

No direction

Management Area 33 (p.206-92)

This MA is a high priority for efforts to reduce the risk of catastrophic fire especially in the ponderosa pine lands. Reference FLEA area-wide direction and the *Forest Plan* related to vegetation and fire management.

Management Area 34 (p.206-95)

As long as these lands remain in National Forest ownership, within the Urban/Rural Influence Zone (entire MA), reduce the risk of catastrophic wildfire, emphasize daytime non-motorized recreation opportunities and balance recreation demands with protection of the soils, water, wildlife and vegetation, and maintain public access to public lands.

Continue efforts in partnership with the City of Flagstaff to treat forested stands to reduce risk of catastrophic wildfire.

Management Area 35 –pp.206-98, 101

The northwestern portion of this MA is within the Urban/Rural Influence Zone. Reduce the risk of catastrophic wildfire, especially within the Urban/Rural Influence Zone.

In the entire MA, re-introduce fire’s natural role as much as possible, and ponderosa pine lands progress towards desired forest structure, including northern goshawk and Mexican spotted owl habitats.

Per the FLEA Area-wide direction, reduce potential for catastrophic wildfire within the Urban/Rural Influence Zone. Because of prevailing winds, lands south and west of the Urban/Rural Influence Zone should be evaluated for wildfire risks and appropriate measures taken to reduce potential for catastrophic fire. Continue partnerships with city, county, and State fire departments to coordinate fire hazard reduction treatments, prevention, and suppression. Take steps to minimize wildfire losses to key wildlife habitat components such as eagle roosts, osprey nests, snags, yellow pines, oaks and rare plant habitat

Management Area 37 (p.206-108)

Protect the community - A small portion of this MA is within the Urban/Rural Influence Zone. Reduce the risk of catastrophic wildfire, especially within the Urban/Rural Influence Zone. Reintroduce fire's natural role as much as possible. Opportunities for firewood or other forest products are rare north and west of the Canyon, however, firewood sales may be used as a tool for management.

Reduce the risk of catastrophic fire especially in the Urban/Rural Influence Zone. There is concern for wildfire losses to the National Monument from fires starting southwest of the park. Balance the need to reduce wildfire risk in these areas with desired conditions for Primitive and Semi-primitive ROS settings and disturbance sensitive species habitat. Reference FLEA area-wide direction and other the *Forest Plan* management direction related to vegetation and fire management.

Management Area 38 (pp.206-114, 117)

More than half of this MA is within the Urban/Rural Influence Zone. Within the Urban/Rural Influence Zone, and along the Highway 89A corridor, reduce the risk of catastrophic wildfire…. In the remainder of the MA, re-introduce fire's natural role as much as possible, progress towards desired conditions described (MSO and goshawk guidelines), restore meadows, and promote healthy pine/oak forests.

The portions of this MA that lie southwest of developed lands are high priority for fire risk reduction efforts. This includes the Urban/Rural Influence Zone and the Wildland Urban Interface as depicted on the Fire Management Analysis Zones map. Reference FLEA area-wide direction

Per the FLEA Area-wide direction, reduce potential for catastrophic wildfire within the Urban/Rural Influence zone. Because of prevailing winds and steep terrain, lands south and west of the Urban/Rural Influence zone should be evaluated for wildfire risks and appropriate measures taken to reduce potential for catastrophic fire. Continue partnerships with city, county, and State fire departments to coordinate fire hazard reduction treatments, prevention, and suppression.

Kaibab National Forest Land Management Plan (as amended 2008)

Forest-wide Direction

Goals - Fire Protection and Use (p.19)

Use prescribed fire and wildland fire use as resource management tools where they can effectively accomplish resource objectives. Areas approved for wildland fire use implementation and their prescriptive criteria will be identified within the fire management plan. Fire management, prevention, and control are used to protect life, property, and resources.

Geographic Area (GA) and Land Use Zone (LUZ) Direction

Geographic Area 1

Management Direction (p.51)

Priority for fuel treatment investment is low and should be limited to rural/urban interface and protection of adjacent, higher value *GAs*.

Fire Management Planning and Analysis

1. Do not allow fires to spread to lands of other ownership.

2. Protect human life and improvements.

Treatment of Activity Fuels (p.86)

NZ: All activity created fuels are promptly removed from areas designated with visual management objectives of "retention foreground" or "partial retention foreground" (VQO Map). Activity created fuels in other areas are treated so that maximum size objectives can be met under the burning conditions which yielded the historical, 50 ile rate of spread in fuel model "K" (National Fire Danger Rating System). Fuel treatment objectives are met with a combination of treatment methods. Preferred treatments are: (1) fuelwood utilization, (2) broadcast burning (prescribed fire and wildland fire use), (3) pile and burn, and (4) mechanical rearrangement such as chipping and lopping.

Geographic Area 2

The fuel profile is conducive to high intensity *wildland fires* that can result in destruction or heavy damage to resources and developed facilities. Prompt *appropriate management response* must be instituted when the threat of high intensity fire exists (p.35)

Standards:

1. Implement resource operations and improvements which contribute to achievement of desired conditions and fulfillment of the Forest Service mission. (Resource operations and improvements are specified in Forest Service Handbook (FSH) 1309.16, National Activity Structure Handbook).

4. Identify and portray, describe, or quantify existing conditions in the landscape. If the land area selected for implementation of a resource operation or improvement is not a specified landscape, an ad hoc area shall be defined and geographically located during the initial stages of Forest Plan Implementation. Standards that apply to the implementation of resource operations or improvements in landscapes, apply as well to resource operations or improvements in ad hoc areas.

5. Formulate and portray, describe, or quantify management objectives and desired conditions for the landscape. In landscapes that involve habitat for threatened, endangered, or sensitive plant or animal species, formulate management objectives and desired conditions for each designated management territory. Formulate, design, and implement resource operations or improvements that contribute to the achievement or maintenance of these management objectives and desired conditions.

Guidelines:

Guidelines for Timber Resource Operations and Improvements:
9. In northern goshawk existing nest areas, the nesting area may be thinned from below removing suppressed and intermediate trees, using prescribed fire or hand operated tools.

Guidelines for Activity and Natural Fuel Operations and Improvements:
1. In northern goshawk suitable nesting areas, preferred method for treating woody debris is fire use, next lopping and scattering, and lastly, hand piling.

2. In northern goshawk replacement nesting areas, preferred method for treating woody debris is fire use, next, lopping and scattering, and last, hand piling. Avoid slash piling with crawler tractor.

3. In northern goshawk PFAs, preferred method for treating woody debris is, in order, fire use, lopping and scattering, hand piling, machine grapple piling, and lastly, crawler tractor piling.

4. In other forested areas, preferred method for treating woody debris is, in order, fire use, lopping and scattering, hand piling, machine grapple piling, and lastly, crawler tractor piling.

5. Priority for fuel treatment investment is given to:

   a. W*ildland*-urban interface.

   b. Areas which exceed the burning conditions which yield the historical, 50 percentile rate of fire spread in fuel model K (National Fire Danger Rating System).
   c. Maintenance of existing fuelbreaks and fuel reduction corridors.

Guidelines for Fire Protection Operations and Improvements – N/A

Geographic Area 3

Management Direction for Fire Protection (p.54)

Priority for fuel treatment investment is low and should be limited to rural/urban interface and protection of adjacent, higher value management areas.

Fire Management Planning and Analysis

1. Do not allow fires to spread to lands of other ownership.

2. Protect human life and improvements.

Treatment of Activity Fuels (p.86)

NZ: All activity created fuels are promptly removed from areas designated with visual management objectives of "retention foreground" or "partial retention foreground" (VQO Map). Activity created fuels in other areas are treated so that maximum size objectives can be met under the burning conditions which yielded the historical, 50 percentile rate of spread in fuel model "K" (National Fire Danger Rating System). Fuel treatment objectives are met with a combination of treatment methods. Preferred treatments are: (1) fuelwood utilization, (2) broadcast burning (prescribed fire and wildland fire use), (3) pile and burn, and (4) mechanical rearrangement such as chipping and lopping.

Geographic Area 8

The fuel profile is not conducive to large, high intensity fires. The potential for resource damage is very low and most fires are more beneficial than damaging (pp. 55-56).

Fire Management Planning and Analysis

1. Do not allow fires to spread to lands of other ownership.

2. Protect human life and improvements.

Treatment of Activity Fuels (p.86)

NZ: All activity created fuels are promptly removed from areas designated with visual management objectives of "retention foreground" or "partial retention foreground" (VQO Map). Activity created fuels in other areas are treated so that maximum size objectives can be met under the burning conditions which yielded the historical, 50percentile rate of spread in fuel model "K" (National Fire Danger Rating System). Fuel treatment objectives are met with a combination of treatment methods. Preferred treatments are: (1) fuelwood utilization, (2) broadcast burning (prescribed fire and wildland fire use), (3) pile and burn, and (4) mechanical rearrangement such as chipping and lopping.

Management Direction for Fire Protection (p.57)

Priority for fuel treatment investment is low and should be limited to rural/urban interface and protection of adjacent, higher value management areas (p.57).

Geographic Area 10

The fuels profile is variable with areas of high hazard fuel loading and areas of very sparse fuels (p.36)

See GA 2 management direction

LUZ 21

Fire Management Planning and Analysis (p.110)

1. Protect human life and improvements. Minimize acreage burned.

2. Do not allow fires to spread to lands of other ownership.

3. The maximum fire size objective is one acre.

4. The average annual burned area objective is five acres.

Treatment of Activity Fuels

NZ: Dispose of all activity created slash.

Treatment of Natural Fuels

Encourage utilization of natural fuels in and adjacent to this area for on-site fuelwood needs

References to fire in wildlife and timber direction

Mexican spotted owl

Standard (p.23): Allow no timber harvest except for fuelwood and fire risk abatement in established protected activity centers. For protected activity centers destroyed by fire, windstorm, or other natural disaster, salvage timber harvest or declassification may be allowed after evaluation on a case-by-case basis in consultation with US Fish and Wildlife Service.

Guidelines (p.24):

Treat fuel accumulations to abate fire risk.

Use combinations of thinning trees less than 9 inches in diameter, mechanical fuel treatment and prescribed fire to abate fire risk in the remainder of the selected protected activity center outside the 100 acre "no treatment" area.

Select for treatment 10 percent of the protected activity centers where nest sites are known in each recovery unit having high fire risk conditions. Also select another 10 percent of the protected activity centers where nest sites are known as a paired sample to serve as control areas.

Use light prescribed *fire* in non-selected protected activity centers on a case-by-case basis. Burning should avoid a 100 acre "no treatment" area around the activity center. Large woody debris, snags, clumps of broad-leafed woody vegetation should be retained and hardwood trees larger than 10 inches diameter at the root collar.

Steep Slopes (p.24):

No seasonal restrictions apply. Treat fuel accumulations to abate fire risk.

Use combinations of thinning trees less than 9 inches in diameter, mechanical fuel removal, and prescribed fire.

Pre and post treatment monitoring should occur within all steep slopes treated for fire risk abatement. (See monitoring guidelines)

C. Restricted Areas (Mixed Conifer, Pine-Oak, and Riparian Forests) – p.26

Encourage prescribed and wildland fire use to reduce hazardous fuel accumulation. Thinning from below may be desirable or necessary before burning to reduce ladder fuels and the risk of crown fire.

D. Other Forest and Woodland Types (p.26)

Apply ecosystem approaches to manage for landscape diversity mimicking natural disturbance conditions and retaining special features such as snags and large trees, *fire use*, and retention of existing old growth in accordance with forest plan old-growth standards and guidelines.

Ecosystem Management In Northern Goshawk Habitats

Standard: Manage for uneven-age stand conditions for live trees and retain live reserve trees, snags, downed logs, and woody debris levels throughout woodland, ponderosa pine, mixed conifer and spruce-fir forest cover types. Manage for old age trees such that as much old forest structure as possible is sustained over time across the landscape. Sustain a mosaic of vegetation densities (overstory and understory), age classes and species composition across the landscape.

Provide foods and cover for goshawk prey (p.27).

Guidelines:

Vegetation Management Landscapes outside Goshawk post-fledgling family areas

The order of preferred treatment for woody debris is: 1) prescribed burning, 2) lopping & scattering, 3) hand piling or machine grapple piling, 4) dozer piling (p.29).

Within Nesting Areas

Preferred treatments to maintain the desired structure are to thin from below with nonuniform spacing and use of handtools and *fire use* to reduce fuel loads. Lopping and scattering of thinning debris is preferred if prescribed fire cannot be used.Piling of debris should be limited. When necessary, hand piling should be used to minimize compaction within piles and to minimize displacement and destruction of the forest floor and the herbaceous layer. Do not grapple or Dozer pile debris. Manage road densities at the lowest level possible to minimize disturbance in the nest area.Use small, permanent skid trails in lieu of roads for timber harvesting (p.30)

Human Disturbance (p.31)

Low intensity surface fires are allowed at any time in all forested cover types, but high intensity crown fires are not acceptable in the post-fledgling family area or nest areas. Avoid burning the entire home range of a goshawk pair in a single year. For fires planned in the occupied nest area, a fire management plan should be prepared. The fire management plan should minimize the risk of goshawk abandonment while low intensity surface fire burns in the nesting area. Prescribed fire within nesting areas should be planned to move with prevailing winds away from the nest tree to minimize smoke and risk of crown fire developing and driving the adults off or consuming the nest tree

Appendix B: References

Abella, S. R. 2006. Effects of smoke and fire-related cues on *Penstemon barbatus* seeds. Faculty Publications (SEPA); School of Environmental & Public Affairs, University of Nevada, Las Vegas, Nevada.

Abella, S. R. 2009. Smoke-cued emergence in Plant Species of Ponderosa Pine Forests: Contrasting Greenhouse and Field Results. Fire Ecology Special Issue 5(1):22-37.

Abella, S. R. 2008a. Managing Gambel oak in southwestern ponderosa pine forests: The Status of our knowledge. USDA Forest Service Gen. Tech. Rep. RMRS-GTR-218.

Abella, S. R2008b. Gambel oak growth forms: Management opportunities for increasing ecosystem diversity (2008). Faculty Publications (SEPA). Paper 348. http://digitalcommons.library.unlv.edu/sea_fac_articles/348.

Abella, S. R., and P. Z. Fulé. 2008. Fire effects on Gambel Oak in southwestern Ponderosa pine-oak forests. Research Note RMRS-RN-34.

Abella, S. R, and P.Z. Fulé. 2008a. Changes in Gambel oak densities in southwestern ponderosa pine forests since Euro-American settlement. Faculty Publications (SEPA). Paper 354. http://digitalcommons.library.unlv.edu/sea_fac_articles/354.

Abella, S. R., C. W. Denton, C. W., D. G. Brewer, W. A. Robbie, R. W. Steinke, W. W. Covington. 2011. Using a terrestrial ecosystem survey to estimate the historical density of ponderosa pine trees. Res. Note. RMRS-RN-45. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 9 pp.

Abella, S. R., J. D. Springer, and W. W. Covington. 2007. Seed banks of Arizona Pinus ponderosa landscape: responses to environmental gradients and fire cues. Canadian Journal of Forest Research 37:552 – 567.

Achtemeier, G. L., B. Jackson, J. D. Brenner, 2001. Problem and Nuisance Smoke. Smoke Management Guide for Prescribed and Wildland Fire 2001 Edition. NWCG. PMS 420-2, NFES 1279. Boise, ID.

Agee, J. K. 1993. Fire Ecology of Pacific Northwest Forests. Island Press, Washington D.C.

Alexander, M. E. 1982. Calculating and interpreting forest fire intensities. Canadian Journal of Botany. Vol. 60.

Alexander, M. E., and F. G. Hawksworth. 1976. Fire and dwarf mistletoes in North American coniferous forests. Journal of Forestry 74(7):446-449.

Allen, C. D. 1989. Changes in the landscape of the Jemez Mountains, New Mexico. Dissertation, University of California, Berkeley, USA.

Allen, C. D., M. Savage, D. A. Falk, D. F. Suckling, T. W. Swetnam, T. Schulke, P. B. Stacey, P. Morgan, M. Hoffman, and J. T. Klingel. 2002. Ecological restoration of southwestern ponderosa pine ecosystems: a broad perspective. Ecological Applications 12(5):1418-1433.

Amacher, Michael C., Amber D. Johnson, Debra E. Kutterer, and Dale L. Bartos. 2001. First-year postfire and postharvest soil temperatures in aspen and conifer stands. Res. Pap. RMRS-

RP-27-WWW. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 24 pp.

Archer, S., T. W. Boutton, and K. A. Hibbard. 2000. Trees in grasslands: Biogeochemical consequences of woody plant expansion. In: Global Biogeochemical Cycles in the Climate System. E. D. Schulze, S. P. Harrison, M. Heimann, E. A. Holland, J. Lloyd, I. C. Prentice, and D. Schimel, eds. Academic Press, San Diego.

Arizona Department of Environmental Quality. 2003. Regional Haze State Implementation Plan for the State of Arizona. Phoenix, AZ. http://www.azdeq.gov/environ/air/haze/download/2sip.pdf. Accessed August 20, 2011.

______. 2004. Revision State Implementation Plan for Regional Haze. Phoenix, AZ http://www.azdeq.gov/environ/air/haze/download/2004_RH_SIP_Revision.pdf.

______ . 2004. Title 18 Environmental Quality, Chapter 2 DEQ Pollution Control, Article 15 Forest and Range Management Burns. Phoenix, AZ. http://www.azdeq.gov/environ/air/smoke/download/prules.pdf. Accessed March 05, 2011.

Arno, Stephen F. 1985. Ecological effects and management implications of Indian fires. General Technical Report INT-GTR-182. Ogden, UT: USDA Forest Service Intermountain Forest and Range Experiment Station. Pp. 81-86.

Barrett, S.; Havlina, D.; Jones, J.; Hann, W.; Frame, C.; Hamilton, D.; Schon, K.; Demeo, T.; Hutter, L.; and Menakis, J. 2010. Interagency Fire Regime Condition Class Guidebook. Version 3.0 [Homepage of the Interagency Fire Regime Condition Class website, USDA Forest Service, US Department of the Interior, and The Nature Conservancy]. [Online], Available: http://www.frcc.gov/

Bartos, D. L. 2001. Landscape dynamics of aspen and conifer forests. In: USDA Forest Service Proceedings RMRS-P-18.

Biswell, H. H., R. P. Gibbens, and H. Buchanan. 1966. Litter production by big trees and associated species. Calif. Agric. 20:5-7.

Bond, W. J., and J. E. Keeley. 2005. Fire as a global “herbivore” the ecology and evolution of flammable ecosystems. Trends in Ecology and Evolution. 20(7): 387-394.

Brewer, D. G., R. K. Jorgensen, L. P. Munk, W. A. Robbie, and J. L. Travis. 1991. Terrestrial Ecosystem Survey of the Kaibab National Forest. USDA Forest Service, Southwestern Region.

Brown, H. E. 1958. Gambel Oak in West-Central Colorado. Ecology 39(2): 317-327.

Brown, J. K., E. D. Reinhardt, and K. A. Kramer. 2003. Coarse Woody Debris: Managing Benefits and Fire Hazard in the Recovering Forest. RMRS-GTR-105.

Bureau of Land Management. 2011. Northern Arizona Proposed Withdrawal Final Environmental Impact Statement. St. George, UT.

Cooper, C. F. 1960. Changes in vegetation, structure, and growth of southwestern pine forests since white settlement. Ecological Monographs 30(2): 129-164.

Core, J. E. 2001. State Smoke Management Programs. Smoke Management Guide for Prescribed and Wildland Fire 2001 Edition. NWCG. PMS 420-2, NFES 1279. Boise, ID.

Core, J. E. 2001a. Visibility. Smoke Management Guide for Prescribed and Wildland Fire 2001 Edition. NWCG. PMS 420-2, NFES 1279. Boise, ID.

Covington, W. W. 2002. Ecological Restoration Thinning of Ponderosa Pine Ecosystems: Alternative Treatment Outcomes Very Widely. In: Fire, fuel treatments and ecological restoration: Conference proceedings. P. N. Omi and J. L., tech eds. April 16 -18, 2002; Fort Collins, CO. Proceedings RMRS-P-29. U. S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 475 pp.

Covington, W. W. 2011. Discussion on Science Friday, 9/23/20011

Covington, W. W., and M. M. Moore. 1994. Southwestern ponderosa forest structure: Changes since Euro-American settlement. Journal of Forestry

Covington, W. W., and S. S. Sackett. 1984. The effect of a prescribed burn in southwestern ponderosa pine on organic matter and nutrients in woody debris and forest floor. Forest Science. 30(1):183-192.

Covington, W. W., and S. S. Sackett. 1992. Soil mineral nitrogen changes following prescribed burning in ponderosa pine. Forest Ecology and Management 54:175-191.

Covington, W. W., P. Z. Fulé, S. C. Hart, and R. P. Weaver. 2001. 'Modeling ecological restoration effects on ponderosa pine forest structure'. Restoration Ecology 9(4):421-431.

Covington, W. W., P. Z. Fulé, M. M. Moore, S. C. Hart, T. E. Kolb, J. N. Mast, S. S. Sackett, and M. R. Wagner.1997. Restoring Ecosystem Health in Ponderosa Pine Forests of the Southwest. Journal of Forestry 95(4):23-29.

Crane, Marilyn F. 1982. Fire ecology of Rocky Mountain Region forest habitat types. Final Report Contract No. 43-83X9-1-884. Missoula, MT. U.S. Department of Agriculture, Forest Service, Northern Region. 272 pp. On file with: U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Fire Sciences Laboratory, Missoula, MT. 5292.

Dahms, Cathy W., and Brian W. Geils, tech. eds. 1997. An assessment of forest ecosystem health in the Southwest. General Technical Report RM-GTR-295. Fort Collins, CO. U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 97 pp. Online: http://www.rmrs.nau.edu/publications/rm_gtr_295/. Accessed April, 5, 2012.

DeByle, N. V. and R. P. Winokur. 1985. Aspen: Ecology and Management in the Western United States. USDA Forest Service, Fort Collins, Colorado. GTR-RM-119.

DeByle, N. V., C. D. Bevins, and W. C. Fischer. 1987. Wildfire Occurrence in Aspen in the Interior Western United States. Western Journal of Applied Forestry 2(3): 73-76.

DeLuca, J. 2008. Aspen Stems per Acre on the Williams Ranger District, Kaibab National Forest. Williams Ranger District Data.

Dieterich, John H. 1980. The composite fire interval – a tool for more accurate interpretation of fire history. In: Proceedings of the fire history workshop. October 20-24, 1980. Tucson, AZ. Gen. Tech. Rep. RM-81. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. Pp 8-14.

Diggins, C., P. Z. Fulé, J. P. Kaye, and W. W. Covington. 2010. Future climate affects management strategies for maintaining forest restoration treatments. International Journal of Wildland Fire. 19:903-913.

Egan, D. 2011. Protecting old trees from prescribed burning. Working Paper No. 24. Ecological Restoration Institute, Northern Arizona University, Flagstaff, Az.

Fairweather, M. L., B. W. Geils, and M. Manthei. 2007. Aspen Decline on the Coconino National Forest. WIFDWC 55.

Ffolliott, P. F., and G. J. Gottfried. 1991. Natural tree regeneration after clearcutting in Arizona's ponderosa pine forests: two long-term case studies. Res. Note RM-507. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 6 pp.

Fiedler, C. E., and C. E. Keegan. 2003. Reducing Crown Fire Hazard in Fire-Adapted Forests of New Mexico. In: Fire, Fuel Treatments, and Ecological Restoration, Conference Proceedings. April 2002. Ft. Collins, CO. USDA Forest Service Proceedings RMRS-P-29. Online: http://www.fs.fed.us/rm/pubs/rmrs_p029.html. Accessed October, 11, 2011.

Finkral, A. J., and A. M. Evans. 2008. The effects of a thinning treatment on carbon stocks in a northern Arizona pine forest. Forest Ecology and Management 255:2743-2750.

Finney, M. A. 2004. Farsite: Fire area simulator – Model Development and Evaluation. USDA Forest Service RMRS-RP-4 Revised.

Finney, M. A. 2006. An overview of FlamMap modeling capabilities. USDA Forest Service Proceedings RMRS-P-4.

Finney, M. A., R. Bartlette, L. Bradshaw, K. Close, B. M. Collins, P. Gleason, W. M. Hao, P. Langowski, J. McGinely, C. W. McHugh, E. Martinson, P. N. Omi, W. Shepperd, and K. Zeller. 2003. Fire behavior, fuel treatments, and fire suppression on the Hayman Fire. Hayman fire case study. R. T. Graham, ed. GTR-RMRS-114. USDA Forest Service, Ogden, Utah.

Fitch, M., R. Truman. 2007. Specialist Report for Air Resources: Kaibab National Forest. Williams, AZ.

Ffolliott, P. F., and G. J. Gottfried. 1991. Natural Tree Regeneration After Clearcutting in Arizona's Ponderosa Pine Forests: Two Long-Term Case Studies. Rocky Mountain Forest and Range Experiment Station. USDA Forest Service. Research Note RM-507.

ForestEra. 2010. GIS data (process and mask for adjusting fire behavior outputs to reflect changes since the base Landfire data layers were updated). Flagstaff, AZ: Northern Arizona University.

Fowler, J. F., C. Hull Sieg, and L. L. Wadleigh. 2010. Effectiveness of Litter Removal to Prevent Cambial Kill-Caused Mortality in Northern Arizona Ponderosa Pine. Forest Science. 56(2): 166-171.

Fulé, P. Z. Personal communication email: 1/6/2011. Faculty, Fire Ecology/Forestry, Northern

Arizona University, Flagstaff, Arizona.

Fulé, P. Z., W. W. Covington, and M. M. Moore. 1997a. Determining reference conditions for ecosystem management of southwestern ponderosa pine forests. Ecological Applications 7(3): 895-908.

Fulé, P. Z., Covington, W. W., Moore, M. M., Heinlein, T. A., Waltz, A. E. M. 1997c. Natural variability in forests of the Grand Canyon. USA Ecological Applications 7(3):895-908.

Fulé, P. Z., A. E. M. Waltz, W. W. Covington, and T. A. Heinlein. 2001. Measuring Forest Restoration Effectiveness in Reducing Hazardous Fuels. Journal of Forestry. November, 2001.

Fulé, P. Z., C. McHugh, T. A. Heinlein, and W. W. Covington. 2001. Potential fire Behavior is Reduced Following Forest Restoration Treatments. USDA, US Forest Service Proceedings RMRS-P-22.

Fulé, P. Z., T. A. Heinlein, W. W. Covington, and M. M. Moore. 2003. Assessing fire regimes on Grand Canyon landscapes with fire-scar and fire-record data. International Journal of Wildland Fire. 12: 129-145.

Fulé, P. Z., D. C. Laughlin, and W. W. Covington. 2005. Pine-oak forest dynamics five years after ecological restoration treatments, Arizona, USA. Forest Ecology and Management 218:129-145.

Fulé, P. Z., and D. C. Laughlin. 2007. Wildland fire effects on forest structure over an altitudinal gradient, Grand Canyon National Park, USA. Journal of Applied Ecology. 44: 136-146.

Fulé, P. Z., J. E. Crouse, J. P. Roccaforte, and E. L. Kalies. 2012. Do thinning and/or burning treatments in western USA ponderosa or Jeffrey pine-dominated forests help restore natural fire behavior? Forest Ecology and Management 269:68-81.

Garlough, E. C., and C. R. Keyes. 2011. Influences of moisture content, mineral content, and bulk density on smoldering combustion of ponderosa pine duff mounds. International Journal of Wildland Fire. 20: 589-596.

Gerdes, J. 2012. Personal communication email: 1/23/2012. United States Environmental Protection Agency, Region 9.

Gori, Dave and Joanna Bate. 2007. Historical Range of Variation and State and Transition Modeling of Historical and Current Landscape Conditions for Pinyon-Juniper of the Southwestern U.S. Prepared for the USDA Forest Service, Southwestern Region by The Nature Conservancy, Tucson, AZ. 141 pp.

Graham, R. 2012a. Personal communication email: 4/25/2012, 6/7/2012; and 9/12/2012. United States Environmental Protection Agency, Region 8.

Graham, R. T., A. E. Harvey, M. F. Jurgensen, T. B. Jain, J. R. Tonn, and D. S. Page-Dumroese. 1994**.** Managing Coarse Woody Debris in Forests of the Rocky Mountains. USDA, Forest Service Research Paper INT-RP-477.

Grand Canyon National Park. 2011. Unpublished fire effects monitoring data from 1992 – 2010.

Gruell, G. E. 1985. Fire on the early western landscape: an annotated record of wildland fires 1776 – 1900. Northwest Sci. 59:97-107.

Hall, W., A. Thode, K. Waring, N. McCusker, and M. Lata. 2011. Using the Forest Vegetation Simulator to Determine Proposed Restoration Treatment Effectiveness and Maintenance Interval: An Analysis of the Four Forest Restoration Initiative (MF Professional Paper). Flagstaff, AZ. Northern Arizona University. 69 pp.

Hann, W. J., A. Shlisky, D. Havalina, K. Schon, S. Barrett, T. D. Meo, K. Pohl, J. Menakis, D. Hamilton, J. Jones, M. Levesque, and C. Frame. 2004. Interagency Fire Regime Condition Class (FRCC) Guidebook Version 1.3.0. Last update, June 2008. Available at www.frcc.gov.

Hardy, C. C. 2005. Wildland fire hazard and risk: Problems, definitions, and context. Forest Ecology and Management. 211:73-82.

Hardy, C. C., K. M. Schmidt, J. P. Menakis, and R. N. Sampson. 2001a. Spatial data for national fire planning and management. International Journal of Wildland Fire. 10(3 and 4): 535-572. Online: http://www.publish.csiro.au/?act=view_file&file_id=WF01034.pdf. Accessed on January 5, 2010.

Hardy, C. C., Roger D. Ottmar, Janice L. Peterson, John E. Core, and Paula Seamon. 2001b. Smoke Management Guide for Prescribed and Wildland Fire, 2001 edition, NFES 1279. National Wildfire Coordinating Group, Fire Use Working Team. 226 pp.

Hardy, C. C., S. M. Hermann, and John E. Core. 2001b. The Smoke Management Imperative. Smoke Management Guide for Prescribed and Wildland Fire 2001 Edition. NWCG. PMS 420-2, NFES 1279. Boise, ID.

Hartford, R. A., and W. H. Frandsen. 1992. When It's Hot, It's Hot…or Maybe It's Not! (Surface Flaming May Not Portent Extensive Soil Heating). International Journal of Wildland Fire 2(3):139-144.

Harrington, M.G., and S.S. Sackett. 1992. Past and present fire influences on Southwestern ponderosa pine old growth. In: Old-growth forests in the Southwest and Rocky Mountain regions; proceedings of a workshop. Pages 44-50. M.R. Kaufmann, WH. Moir, and R.L. Bassett, tech. coords. March 9, 1992. Portal, Arizona. Gen. Tech. Rep. RM-213. Fort Collins, CO. U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 201 pp.

Havlina et al. 2010. Interagency Fire Regime Condition Class website. USDA Forest Service, USDA Department of the Interior, and The Nature Conservancy [http://www.frcc.gov/].

Heinlein, T. A., M. M. Moore, P. Z. Fulé, and W. W. Covington, 2005. Fire history and stand structure of two ponderosa pine – mixed conifer sites: San Francisco Peaks, Arizona, USA. International Journal of Wildland Fire 14: 307-320.

Higgins, B. J., H. P. Kleindienst. 2011. Vegetation, Fire and Fuels Specialist Report. Kaibab National Forest. Williams, AZ.

Huffman, D. W., P. Z. Fulé, K. M. Pearson, J. E. Crouse, and W. W. Covington. 2006. Pinyon-Juniper Fire Regime: Natural Range of Variability. 04-JF-11221615-271. Final Report. Ecological Restoration Institute, Northern Arizona University.

Huffman, D. W., P. Z. Fulé, J. E. Crouse, and K. M. Pearson. 2009. A comparison of fire hazard mitigation alternatives in pinyon-juniper woodlands of Arizona. Forest Ecology and Management. 257: 628-635.

Huffman, D. W., P. Z. Fulé, K. M. Pearson, and J. E. Crouse. 2008. Fire history of pinyon-juniper woodlands at upper ecotones with ponderosa pine forests in Arizona and New Mexico. Canadian Journal of Forest Research. 38:2097-2108.

Hungerford, Roger D. 1988. Soil temperatures and suckering in burned and unburned aspen stands in Idaho. Research Note INT-378. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station.

Hurteau, M. D., and M. North. 2009. Fuel treatment effects on tree-based forest carbon storage and emissions under modeled wildfire scenarios. Frontiers in Ecology and the Environment. Vol. 7. Oct. 2009. pp. 409-414.

Hurteau, M. D., M. T. Stoddard, and P. Z. Fulé. 2011. The carbon costs of mitigating high-severity wildfire in southwestern ponderosa pine. Global Change Biology 17:1516-1521.

Jones, J. R. and N. V. DeByle. 1985. Chapter II. Ecology/Fire in Aspen Ecology and Management in the Western United States. United States. Eds. N. V. DeByle and R. P. Winokur. USDA Forest Service, Fort Collins, Colorado. GTR-RM-119.

Kean, R. E., E. D. Reinhardt, J. Scott, K. Gray, and J. Reardon. 2005. Estimating forest canopy bulk density using six indirect methods. Canadian Journal of Forestry Research. 35(3): 724 – 739.

Keeley, J. E. 2009. Fire intensity, fire severity, and burn severity: a brief review and suggested usage. International Journal of Wildland Fire. 18:116-126

Keeley, J. E., and C. J. Fotheringham. 2000. Role of Fire in Regeneration from Seed. In: Seeds: The Ecology of Regeneration in Plant Communities, 2nd edition. Michael Fenner, ed. Cab International.

Kleindienst, H. P. 2012. Specialists Report on Air Quality for the Kaibab National Forest Plan Revision. Kaibab National Forest, USDA Forest Service.

Ketterer, M. E., K. M. Hafer, C. L. Link, D. Kolwaite, J. Wilson, and J. W. Mietelski. 2004. ‘Resolving global *versus* local/regional PU sources in the environment using sector ICP – MS’. Journal of Analytical Atomic Spectrometry. Vol. 19:241 – 245.

Kolb, T. E., J. K. Agee, P. Z. Fulé, N. G. McDowell, K. Pearson, A. Sala, and R. H. Waring. 2007. Perpetuating old ponderosa pine. Forest Ecology and Management 249:141-157.

Koo, B., C.-H. Chien, G. Tonnesen, R. Morris, J. Johnson, T. Sakulyanontvittaya, P. Piyachaturawat, and G. Yarwood. 2010. Natural emissions for regional modeling of background ozone and particulate matter and impacts on emissions control strategies. Atmospheric Environment 44: 2372-2382.

Kozlowski, T. T., and C. E. Ahlgren. 1974. Fire and Ecosystems. Academic Press, New York.542 pp.

Kunzler, L. M.; Harper, K.T. 1980. Recovery of Gambel oak after fire in central Utah. Great Basin Naturalist 40:127-130.

LANDFIRE. 2010a. LANDFIRE 1.1.0 Landscape (LCP) File – FBFM40. U.S. Forest Service. Online: http://www.landfire.gov/datatool.php. Accessed: January, 2012.

LANDFIRE. 2010b. LANDFIRE Data Access Tool. LANDFIRE Project, U. S. Department of

Agriculture, Forest Service; U. S. Department of Interior. Online: http://landfire.gov/.

Lata, M. 2006. Variables affecting first order fire effects, characteristics, and behavior in experimental and prescribed fires in mixed and tallgrass prairie. Doctoral dissertation. University of Iowa, Department of Geoscience.

Laughlin, D. C., and P. Z. Fulé. 2008. Wildland fire effects on understory plant communities in two fire-prone forests. Canadian Journal of Forestry Research 38:133-142.

Laughlin, D. C., M. M. Moore, P. Z. Fulé. 2011. A century of increasing pine density and associated shifts in understory plant strategies. Ecology 92(3):556 -561.

Leopold, A. 1924. Grass, brush, timber and fire in southern Arizona. Journal of Forestry 22:1-10.

Leiberg, John B., Theodore F. Rixon, and Arthur Dodwell. 1904. Forest Conditions in the San Francisco Forest Reserve, Arizona. U.S. Department of the Interior, United States Geological Survey. Professional Paper No. 22.

Low, K. 2006. Effects of forest thinning treatments on fire behavior. Working Paper No.15 in Southwestern Ponderosa Pine Forest Restoration. Northern Arizona University, Ecological Restoration Institute, Flagstaff, AZ.

Lynch, D. L., W. H. Romme, and M. L. Floyd. Forest Restoration in Southwestern Ponderosa Pine' Journal of Forestry. August, 2000.

McCusker, N. A. 2012. Four-Forest Restoration Initiative Silviculture Specialist Report. Unpublished report on file with USDA Forest Service, Coconino National Forest, Flagstaff, AZ. 168 pp.

Margolis, E. Q., T. W. Swetnam, and C. D. Allen. 2011. Historical stand-replacing fire in upper montane forests of the Madrean sky islands and Mogollon Plateau, Southwestern USA. Fire Ecology. 7(3):88-107.

Mast, J. N., P. Z. Fulé, M. M. Moore, W. W. Covington, A. E. M. Waltz. 1999. Restoration of pre-settlement age structure of an Arizona ponderosa pine forest. Ecological Applications 9(1):228-239.

McPherson, Guy R., Dale D. Wade, and Clinton B. Phillips. 1990. Glossary of wildland fire management terms. Bethesda, MD: Society of American Foresters.

Mitchell, Jerry M. 1984. Fire management action plan: Zion National Park, Utah. Record of Decision. 73 pp. Report on file at: U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Fire Sciences Laboratory, Missoula, MT. 17278

Moir, W. H. and J. H. Deiterich. 1988. Old-Growth ponderosa pine from succession in pine-bunchgrass forests in Arizona and New Mexico. Natural Areas Journal 8(1):17-24.

Moore, M. M., and D. W. Huffman. 2004. Tree Encroachment on Meadows of the North Rim, Grand Canyon National Park, Arizona, U.S.A. Arctic, Antarctic, and Alpine Research 36(4):474-483.

Moore, M. M, D. W. Huffman, P. Z. Fulé, W. W. Covington, and J. E. Crouse. 2004. Comparison of Historical and Contemporary Forest Structure and Composition on Permanent Plots in Southwestern Ponderosa Pine Forests. Forest Science 5(2):162-176.

Moore, M. M., W. W. Covington, and P. Z. Fulé. 1999. Reference conditions and ecological restoration: a southwestern ponderosa pine perspective. Ecological Applications 9(4):1266-1277.

National Wildfire Coordinating Group (NWCG). 2008. Glossary of Wildland Fire Terminology. Incident Operations Standards Working Team. Online: http://www.nwcg.gov. Accessed January 4, 2010.

National Interagency Fuels, Fire & Vegetation Technology Transfer (NIFTT). 2010. Fire Regime Condition Class Software Application User's Guide Version 3.0.3.0

Neary, Daniel G., Kevin C. Ryan, and Leonard F. DeBano, eds. 2005. (Revised 2008). Wildland fire in ecosystems: effects of fire on soils and water. Gen. Tech. Rep. RMRS-GTR-42-Vol.4. Ogden, UT. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 250 pp.

Nicolet, T. 2011. Fire and Fuels Specialist Report for the Rim Lakes Forest Health Project. Unpublished report on file with USDA Forest Service, Sitgreaves National Forest, Springerville, AZ

New Mexico Environment Department. 2002. Fact Sheet: Cerro Grande Fire. NMED DOE Oversight Bureau at http://www.nmenv.state.nm.us/DOE_Oversight/RAC.htm

Noble, W. O. 2012. Four-Forest Restoration Initiative Wildlife Specialist Report. Unpublished report on file with USDA Forest Service, Coconino National Forest, Flagstaff, AZ.

North, M., M. Hurteau, and J. Innes. 2009. Fire suppression and fuels treatment effects on mixed-conifer carbon stocks and emissions. Ecological Applications 19(6):1385-1396.

Omi, P. N., and E. J. Martinson. 2004. Effectiveness of Thinning and Prescribed Fire in Reducing Wildfire Severity. USDA Forest Service Gen. Tech. Rep. PSW-GTR-193.

Ottmar, R. D. 2001. Smoke Source Characteristics. Smoke Management Guide for Prescribed and Wildland Fire 2001 Edition. NWCG. PMS 420-2, NFES 1279. Boise, ID.

Passovy, M. D., and P. Z. Fule. 2006. Snag and woody debris dynamics following severe wildfires in northern Arizona ponderosa pine forests. Forest Ecology and Management 223: 237 - 246

Parmeter, J. R., and B. Uhrenholdt. 1974. Some Effects of Pine-Needle or Grass Smoke on Fungii. Pre-published work, Department of Plant Pathology, University of California, Berkeley.
Online: http://www.apsnet.org/publications/phytopathology/backissues/Documents/1975Articles/Phyto65n01_28.PDF. Accessed July, 2012.

Peterson, J. L. 2001. Regulations for Smoke Management. Smoke Management Guide for Prescribed and Wildland Fire 2001 Edition. NWCG. PMS 420-2, NFES 1279. Boise, ID.

Pearson, G. A. 1931. Forest types in the Southwest as determined by climate and soil. Technical Bulletin 247. Washington, DC. U.S. Department of Agriculture.

Puhlick, J. J., D. C. Laughlin, and M. M. Moore. 2012. Factors influencing ponderosa pine regeneration in the southwestern USA. Forest Ecology and Management 264:10-19.

Pyke, A. D., M. L. Brooks, and C. D'Antonio. 2010. Fire as a restoration tool: a decision framework for predicting the control or enhancement of plants using fire. Restoration Ecology 18(3):274-284.

Pyne, S. 2011. Interview with the National Fire Protection Association. Online: http://www.nfpa.org/publicJournalDetail.asp?categoryID=&itemID=53565&src=NFPAJournal&cookie_test=1. Accessed in November, 2002.

Rebain, S. A. comp. 2010 (revised May 10, 2011). The Fire and Fuels Extension to the Forest Vegetation Simulator: Updated Model Documentation. Internal Rep. Fort Collins, CO. U. S. Department of Agriculture, Forest Service, Forest Management Service Center. 387 pp.

Reynolds, R. T., R. T. Graham, M. Hildegard Reiser, R. L. Bassett, P. L. Kennedy, D. A. Boyce Jr., G. Goodwin, R. Smith, and E. L. Fisher. 1992. Management Recommendations for the Northern Goshawk in the Southwestern United States. USDA Forest Service. Gen Tech Report RM-217.

Roccaforte, J. P., P. Z. Fule, W. W. Walker Chancellor, and D. C. Laughlin. 2012. Woody debris and tree regeneration dynamics following severe wildfires in Arizona ponderosa pine forests. Canadian Journal of Forest Research. 42:593 – 604.

Roccaforte, J. P., P. Z. Fulé, and W. W. Covington. 2008. Landscape-scale changes in canopy fuels and potential fire behavior following ponderosa pine restoration treatments. International Journal of Wildland Fire 17:293- 203.

Rothermel, R. C. 1991. Predicting behavior and size of crown fires in the Northern Rocky Mountains. USDA Forest Service Intermountain Research Station Research Paper INT-438. Ogden, UT.

Ryan, M. G. 2010. Temperature and tree growth. Tree Physiol. 30:667-668.

Ryan, K. C., and W. H. Frandsen. 1991. Basal Injury from smoldering fires in mature Pinus ponderosa Laws. International Journal of Wildland Fire 1(2):107-118.

Sackett, Stephen S., and Sally M. Haase. 1998. Two case histories for using prescribed fire to restore ponderosa pine ecosystems in northern Arizona. In: Fire in ecosystem management: shifting the paradigm from suppression to prescription. Teresa L. Pruden and Leonard A. Brennan, eds. Pp 380-389. Tall Timbers Fire Ecology Conference Proceedings, No. 20. Tall Timbers Research Station. Tallahassee, FL.

Sánchez Meador, A. J., M. M. Moore, J. D. Bakker, and P. F. Parysow. 2009. 108 years of change in spatial pattern following selective harvest of a Pinus ponderosa stand in northern Arizona, USA. Journal of Vegetation Science 20:79-90.

Savage, M., and J. N. Mast. 2005. How resilient are southwestern ponderosa pine forests after crown fires? Canadian Journal of Forestry Research 35:967-977.

Schmidt, Kirsten M., James P. Menakis, Colin C. Hardy, Wendall J. Hann, and David L. Bunnell. 2002. Development of coarse-scale spatial data for wildland fire and fuel management. General Technical Report RMRS-GTR-87. Fort Collins, CO: USDA Forest Service, Rocky Mountain Research Station. 41 pp.
Online: http://www.fire.org/niftt/released/Schmidt_et_al_2002.pdf Data accessed January 4, 2010.

Schollnberger, H., J. Aden, and B. R. Scott. 2002. Respiratory Tract Deposition Efficiencies:

Evaluation of Effects from Smoke Released in the Cerro Grande Forest Fire. Journal of Aerosol Medicine 15(4):387-399.

Schubert, G. H. 1974. Silviculture of southwestern ponderosa pine: the status of our knowledge. Research Paper RM-123. Fort Collins, CO: US. Department of Agriculture, Forest Service. 71 pp.

Schwilk, D. W., and N. Zavala. 2012. Germination response of grassland species to plant-derived smoke. Journal of Arid Environments. 79:111-115.

Scott, Joe H. 2003. Canopy fuel treatment standards for the wildland-urban interface. In: Fire, Fuel Treatments, and Ecological Restoration, Conference Proceedings. April 16-18, 2002. Ft. Collins, CO. Philip N. Omi and Linda A. Joyce, tech. eds. 2003. USDA Forest Service Proceedings RMRS-P-29. Online: http://www.fs.fed.us/rm/pubs/rmrs_p029.html. Accessed October 11, 2011.

Scott, Joe H., and Elizabeth D. Reinhardt, 2001. Assessing crown fire potential by linking models of surface and crown fire behavior. Research Paper RMRS-RP-29. Fort Collins, CO: USDA Forest Service, Rocky Mountain Research Station. 59 pp. Online: http://www.treesearch.fs.fed.us/pubs/4623.

Scott, Joe H., and Elizabeth D. Reinhardt. 2005. Stereo photo guide for estimating canopy fuel characteristics in conifer stands. General Technical Report RMRS-GTR-145. Fort Collins, CO: USDA Forest Service, Rocky Mountain Research Station. 49 pp. Online: http://www.treesearch.fs.fed.us/pubs/8473.

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. RMRS-GTR-153. USDA Forest Service.

Shepperd, W. D. 1986. 'Silviculture of Aspen Forests in the Rocky Mountains and Southwest'. USDA Forest Service RM-TT-7.

Smith, Ed. 2006. Historical Range of Variation and State and Transition Modeling of Historical and Current Landscape Conditions for Ponderosa Pine of the Southwestern U.S. Prepared for the USDA Forest Service, Southwestern Region by The Nature Conservancy, Tucson, AZ. 43 pp.

Smith, E. and H. Schussman. 2007. Historical Range of Variation and State and Transition Modeling of Historic and Current Landscape Conditions for Potential Natural Vegetation Types of the Southwest. The Nature Conservancy, Southwest Forest Assessment Project.

Sorensen D. C., J. A Finkral, E. T. Kolb, and H. C. Huang. 2011. Short- and long-term effects of thinning and prescribed fire on carbon stocks in ponderosa pine stands in northern Arizona. Forest Ecology and Management. 261 (2011) 460-472.

Steinke, R. 2007. Historic Ponderosa Pine Stand Structure of Mollisols, and Mollic Integrade Soils on the Coconino National Forest, USDA Forest Service Coconino National Forest. Unpublished internal study.

Strand, E. K., L. A. Vierling, S. C. Bunting, and P. E. Gessler. 2009. Quantifying successional rates in western aspen woodlands: Current conditions, future predictions. Forest Ecology and Management 257:1705-1715.

Stratton, Richard D. 2004. Assessing the Effectiveness of Landscape Fuel Treatments on Fire Growth and Behavior. Journal of Forestry 102(7):32-40.

_____. 2006. Guidance on spatial wildland fire analysis: models, tools, and techniques. Gen. Tech. Rep. RMRS-GTR-183. Fort Collins, CO: USDA Forest Service, Rocky Mountain Research Station. 15 pp.

_____. 2009. Landfire Fuels Data Acquisition, Critique, Modification, Maintenance, and Model Calibration. USDA Forest Service. RMRS-GTR-220.

Strom, B. A., and P. Z. Fulé. 2007. Pre-wildfire fuel treatments affect long-term ponderosa pine forest dynamics. International Journal of Wildland Fire 16:128-138.

Sugihara, Neil G., Jan W. van Wagtendonk, and JoAnn Fites-Kaufman. 2006. Fire as an ecological process. In: Fire in California's Ecosystems. Neil G. Sugihara, Jan W. van Wagtendonk, Kevin E. Shaffer, JoAnn Fites-Kaufman, and Andrea E. Thode, eds. California: University of California Press. Berkeley. Pp. 58-74.

Swetnam, T. 1990. Fire History and Climate in the Southwest. Panel paper presented at the conference, Effects of Fire Management of Southwestern Natural Resources. Tucson, AZ, November 14-17, 1988.

Swetnam, T.W., and C. H. Baisan. 1996. Historical fire regime patterns in the southwestern United States since AD 1700. Fire effects in southwestern forest: Proceeding of the 2nd La Mesa Fire symposium. Fort Collins, CO: USDA Forest Service Technical Report RM-GTR-286. Pages 11-32.

Swetnam, T. W., and J. L. Betancourt. 1998. Mesoscale disturbance and Ecological Response to Decadal Climatic Variability in the American Southwest. Journal of Climate 11:3128-3147.

Swetnam, T. W., and J. H. Dieterich. 1985. Fire history of ponderosa pine forests in the Gila Wilderness, New Mexico. pp. 390-397. In: Proceedings of the Symposium and Workshop on Wilderness Fire. Nov. 15-18, 1983, Missoula, MT. USDA For. Serv., Gen. Tech. Rep. INT-182.

Tong, D. Q., and D. L. Mauzerall. 2008. Summertime State-Level Source-Receptor Relationships between Nitrogen Oxides Emissions and Surface Ozone Concentrations over the Continental Unites States. Environmental Science and Technology 42:7976-7984.

Triepke, F. J., B. J. Higgins, R. N. Weisz, J. A. Youtz, and T. Nicolet. 2011. Diameter caps and forest restoration – Evaluation of a 16-inch cut limit on achieving desired conditions. USDA Forest Service Forestry Report FR-R3-13-3. Southwestern Region, Regional Office, Albuquerque, NM. 31 pp.

USDA. 2008. Fire Effects Information System Glossary. In: Fire Effects Information System, [Online]. USDA Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory (Producer). Online: http://www.fs.fed.us/database/feis/glossary.html. Accessed October 14, 2008.

USDA Forest Service. Kaibab National Forest. 2006. Ecological Sustainability Analysis of the Kaibab National Forest: An Evaluation of Terrestrial Ecosystems (Ecological Units, Soil

Composition, Structure and Processes) that Affect Ecosystem Diversity and Contribute to Ecological Sustainability. R. Steinke, author.

USDA and USDI. 1995. Federal Wildland Fire Management: Policy and Program Review: Final Report. Washington, D.C.

US Environmental Protection Agency. 1999. Regional Haze Rule. 40 CFR 51.300-309. http://www..epa.gov/ttncaaa1/t1/fr_notices/rhfedreg.pdf.

_______. 2010. Air Quality Index Charts for Coconino County. http://www.epa.gov/air/data/reports.html.

U.S. Laws, Statutes, etc.; Public Law 101-549. Clean Air Act as Amended Nov. 1990. 42 U.S.C. §7401.

Van Wagner, C. E. 1973. Height of crown scorch in forest fires. Canadian Journal of Forest Resource 3:373-378.

Waltz, A., P. Z. Fulé, W. W. Covington, and M. M. Moore. 2003. Diversity in ponderosa pine forest structure following ecological restoration treatments. Forest Science 49(6): 885-900.

Ward, D. E., and C. C. Hardy. 1991. Smoke emissions from wildland fires. Environmental International 17:117-134.

Waring, K. M., D. M. Reboletti, L. A. Mork, C-H. Huang, R. W. Hofstetter, A. M. Garcia, P. Z. Fulé, and T. S. Davis. 2009. Modeling the impacts of two bark beetle species under a warming climate in the southwestern USA: Ecological and Economic Consequences. Environmental Management DOI 10.1007/s00267-009-9342.

Weaver, H. 1951. Fire as an Ecological factor in southwestern ponderosa pine forests. Journal of Forestry. 49: 93-98.

Westerling, A. L., H. D. Hidalgo, D. R. Cayan, and T. W. Swetnam. 2006. Warming and earlier spring increases western U. S. forest wildfire activity. Science 313:940-943.

Wiedinmyer, C., and M. D. Hurteau. 2012. Prescribed Fire as a Means of Reducing Forest Carbon Emissions in the Western United States. Environmental Science and Technology 44:1926-1932.

Williams, A. P., C. D. Allen, C. I. Millar, T. W. Swetnam, J. M. Michaelsen, C. J. Still, and S. W. Leavitt. 2010. Forest responses to increasing aridity and warmth in the southwestern United States. Proceedings of the National Academy of Sciences of the United States of America 107(50):21289-21294.

Woods, K. W., J. Langer, K. Mesaros, and S. Plumb. 2012. Carbon Commodities Funding Forest Restoration Draft Report. Prepared for M. Selig, Grand Canyon Trust.

Zimmerman, G. T., and R. D. Laven. 1987. Effects of Forest Fuel Smoke on Dwarf Mistletoe Seed Germination. Great Basin Naturalist 47(4):652-659.

Appendix C: Glossary

Active crown fire – a fire in which a solid flame develops in the crowns of trees, but the surface and crown phases advance as a linked unit dependent on each other.

Adaptive Management: a type of planning and implementation that incorporates the results of prior actions, new scientific findings, and changing societal needs into constantly evolving conservation goals and practices. This management style requires monitoring of baseline ecological data as well as the results of ongoing activities and the solicitation of public needs. Under adaptive management, plans and activities are treated as working hypotheses rather than final solutions to complex problems. The process generally includes four phases: planning, implementation, monitoring, and evaluation. The level of success of this process is dependent upon the participation of critical stakeholders.

Biomass: multiple definitions include: organic matter produced by plants and other photosynthetic organisms; total dry weight of all living organisms that can be supported at each level of a food chain or web; dry weight of all organic matter in plants and animals in an ecosystem; plant materials and animal wastes that functions as fuel for fire.

Burn: an effect produced by heating. To undergo combustion, consuming fuel and giving off light, heat and gasses. Also, an area where fire has occurred in the past.

Canopy Base Height (CBH): The lowest height above the ground at which there is a sufficient amount of canopy fuel to propagate fire vertically into the canopy (Scott and Reinhardt 2001). Canopy base height is a value that describes 'ladder fuels', such as understory trees, the lower branches of mature trees, or shrubs and/or herbaceous vegetation sufficient to produce a fire of high enough intensity to initiate crown fire (Figure 102). The lower the canopy base height, the easier is for crown fire to initiate (Van Wagner 1977), because shorter flame lengths may be sufficient to ignite the canopy. Continuity of canopy base height across a forest or a stand is not necessary to initiate crown fire, technically, a single ladder fuel is sufficient.

Canopy Bulk Density (CBD): The mass of available canopy fuel per unit volume. It is a bulk property of a stand of trees, not individual trees (Scott and Reinhardt 2001). The greater (higher) the canopy bulk density is, the harder it is to see the sky though the canopy when you're looking up through it. The higher the canopy bulk density, the more easily fire can move through the crowns of trees, and the more fuel there is to burn, influencing fire intensity as well, so that greater flame lengths and radiant heat are more likely to carry fire though the canopy.

Canopy Cover: as used in modeling fire, is the horizontal fraction of the ground that is covered directly overhead by tree canopy, the percent of vertically projected canopy cover in the stand (Scott and Reinhardt 2005).

Condition Class (reference **FRCC**) – A measure of departure from reference conditions that can be used to determine how 'at risk' key ecosystem components are in the event of a disturbance event, such as fire.

Conditional crown fire – a crown fire that is dependent on ladder fuels in adjacent stands in order for fire to access the crowns. In an area with conditional crown fire, ladder fuels are insufficient in a stand for crown fire to initiate, but canopy fuels are sufficient to support crown fire if it moves in from an adjacent stand.

Controlled burn – synonymous with Prescribed Fire.

Crown fire – a fire that advances from top to top of trees or shrubs more or less independent of a surface fire. Crown fires are sometimes classed as independent, conditional, or dependent (active or passive) to distinguish the degree of independence from the surface fire. Crown fires are common in coniferous forests and chaparral shrublands.

Disturbance: any relatively discrete event or series of events—either natural or human-induced—that causes a change in the existing condition of an ecosystem, community, or population structure and alters the physical environment.

Disturbance Regime: a set of recurring conditions due to a variety of disturbances (e.g., fire, flooding, insect outbreak) and their interaction, which characterize an ecosystem within a historic, natural or human induced context, within a given climate. This set of recurring conditions includes a specific range for each of the attributes of these disturbances. These attributes include: frequency, rotation period, intensity, severity, seasonality, patch size and distribution, residual structure, casual agent, the relative influence of each causal agent and how they interact (Suffling and Perera 2004). The attributes researchers choose to represent a regime will vary depending on a researcher's area of interest (Sousa 1984, Pickett and White 1985, Agee 1993, Skinner and Chang 1996, Turner et al 2001). An accurate description of a disturbance regime must include the full range of disturbance events, including those that are rare.

Drought: periods of abnormally dry weather sufficiently long enough to cause a serious hydrological imbalance. Drought is a relative term; therefore any discussion in terms of precipitation deficit must refer to the particular precipitation-related activity that is under discussion. For example, there may be a shortage of precipitation during the growing season resulting in crop damage (agricultural drought), or during the winter runoff and percolation season affecting water supplies (hydrological drought).

Duff: the fermentation and humus layer lying below the litter layer and above mineral soil; consisting of partially decomposed organic matter whose origins can still be visually determined, as well as the fully decomposed humus layer. This layer does not include the freshly cast material in the litter layer, nor in the post-burn environment, ash (Brown 2000). The top of the duff is where needles, leaves, fruits and other castoff vegetative material have noticeably begun to decompose. Individual particles usually are bound by fungal mycelia. The bottom of the duff is mineral soil. There is a gradient, not a clear division between litter and duff.

Ecological Process: events or combinations of events (including ecological disturbances and perturbations) that occur in natural environments within a range of conditions and cause a range of dynamic effects on the structure, composition, and functioning of ecosystems

Ecosystem: a biotic community and its surroundings, part inorganic (abiotic) and part organic (biotic).

Erosion: the wearing away of the land surface by rain or irrigation water, wind, ice, or other natural or anthropogenic agents that abrade, detach and remove geologic parent material or soil from one point on the earth's surface and deposit it elsewhere.

FRCC – see Fire Regime/Condition Class

Fire: rapid oxidation, usually with the evolution of heat and light; heat fuel, oxygen and interaction of the three. We generally recognize two basic kinds of fire: structure fires and wildland fires.

Fire Adapted Ecosystem: an associated group of plant and animals that have made long term genetic changes in response to the presence of fire in their environment.

Fire Ecology: the study of fire's interaction with ecosystems.

Fireline Intensity: rate of heat release in the flaming front. A quantitative measure of fire behavior that is a measure of the fire itself (not it's effects). Indicators include flame length, flame height, peak temperatures, energy output/time, scorch height (as in indicator of flame height).

Fire Regime: a set of recurring fire conditions that characterize an ecosystem, within a historic, natural or human induced context, within a given climate. This set of recurring conditions includes a specific range of attributes: Sugihara et al. (2006) uses the following attributes: seasonality, frequency (fire return interval), intensity, severity, size, spatial complexity, and fire type. An accurate description of a fire regime will include the full range of fire events, including those that are rare and connect to the larger disturbance regime which contains the fire regime as a subset.

Fire Return Interval: the number of years between two successive fires in a designated area (i.e., the interval between two successive fires); the size of the area must be clearly specified (McPherson and others 1990).

Fire Regime/Condition Class (**FRCC**) – an ecological evaluation protocol that uses three classes for describing the relative degree of departure from historical fire regimes.

Fire Severity A qualitative evaluation of immediate post-fire effects produced by the heat pulse on the biotic an abiotic components of an ecosystem. Indicators include the amount of biomass consumed, changes in the amount of mineral soil exposed, soil color, topkilled surface vegetation.

Fire Type: flaming front patterns that are characteristic of a fire.

First Order Fire Effects: effects resulting directly from the fire, such as fuel consumption and smoke production.

Flame Length: the length of flames in the propagating fire front measured along the slant of the flame from the midpoint of its base to its tip.

Fuel Continuity: a qualitative description of the distribution of fuel, both horizontally and vertically. Continuous fuel supports fire spread better than discontinuous fuel. See Fuel.

Fuel Load: weight of fuel per unit area. See Fuel.

Fuel: living and dead vegetation that can be ignited.

Fuel Type: an identifiable association of fuel elements of distinctive species, form, size, arrangement, or other characteristics that will cause a predictable rate of spread, or resistance to control under specified weather conditions.

Ground fire **-** fire that burns in the organic material below the litter layer, mostly by smoldering combustion. Fires in duff, peat, dead moss and lichens, and partly decomposed wood are typically ground fires.

Habitat: place where an animal or plant normally lives, often characterized by a dominant plant form or physical characteristic. Often described for individual species, e.g., spotted owl habitat, it is usually used as a generalization of where an animal may live.

Hazard - A fuel complex, defined by volume, type, condition, arrangement, and location that determines the degree of ease of ignition and the resistance to control. The state of the fuel, exclusive of weather or the environs in which the fuel is found (NWCG 2003, Hardy 2005).

Historic Range of Variation (HRV): refers to ecosystem composition, structure, and process for a specified area and time period. Historic range of variation (HRV) is often used to determine our best estimate of "natural" conditions and functions, and thus is often our best estimate of the natural range of variation (NRV). Ecosystems change over time. It is assumed that native species have adapted over thousands of years to natural change and that change outside of NRV may affect composition and distribution of species and their persistence.

Invasive: any species which can establish, persist, and spread in an area, and be detrimental or destructive to native ecosystems, habitats, or species and difficult to control or eradicate.

Ladder Fuel: fuel, such as branches, shrubs or an understory layer of trees, which allow a fire to spread from the ground to the canopy.

Landscape Pattern: the term for the contents and internal order of a diverse area of land. These include the number, frequency, size, and juxtaposition of landscape elements, such as corridors and patches, which are important to determine or interpret ecological processes.

Land/Resource Management Plan (L/RMP) – a document prepared with public participation and approved by an agency administrator that provides general guidance and direction for land and resource management activities for an administrative area. The L/RMP identifies the need for fire's role in a particular area and for a specific benefit. The objectives in the L/RMP provide the basis for the development of fire management objectives and the fire management program in the designated area.

Litter: the top layer of the forest, shrubland or grassland floor above the duff layer, including freshly fallen leaves, needles, bark, flakes, fruits (e.g., acorns, cones), cone scales, dead matted grass, and a variety of accumulated dead organic matter which is unaltered, or only slightly decomposed. This layer typically does not include twigs and larger stems. One rough measure to distinguish litter from duff is that you can pick up a piece of litter and tell what it was (a leaf or leaf part, a needle, etc.). Duff is generally not identifiable. There is a gradient, not a clear division between litter and duff.

Monitoring: a systematic process of collecting and storing data related to natural systems at specific locations and times. Determining a system's status at various points in time yields information on trends, which is crucial in detecting changes in systems.

Mosaic: the spatial arrangement of habitat where there is stand heterogeneity **-** measured at many spatial scales from the patch, the stand, and the vegetative community.

National Environmental Policy Act (NEPA): the environmental law passed by the U. S. Congress in 1969 that requires the preparation of specific environmental documentation for major undertakings using federal funds. Public involvement is an integral component of this process.

Native: a species which is an indigenous (originating where it is found) member of a biotic community. The term implies that humans were not involved in the dispersal or colonization of the species.

Objective: a defensible target or specific component of a goal, whose achievement represents measurable progress toward a goal. Thus an objective needs to be a clear, measurable and attainable refinement of a goal, which you intend to achieve within a stated time-period.

Objectives need to be concise statements of what we want to achieve, how much we want to achieve, when and where we want to achieve them, and who is responsible for the work. Objectives provide the basis for determining strategies, monitoring accomplishments, and evaluating success. Goals usually have more than one objective.

Passive crown fire – a fire in the crowns of the trees in which trees or groups of trees torch, ignited by the passing front of the fire. The torching trees reinforce the spread rate, but these fires are not basically different from surface fires.

Percentile weather – For a given weather parameter (such as temperature, wind speed, relative humidity, precipitation, etc.,) the percent of days in a year that fall below it. For example, if the 90^{th} percentile temperature for a given location is 90°F, it means that for 90 percent of days in a year, the temperature is lower than 90°F.

Pile burning – Activity fuels, once piled by machine or by hand, are burned in place.

Planned Ignition –the intentional initiation of a wildland fire by hand-held, mechanical or aerial device where the distance and timing between ignition lines or points and the sequence of igniting them is determined by environmental conditions (weather, fuel, topography), firing technique, and other factors which influence fire behavior and fire effects (see prescribed fire).

Prescribed Fire—is a wildland fire originating from a planned ignition to meet specific objectives identified in a written, approved, prescribed fire plan for which NEPA requirements (where applicable) have been met prior to ignition (see planned ignition).

Protection - the actions taken to limit the adverse environmental, social, political, and economical effects of fire (FEC Briefing Paper, 3/14/2008).

Reference Condition: a range of conditions (found in the present or the past) against which the effects of past and future actions can be compared. These states can provide an explicit, historically-based context for comparing different management effects. Examples include periods before fire suppression or the arrival of an invasive species, or a similar but "healthier" modern ecosystem. Ideally these environmental conditions are based on functioning ecosystems where natural ecosystem structure, composition, and function are operating with limited human intervention (very minor human-caused ecological effects).

Residence Time: time required for the flaming front of a fire to pass a stationary point at the surface of the fuel. The length of time the flaming front occupies one point; relates to downward heating and fire effects below the surface.

Resilience: the ability of an ecosystem to maintain the desired condition of diversity, integrity, and ecological processes following disturbance. The ability of a system to absorb or recover from disturbance and change, while maintaining its functions and services.

Response to wildland fire - the mobilization of the necessary services and responders to a fire based on ecological, social, and legal consequences, the circumstances under which a fire occurs, and the likely consequences on firefighter and public safety and welfare, natural and cultural resources, and values to be protected.

Risk – In the context of technical risk assessments, the term "risk" considers not only the probability of an event, but also includes values and expected losses. Within wildland fire, 'risk' refers only to the probability of ignition (both man- and lightning-caused) (Hardy 2005).

Seasonality: the timing of a fire during the year or the period(s) of the year during which fires are likely to start and spread—seasonal component of a fire regime.

Second Order Fire Effects: the secondary effects of fire such as tree regeneration, plant succession, and changes in site productivity. Although second order fire effects are dependent, in part, on first order fire effects, they also involve interaction with many other non-fire variables, eg. weather.

Seed Bank: the community of viable seeds present in the soil.

Seral Stage: a transitory or developmental stage of a biotic community in an ecological succession (does not include structural seral stage).

Severity: the quality or state of distress inflicted by a force. The degree of environmental change caused by a disturbance, e.g. Fire.

Soil Heating: an increase in soil temperature as a result of heat transfer from the combustion of surface fuel and smoldering combustion of organic soil horizons. Because of the variability of fuel consumption, soil heating is typically variable across landscapes. In many cases, the highest soil temperatures are associated with high fuel consumption and/or complete duff consumption. Under these circumstances, the duration and intensity of burning are affected.

Soil Texture: description of soil composition based on of sand, silt, and clay.

Stakeholder: any individual, group, or institution that has a vested interest (financial, cultural, value-based, or other) in the conservation, management and use of a resource and/or might be affected by management activities and have something to gain or lose if conditions change or stay the same. Stakeholders are all those who need to be considered in achieving project goals and whose participation and support are crucial to its success. Stakeholders can be internal (work for the management unit) or external.

Succession: the sequential change in vegetation and the animals and plants associated with it, either in response to an environmental change or induced by the intrinsic properties of the organisms themselves.

Suppression - all the work of extinguishing a fire or confining fire spread.

Surface Fire: a fire that burns over the forest floor, consuming litter, killing aboveground parts of herbaceous plants and shrubs, and typically scorching the bases and crowns of trees. See Backing Fire, Crown Fire, Fire, Flanking Fire, Ground Fire, Head Fire and Understory Fire.

Surface Fuel: fuels lying on or near the surface of the ground, consisting of leaf and needle litter, dead branch material, downed logs, bark, tree cones, and low stature living plants. See Duff, Fuel, Large Woody Debris and Litter.

Sustainability: the condition of maintaining ecological integrity and basic human needs over human generations.

Temporal: a characteristic that refers to the time at which a given data set was acquired; relating to measured time.

Threatened Species: any species of plant or animal likely to become endangered—within the foreseeable future—throughout all or a significant portion of its range. See Endangered Species.

Top Kill: for individual plants, when some portion of the aboveground portion of an individual is killed, by any cause.

Topography: the physical features of a geographic area, such as those represented on a map, taken collectively—especially, the relief and contours of the land.

Torching – see Passive crown fire.

Type Conversion: changing one vegetative type to another. Generally thought of as a rapid conversion from one type to a completely different type but can also occur subtly over time. This is different than successional trajectory where vegetation follows expected changes in type over time. An example is converting an area that would naturally contain mixed conifer hardwood forest to a pure conifer forest by removing hardwoods and planting only conifers. Another example could be suppressing frequent fires allowing conifers to shade out hardwoods converting mixed conifer hardwood forests to conifer forests.

Unplanned Ignition – the initiation of a wildland fire by lightning, volcanoes, unauthorized and accidental human-caused fires (see wildfire).

VSS class – Classification of trees by size using DBH and Height as the primary criteria (see Silvicultural report for details (McCusker, 2012).

Weather: the specific condition of the atmosphere at a particular place and time. It is measured in terms of such things as wind, temperature, humidity, atmospheric pressure, cloudiness, and precipitation. In most places, weather can change from hour-to-hour, day-to-day, and season-to-season. Climate is the average of weather over time and space. A simple way of remembering the difference is that climate is what you expect (e. g. Cold winters) and ‘weather' is what you get (e.g. a blizzard).

Wildfire – unplanned ignition of a wildland fire (such as a fire caused by lightning, volcanoes, unauthorized and accidental human-caused fires) and escaped prescribed fires. (See unplanned ignition and escaped prescribed fire).

Wildland Fire – a general term describing any non-structure fire that occurs in the wildland. Wildland Urban Interface (WUI) – The line, area, or zone where structures and other human development meet or intermingle with undeveloped wildland or vegetation fuels.

Woody Debris: the dead and downed material on the forest floor consisting of fallen tree trunks and branches.

Appendix D: Descriptions of models and processes used in fire modeling

Fire models are tools to help depict relative change in fire behavior and effects across the landscape. Although there are limitations to fire modeling, the model outputs provide useful information for planning and assessing restoration treatments (Stratton 2004, Stratton 2006). Interpretation, professional judgment and local knowledge of fire behavior and effects were used to evaluate the outputs from the models. Data used for modeling fire across a landscape will rarely use the exact numbers as measured in the fields for canopy characteristics. The intent of fire modeling is to find the combination of fuel models, fuel characteristics (canopy base height, canopy bulk density, canopy cover, canopy height), fuel moistures, and weather parameters that produce the most accurate modeled fire behavior. That usually means 'gaming' the fuel models, adjusting various characteristics until the modeled fire behavior most closely represents known fire behavior. In this manner, canopy cover in a fuel model is adjusted by the same age as shown in modeled silvicultural change/s. The degree of change is what is important for the modeling exercise, and that requires canopy cover numbers that are measured in a consistent manner so that the change is valid.

Forest Vegetative Simulator/Fire Fuels Extension (FVS/FFE) Model

The FVS is a model used for predicting forest stand dynamics throughout the United States and is the standard model used by various government agencies including the USDA Forest Service, USDI Bureau of Land Management, and USDI Bureau of Indian Affairs (Dixon 2008). The FVS is an individual tree, distance independent growth and yield model with linkable modules called extensions, which simulate various insect and pathogen impacts, fire effects, fuel loading, snag dynamics, and development of understory tree vegetation. FVS can simulate a wide variety of forest types, stand structures, and pure or mixed species stands (CRVAR 2010). Forest managers have used FVS extensively to summarize current stand conditions, predict future stand conditions under various management alternatives, and update inventory statistics.

Geographic variants of FVS have been developed for most of the forested lands in the United States. New "variants" of the FVS model are created by imbedding new tree growth, mortality, and volume equations for a particular geographic area into the FVS framework (CRVAR 2010). The Central Rockies (CR) variant covers all forested land in Forest Service Regions 2 and 3 and was used in the vegetation analysis for this project area. This variant was initially developed in 1990 and has been continually updated to correct known deficiencies and quirks, take advantage of advances in FVS technology, incorporate additional data into model relationships, and improve default values and surrogate species assignments (CRVAR 2010).

For simulation purposes, each data set was grouped by current forest type, VSS code, site class and treatment type. Simulations were developed for each treatment based on desired conditions. A multitude of vegetation and fuels attributes were computed for each growth cycle. Attributes include tree density (trees per acre, basal area and SDI) by species or species groups and VSS size class, dwarf mistletoe infection, cubic feet of biomass removed, canopy base height and bulk density, live and dead surface fuel loading, live and dead standing wood, coarse woody debris and snags. These attributes were then averaged for all the data sets represented in the simulation. The averaged computed attributes from FVS were also used to calculate other attributes such as dominate VSS size class, canopy density and even-aged or uneven-aged structure. All of these attributes were then compiled into an "effects" database by alternative and used to analyze and display the direct and indirect effects to the vegetation resource.

Fire and Fuels Extension

The Fire and Fuels Extension (FFE) to FVS was used to simulate fuel dynamics over time. Those data were used to inform the process of assigning post-treatment fuel models. Additionally, FFE provided the data for evaluating modeled treatment effects for 2020 and 2050.

FlamMap

FlamMap is a fire behavior mapping and analysis program that computes potential fire behavior characteristics over an entire landscape for given weather and fuel moisture conditions. FlamMap uses GIS-based raster inputs for terrain and fuel characteristics (elevation, slope, aspect, fire behavior fuel models, and canopy characteristics), computes fire behavior outputs for a given landscape using standard fire behavior prediction models, and generates raster maps of potential fire behavior characteristics (spread rate, flame length, crown fire activity, etc.) over an entire landscape.

Uniform Conditions

FlamMap employs the fire behavior model (Rothermel 1972). The Rothermel fire behavior model makes several assumptions which include:

• The fire is free-burning

• Fire behavior is predicted for the flaming front of a surface fire

• Fine fuels are the primary carrier of the initial fire front

• Fuels are continuous and uniform

FlamMap then utilizes Van Wagner's 1977 crown fire initiation model, Rothermel's 1991 crown fire spread model, and Nelson's 2000 dead fuel moisture model to model both crown fire.

Fire behavior outputs generated from modeling exercises only reflect static conditions and do not take into account changing weather conditions. Any change in these factors could drastically affect fire behavior. Given the uncertainty of any modeling exercise, the results are best used to compare the relative effects of the alternatives, rather than as an indicator of absolute effects. Interpretation, professional judgment, and local knowledge of fire behavior were used to evaluate the outputs from the models and adjustments made as necessary to refine the predictions.

FlamMap assumptions and limitations

Since FlamMap uses the same underlying models (Rothermel’s 1972, 1991, Van Wagner’s 1977, and Nelson’s 2000) for surface fire spread, crown fire spread, and dead fuel moisture, it will inherently have the same assumptions and limitations as each of those models. In addition, FlamMap 3.0 has a number of additional limitations:

- All fire behavior calculations in FlamMap Basic assume that fuel moisture,
- wind speed, and wind direction are constant for the simulation period.
- The fire behavior calculations are performed independently for each cell on the gridded landscape.
- Flammap doesn’t use a 24 hour clock, so diurnal weather changes, which could affect fire

behavior, are not accounted for

- Canopy characteristic in the Landfire data were adjusted by the percent change indicated by the changes in the FVS data to represent post-treatment conditions.

Canopy cover for fire modeling:
Canopy cover (cc) is one of four canopy characteristics are necessary for evaluating and modeling fire behavior and/or effects. In the fire models, canopy cover affects outputs for:

- Active crown fire (horizontal continuity)
- Passive crown fire (as it affects surface fire intensity)
- Fireline intensity/flame length (more wind means higher intensity, longer flame lengths, affects crown fire initiation)
- Rate of spread (open canopies allow higher winds at the surface)

Fuel models, used for modeling fire, rarely use *measured* canopy characteristics. The intent is to find the combination of fuel models, fuel moistures, and weather parameters that allow models to most accurately predict fire behavior. That usually means 'gaming' the fuel models, adjusting various characteristics until the modeled fire behavior most closely represents known fire behavior. In this manner, canopy cover in a fuel model is adjusted by the same percentage as shown in modeled silvicultural change/s. The degree of change is what is important for the modeling exercise, and that requires canopy characteristic data that are obtained in a consistent manner so that the percent change is valid.

Farsite

In the context of this analysis, Farsite was only used to edit the .lcp files used in FlamMap.

FireFamilyPlus (FF+)

FireFamily Plus is a software system for summarizing and analyzing historical daily fire weather observations and fire occurrences and computing fire danger indices based on the National Fire Danger Rating System or the Canadian Fire Danger Rating System. Fire occurrence data can also be analyzed and cross referenced with weather data to help determine critical fire weather, fuel moistures, and fire danger for an area.

FF+ was used to:

- evaluate weather percentiles for determining the overall context of the Schultz Fire conditions.
- Identify fires of interest to this analysis (this was verified with local fire managers)
- Produce wind roses and wind data
- Produce precipitation data from the three Remote Automated Weather Stations most pertinent to the project areaFire Regime/Condition Class:

The default values for these were used for reference FRI, severity, and seral stage. For the ponderosa pine, this was an FRI of 6 (indicating fires, on average, burned every 6 years) and severity of 6 percent (indicating 6 percent of the landscape would have supported high severity fire). These conditions were compared with modeled conditions from 2020 and 2050 for each alternative (details are in Appendix D). Seral stages were cross-walked to VSS classes bases on:

VSS1/2 – Class A: post-replacement; Grass-oak-shrub; stands post-replacement from crown fire or reburn

VSS 3C - Class B: mid-development closed; >30% canopy cover of sapling/poles

VSS 4A/B - Class C: mid-open; <30% canopy cover of sapling/poles; oak or grass understory

VSS 5/6A/B - Class D: late-open; <30% ponderosa pine dominated canopy; oak or grass understory

VSS 5/6C - Class E: late-closed; >30% canopy cover ponderosa pine

Current severity in ponderosa pine was estimated at 40%, assuming the 37% that was modeled as crown fire would all be high severity, and there would be additional acres that would burn with high severity from high intensity surface fire that would lethally scorch canopies without crowning.

This first figure applies to all alternatives for all years. It shows the classifications that were used to represent the biophysical land units for the Fire Regime/Condition Class (FRCC) analysis.

Fire Regime Condition Class
Landscape Report - Code Summary

Stratum Biophysical Land Unit(BpS)		Species	
PPIN5	Ponderosa Pine (Colorado Plateau)	DACRY3	Dacrydium (pine)
MGRA2	Mtn. Grassland With Trees	PSEUD7	Pseudotsuga (Douglas-fir)
		ABIES	Abies (fir)
Lifeforms		PIPO	Pinus ponderosa (ponderosa pine)
CF	Coniferous upland forest -- Pine, spruce, hemlock		
HU	Herbaceous dominated upland -- grasslands, bunchgrass	Size	

Landform

Average Slope

Reference Composition Source

D coarse-scale default values from lit. review/modeling workshops

Current Composition Source

R walk through and visual estimate

Insolation Class

Upper Layer Majority Lifeform

HERB Herbaceous (graminoids, forbs and ferns

Figure 73. Summary of stratum biophysical codes used for all alternatives, all years

Existing Conditions

Fire Regime Condition Class
Landscape Report

version 3.0.3.0

Landscape

Registration Code: 4FRI-Lata   Landscape Code: 4FRI   Characterization Date: 04/24/2012

Examiner: Lata   Landscape Name: 4FRI-existing condition   Area: 560952 Acres

Lat: 35.000000   Lon: 112.000000   Datum: NAD83

Comment: Will add photos later

Biophysical Stratification

Num	Life-form	BpS	Species	Land-form	Slope Class	Insol Class	Elevation Low	Elevation High	Stratum Comp (%)	Ref Freq	Curr Freq	Ref Sev	Curr Sev	Strata Depart	Strata FRCC
1	CF	PPIN5							90	7	40	6	38	75	3
2	HU	MGRA2							10	10	45	60	75	51	2
									100						

Figure 74. Biophysical stratification for existing condition

Fire Regime Condition Class
Landscape Report - Stratum Data

Registration Code: 4FRI-Lata   Landscape Code: 4FRI   Characterization Date: 04/24/2012

Stratum Num: 1   Biophysical Setting: PPIN5   Stratum Name: Ponderosa Pine (Colorado Plateau)

Stratum Composition (% of area): 90   BpS Lifeform: CF   Landform: Avg Slope Class: Insol Class:

Stratum Area: 504856 Acres   Species: Low Elevation: High Elevation:

Reference Frequency: 7   Current Frequency: 40   Latitude: Longitude: Datum: WGS84

Reference Severity: 6   Current Severity: 38   Reference Composition Source: D   Current Composition Source: R

Comments:

Succession Classes

Code	Upper Layer Lifeform	Majority Size	Dominant Species			Ref Comp	Curr Comp	Acres	Sim	Diff	Relative Amount	Stand FRCC	Stand Depart	S-Class Acres Departed from Reference
A						5	2	10097	2	-60	UNDER REP	1	0	-15145
B			DACRY3	PSEUD7	ABIES	5	57	287768	5	91	ABUNDANT	3	91	262525
C						15	27	136311	15	44	OVER REP	2	44	60582
D			PIPO			65	5	25242	5	-92	TRACE	1	0	-302914
E			PIPO	PSEUD7	ABIES	10	7	35339	7	-30	SIMILAR	1	0	-15145
U						0	2	10097	0	100	ABUNDANT	3	100	10097
					Total	100	100		34					

Stratum Vegetation Departure: 66   Stratum Fire Frequency Departure: 83   Stratum Regime Departure: 83

Stratum Vegetation Condition Class: 2   Stratum Fire Severity Departure: 84   Stratum Regime Condition Class: 3

Stratum Fire Regime: I - Frequent Surface and Mixed   Stratum Departure: 75   Stratum Fire Regime Condition Class: 3

Figure 75. Landscape report with succession classes for ponderosa pine, existing condition

Fire Regime Condition Class
Landscape Report - Stratum Data

Registration Code: 4FRI-Lata   Landscape Code: 4FRI   Characterization Date: 04/24/2012

Stratum Num: 2 Biophysical Setting: MGRA2   Stratum Name: Mtn. Grassland With Trees

Stratum Composition (% of area): 10   BpS Lifeform: HU   Landform: Avg Slope Class: Insol Class:

Stratum Area: 56095 Acres   Species: Low Elevation: High Elevation:

Reference Frequency: 10 Current Frequency: 45   Latitude: Longitude: Datum: WGS84

Reference Severity: 60 Current Severity: 75   Reference Composition Source: D   Current Composition Source: R

Comments:

Succession Classes

Code	Upper Layer Majority Lifeform	Size	Dominant Species	Ref Comp	Curr Comp	Acres	Sim	Diff	Relative Amount	Stand FRCC	Stand Depart	S-Class Acres Departed from Reference
A	HERB			10	3	1682	3	-70	TRACE	1	0	-3926
B				60	15	8414	15	-75	TRACE	1	0	-25242
C	HERB			30	72	40388	30	58	OVER REP	2	58	23559
D				0	0	0	0	N/A				0
E				0	0	0	0	N/A				0
U				0	10	5609	0	100	ABUNDANT	3	100	5609
			Total	100	100		48					

Stratum Vegetation Departure: 52   Stratum Fire Frequency Departure: 78   Stratum Regime Departure: 49

Stratum Vegetation Condition Class: 2   Stratum Fire Severity Departure: 20   Stratum Regime Condition Class: 2

Stratum Fire Regime: I - Frequent Surface and Mixed   Stratum Departure: 51   Stratum Fire Regime Condition Class: 2

Figure 76. Landscape report with succession classes for grassland stratum, existing condition

Fire Regime Condition Class
Landscape Report - Reference Fire Regime Summary

Registration Code: 4FRI-Lata   Landscape Code: 4FRI   Char Date: 04/24/2012

Stratum #	Reference Frequency	Reference Severity	Fire Regime Group
1	7	6	I
2	10	60	I

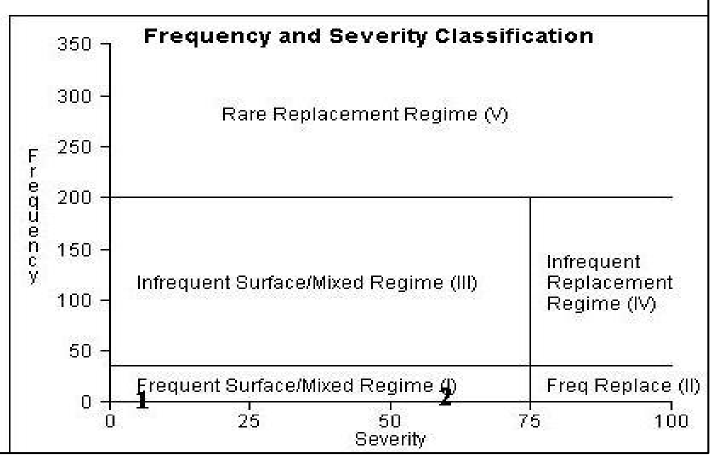


Figure 77. Reference Fire Regime summary for existing condition

Fire Regime Condition Class
Landscape Report - FRCC Summary

Registration Code: 4FRI-Lata Landscape Code: 4FRI Char Date: 04/24/2012

Stratum #	Stratum Depart (%)	Stratum Comp (%)	Weighted Depart (%)
1	75	90	67
2	51	10	5
Sum		100	72

Landscape Departure: 72
Landscape FRCC: 3 (67-100%)

Legend
Vegetation Departure
Regime Departure
Stratum Departure
Landscape Departure
No Departure *

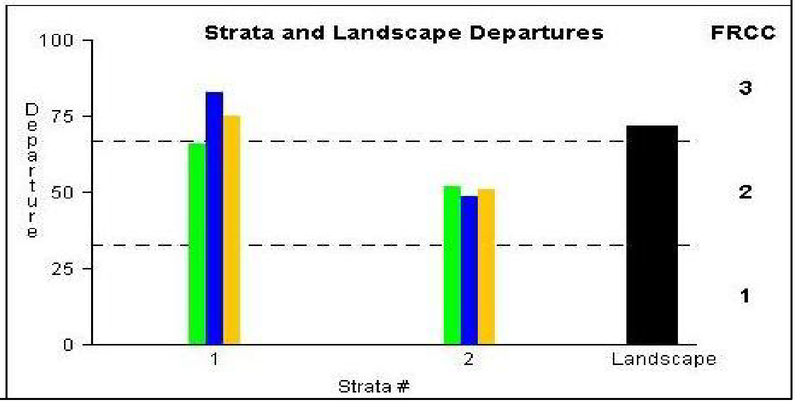


Figure 78. FRCC summary for ponderosa pine and grassland, existing condition

Table 118. FRCC summary, existing condition for ponderosa pine and grasslands

FRCC Landscape Report for 4FRI-existing condition						
Biophysical Setting (BpS Code)		**FRG (I-V)**	**Condition Class 1 (Acres)**	**Condition Class 2 (Acres)**	**Condition Class 3 (Acres)**	**Total Acres**
Ponderosa Pine (Colorado Plateau)	(PPIN5)	I	70680	136311	297866	504857
Mtn. Grassland With Trees	(MGRA2)	I	10097	40389	5610	56095
Total Acres			80777	176700	303475	560952

Fire Regime Condition Class
Landscape Report

version 3.0.3.0

Landscape

Registration Code: 4FRI-Lata Landscape Code: 4FRI Characterization Date: 04/24/2012

Examiner: Lata Landscape Name: 4FRI-existing condition Area: 560952 Acres

Lat: 35.000000 Lon: 112.000000 Datum: NAD83

Comment: Will add photos later

Biophysical Stratification

Num	Life-form	BpS	Species	Land-form	Slope Class	Insol Class	Elevation Low	Elevation High	Stratum Comp (%)	Ref Freq	Curr Freq	Ref Sev	Curr Sev	Strata Depart	Strata FRCC
1	CF	PPIN5							90	7	80	6	37	81	3
2	HU	MGRA2							10	10	80	60	75	56	2
									100						

Figure 79. Alternative A Biophysical stratification (2020)

Fire Regime Condition Class
Landscape Report - Stratum Data

Registration Code: 4FRI-Lata Landscape Code: 4FRI Characterization Date: 04/24/2012

Stratum Num: 1 Biophysical Setting: PPIN5 Stratum Name: Ponderosa Pine (Colorado Plateau)

Stratum Composition (% of area): 90 BpS Lifeform: CF Landform: Avg Slope Class: Insol Class:

Stratum Area: 504856 Acres Species: Low Elevation: High Elevation:

Reference Frequency: 7 Current Frequency: 80 Latitude: Longitude: Datum: WGS84

Reference Severity: 6 Current Severity: 37 Reference Composition Source: D Current Composition Source: R

Comments:

Succession Classes

Code	Upper Layer Lifeform	Majority Size	Dominant Species			Ref Comp	Curr Comp	Acres	Sim	Diff	Relative Amount	Stand FRCC	Stand Depart	S-Class Acres Departed from Reference
A						5	0	0	0	-100	TRACE	1	0	-25242
B			DACRY3	PSEUD7	ABIES	5	66	333205	5	92	ABUNDANT	3	92	307962
C						15	9	45437	9	-40	UNDER REP	1	0	-30291
D			PIPO			65	2	10097	2	-97	TRACE	1	0	-318059
E			PIPO	PSEUD7	ABIES	10	19	95922	10	47	OVER REP	2	47	45437
U						0	4	20194	0	100	ABUNDANT	3	100	20194
					Total	100	100		26					

Stratum Vegetation Departure: 74 Stratum Fire Frequency Departure: 91 Stratum Regime Departure: 87

Stratum Vegetation Condition Class: 3 Stratum Fire Severity Departure: 84 Stratum Regime Condition Class: 3

Stratum Fire Regime: I - Frequent Surface and Mixed Stratum Departure: 81 Stratum Fire Regime Condition Class: 3

Figure 80. Alternative A Landscape report with succession classes (2020)

Fire Regime Condition Class
Landscape Report - Stratum Data

Registration Code: 4FRI-Lata Landscape Code: 4FRI Characterization Date: 04/24/2012

Stratum Num: 2 Biophysical Setting: MGRA2 Stratum Name: Mtn. Grassland With Trees

Stratum Composition (% of area): 10 BpS Lifeform: HU Landform: Avg Slope Class: Insol Class:

Stratum Area: 56095 Acres Species: Low Elevation: High Elevation:

Reference Frequency: 10 Current Frequency: 80 Latitude: Longitude: Datum: WGS84

Reference Severity: 60 Current Severity: 75 Reference Composition Source: D Current Composition Source: R

Comments:

Succession Classes

Code	Upper Layer Lifeform	Majority Size	Dominant Species	Ref Comp	Curr Comp	Acres	Sim	Diff	Relative Amount	Stand FRCC	Stand Depart	S-Class Acres Departed from Reference
A	HERB			10	2	1121	2	-80	TRACE	1	0	-4487
B				60	10	5609	10	-83	TRACE	1	0	-28047
C	HERB			30	76	42632	30	61	OVER REP	2	61	25803
D				0	0	0	0	N/A				0
E				0	0	0	0	N/A				0
U				0	12	6731	0	100	ABUNDANT	3	100	6731
			Total	100	100		42					

Stratum Vegetation Departure: 58 Stratum Fire Frequency Departure: 88 Stratum Regime Departure: 54

Stratum Vegetation Condition Class: 2 Stratum Fire Severity Departure: 20 Stratum Regime Condition Class: 2

Stratum Fire Regime: I - Frequent Surface and Mixed Stratum Departure: 56 Stratum Fire Regime Condition Class: 2

Figure 81. Alternative A Landscape report with succession classes (2020)

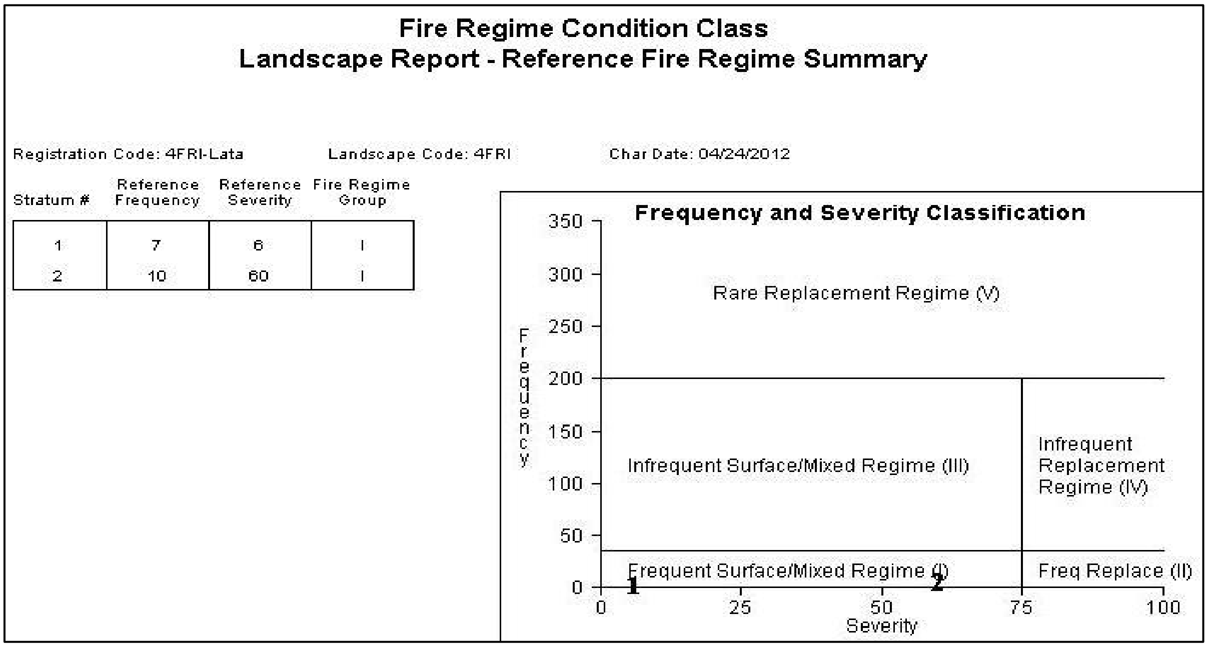


Figure 82. Alternative A Fire Regime summary (2020)

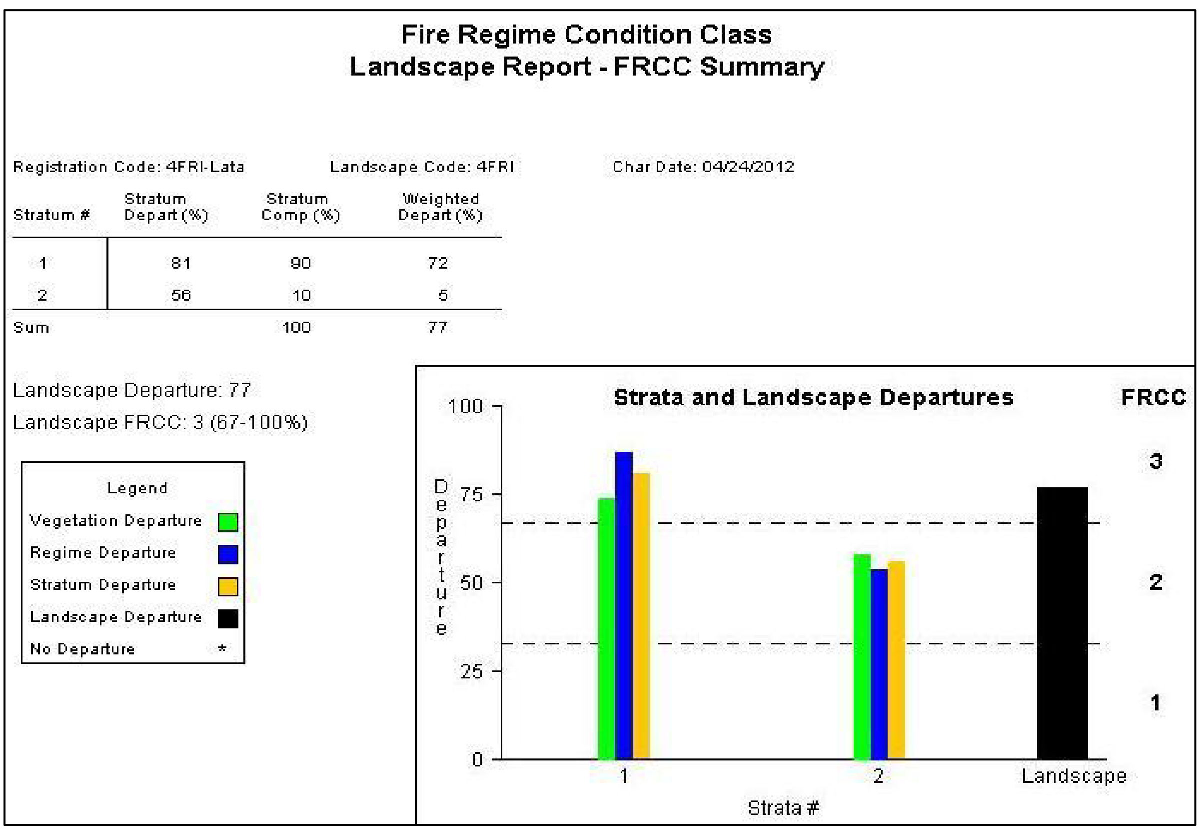


Figure 83. Alternative A Fire Regime/Condition Class summary (2020)

Table 119. Alternative A Fire Regime/Condition Class summary (2020)

Biophysical Setting (BpS Code)		FRG (I-V)	Condition Class 1 (Acres)	Condition Class 2 (Acres)	Condition Class 3 (Acres)	Total Acres
Ponderosa Pine (Colorado Plateau)	(PPIN5)	I	55534	95923	353400	504857
Mtn. Grassland With Trees	(MGRA2)	I	6731	42632	6731	56095
Total Acres			62266	138555	360131	560952

Fire Regime Condition Class Landscape Report

version 3.0.3.0

Landscape

Registration Code: 4FRI-Lata Landscape Code: 4FRI Characterization Date: 04/24/2012

Examiner: Lata Landscape Name: 4FRI-existing condition Area: 560952 Acres

Lat: 35.000000 Lon: 112.000000 Datum: NAD83

Comment: Will add photos later

Biophysical Stratification

Num	Life-form	BpS	Species	Land-form	Slope Class	Insol Class	Elevation Low	Elevation High	Stratum Comp (%)	Ref Freq	Curr Freq	Ref Sev	Curr Sev	Strata Depart	Strata FRCC
1	CF	PPIN5							90	7	160	6	50	88	3
2	HU	MGRA2							10	10	160	60	85	65	2
									100						

Figure 84. Alternative A Biophysical stratification (2050)

Fire Regime Condition Class Landscape Report - Stratum Data

Registration Code: 4FRI-Lata Landscape Code: 4FRI Characterization Date: 04/24/2012

Stratum Num: 1 Biophysical Setting: PPIN5 Stratum Name: Ponderosa Pine (Colorado Plateau)

Stratum Composition (% of area): 90 BpS Lifeform: CF Landform: Avg Slope Class: Insol Class:

Stratum Area: 504856 Acres Species: Low Elevation: High Elevation:

Reference Frequency: 7 Current Frequency: 160 Latitude: Longitude: Datum: WGS84

Reference Severity: 6 Current Severity: 50 Reference Composition Source: D Current Composition Source: R

Comments:

Succession Classes

Code	Upper Layer Lifeform	Majority Size	Dominant Species			Ref Comp	Curr Comp	Acres	Sim	Diff	Relative Amount	Stand FRCC	Stand Depart	S-Class Acres Departed from Reference
A						5	0	0	0	-100	TRACE	1	0	-25242
B			DACRY3	PSEUD7	ABIES	5	45	227185	5	89	ABUNDANT	3	89	201942
C						15	1	5048	1	-93	TRACE	1	0	-70679
D			PIPO			65	0	0	0	-100	TRACE	1	0	-328156
E			PIPO	PSEUD7	ABIES	10	27	136311	10	63	OVER REP	2	63	85825
U						0	27	136311	0	100	ABUNDANT	3	100	136311
					Total	100	100		16					

Stratum Vegetation Departure: 84 Stratum Fire Frequency Departure: 96 Stratum Regime Departure: 92

Stratum Vegetation Condition Class: 3 Stratum Fire Severity Departure: 88 Stratum Regime Condition Class: 3

Stratum Fire Regime: I - Frequent Surface and Mixed Stratum Departure: 88 Stratum Fire Regime Condition Class: 3

Figure 85. Alternative A Landscape report with succession classes (2050)

Fire Regime Condition Class
Landscape Report - Stratum Data

Registration Code: 4FRI-Lata　Landscape Code: 4FRI　Characterization Date: 04/24/2012

Stratum Num: 2　Biophysical Setting: MGRA2　Stratum Name: Mtn. Grassland With Trees

Stratum Composition (% of area): 10　BpS Lifeform: HU　Landform:　Avg Slope Class:　Insol Class:

Stratum Area: 56095 Acres　Species:　Low Elevation:　High Elevation:

Reference Frequency: 10　Current Frequency: 160　Latitude:　Longitude:　Datum: WGS84

Reference Severity: 60　Current Severity: 85　Reference Composition Source: D　Current Composition Source: R

Comments:

Succession Classes

Code	Upper Layer Majority Lifeform	Size	Dominant Species	Ref Comp	Curr Comp	Acres	Sim	Diff	Relative Amount	Stand FRCC	Stand Depart	S-Class Acres Departed from Reference
A	HERB			10	0	0	0	-100	TRACE	1	0	-5609
B				60	3	1682	3	-95	TRACE	1	0	-31974
C	HERB			30	82	45998	30	63	OVER REP	2	63	29169
D				0	0	0	0	N/A				0
E				0	0	0	0	N/A				0
U				0	15	8414	0	100	ABUNDANT	3	100	8414
			Total	100	100		33					

Stratum Vegetation Departure: 67　Stratum Fire Frequency Departure: 94　Stratum Regime Departure: 62

Stratum Vegetation Condition Class: 3　Stratum Fire Severity Departure: 30　Stratum Regime Condition Class: 2

Stratum Fire Regime: I - Frequent Surface and Mixed　Stratum Departure: 65　Stratum Fire Regime Condition Class: 2

Figure 86. Alternative A Landscape report with succession classes (2050)

Fire Regime Condition Class
Landscape Report - Reference Fire Regime Summary

Registration Code: 4FRI-Lata　Landscape Code: 4FRI　Char Date: 04/24/2012

Stratum #	Reference Frequency	Reference Severity	Fire Regime Group
1	7	6	I
2	10	60	I

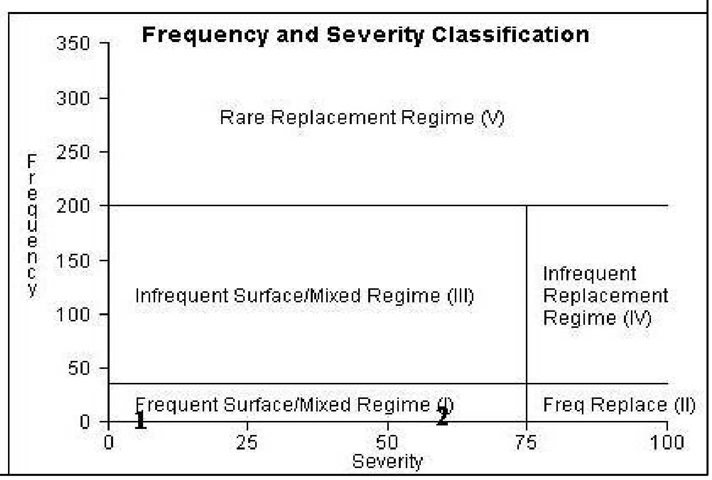


Figure 87. Alternative A Fire Regime summary (2050)

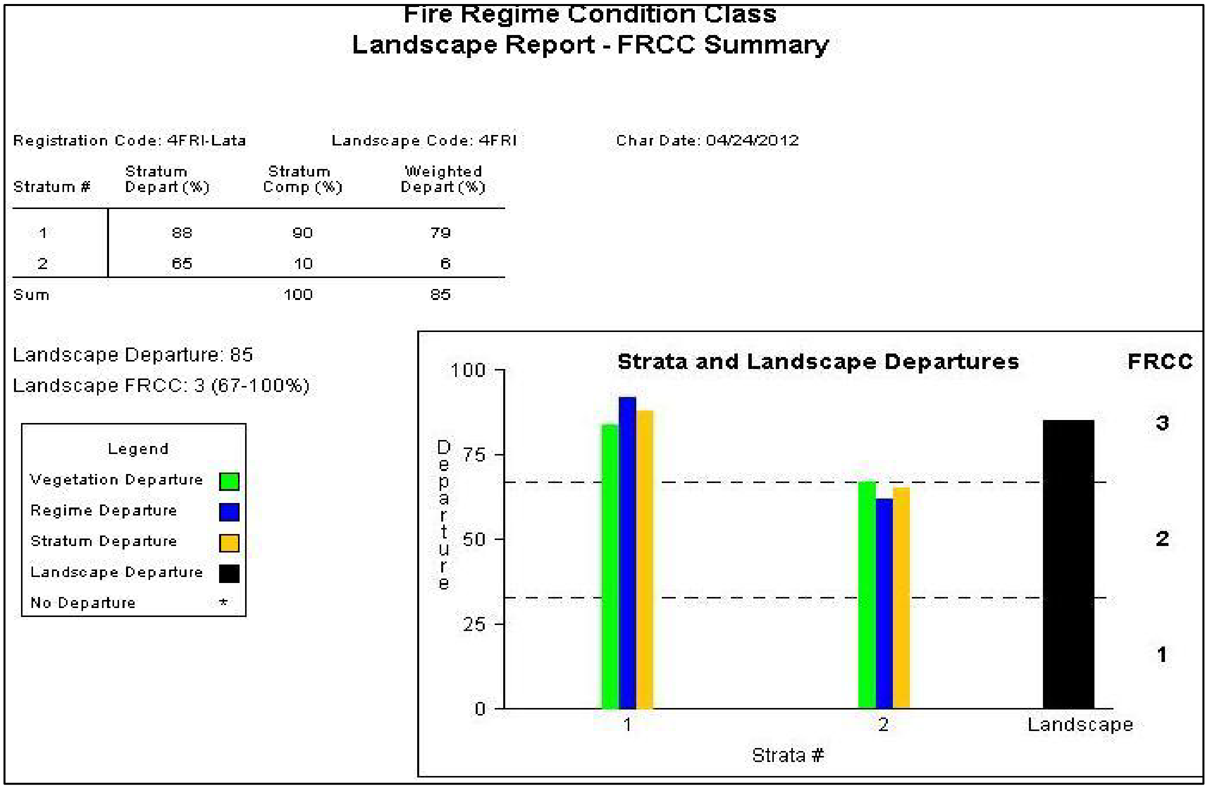


Figure 88. Alternative A Fire Regime/Condition Class summary (2050)

Table 120. Alternative A Fire Regime/Condition Class summary (2050)

Biophysical Setting (BpS Code)		FRG (I-V)	Condition Class 1 (Acres)	Condition Class 2 (Acres)	Condition Class 3 (Acres)	Total Acres
Ponderosa Pine (Colorado Plateau)	(PPIN5)	I	5049	136311	363497	504857
Mtn. Grassland With Trees	(MGRA2)	I	1683	45998	8414	56095
Total Acres			6731	182309	371911	560952

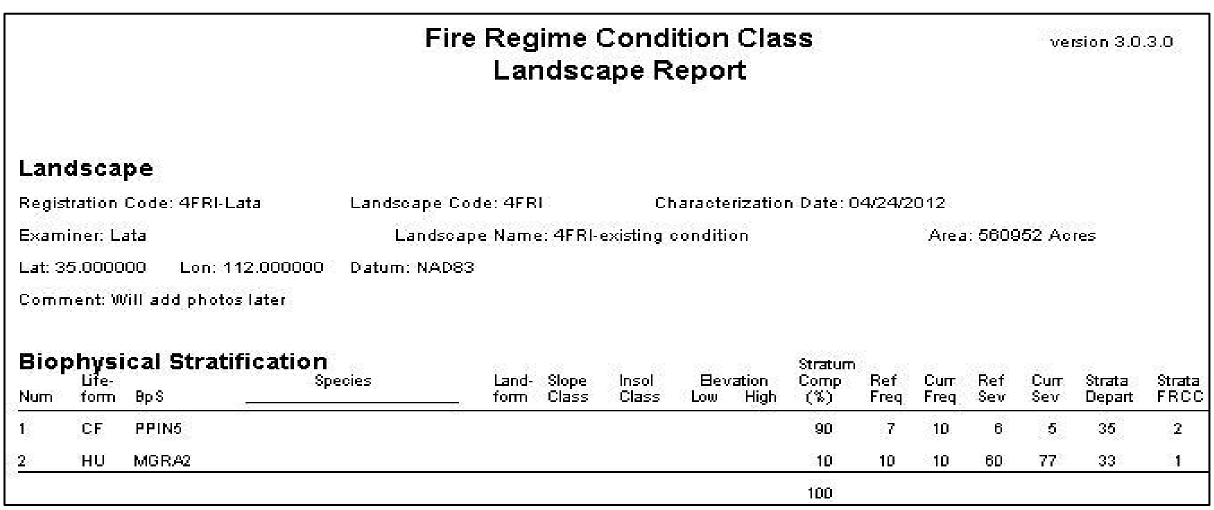


Figure 89. Alternative B Biophysical stratification (2020)

Fire Regime Condition Class
Landscape Report - Stratum Data

Registration Code: 4FRI-Lata | Landscape Code: 4FRI | Characterization Date: 04/24/2012

Stratum Num: 1 | Biophysical Setting: PPIN5 | Stratum Name: Ponderosa Pine (Colorado Plateau)

Stratum Composition (% of area): 90 | BpS Lifeform: CF | Landform: | Avg Slope Class: | Insol Class:

Stratum Area: 504856 Acres | Species: | Low Elevation: | High Elevation:

Reference Frequency: 7 | Current Frequency: 10 | Latitude: | Longitude: | Datum: WGS84

Reference Severity: 6 | Current Severity: 5 | Reference Composition Source: D | Current Composition Source: R

Comments:

Succession Classes

Code	Upper Layer Majority Lifeform	Size	Dominant Species			Ref Comp	Curr Comp	Acres	Sim	Diff	Relative Amount	Stand FRCC	Stand Depart	S-Class Acres Departed from Reference
A						5	9	45437	5	44	OVER REP	2	44	20194
B			DACRY3	PSEUD7	ABIES	5	23	116117	5	78	OVER REP	2	78	90874
C						15	30	151457	15	50	OVER REP	2	50	75728
D			PIPO			65	18	90874	18	-72	TRACE	1	0	-237282
E			PIPO	PSEUD7	ABIES	10	16	80777	10	38	OVER REP	2	38	30291
U						0	4	20194	0	100	ABUNDANT	3	100	20194
					Total	100	100		53					

Stratum Vegetation Departure: 47 | Stratum Fire Frequency Departure: 30 | Stratum Regime Departure: 23

Stratum Vegetation Condition Class: 2 | Stratum Fire Severity Departure: 17 | Stratum Regime Condition Class: 1

Stratum Fire Regime: I - Frequent Surface and Mixed | Stratum Departure: 35 | Stratum Fire Regime Condition Class: 2

Figure 90. Alternative B Landscape report with succession classes (2020)

Fire Regime Condition Class
Landscape Report - Stratum Data

Registration Code: 4FRI-Lata | Landscape Code: 4FRI | Characterization Date: 04/24/2012

Stratum Num: 2 | Biophysical Setting: MGRA2 | Stratum Name: Mtn. Grassland With Trees

Stratum Composition (% of area): 10 | BpS Lifeform: HU | Landform: | Avg Slope Class: | Insol Class:

Stratum Area: 56095 Acres | Species: | Low Elevation: | High Elevation:

Reference Frequency: 10 | Current Frequency: 10 | Latitude: | Longitude: | Datum: WGS84

Reference Severity: 60 | Current Severity: 77 | Reference Composition Source: D | Current Composition Source: R

Comments:

Succession Classes

Code	Upper Layer Majority Lifeform	Size	Dominant Species	Ref Comp	Curr Comp	Acres	Sim	Diff	Relative Amount	Stand FRCC	Stand Depart	S-Class Acres Departed from Reference
A	HERB			10	2	1121	2	-80	TRACE	1	0	-4487
B				60	13	7292	13	-78	TRACE	1	0	-26364
C	HERB			30	77	43193	30	61	OVER REP	2	61	26364
D				0	0	0	0	N/A				0
E				0	0	0	0	N/A				0
U				0	8	4487	0	100	ABUNDANT	3	100	4487
			Total	100	100		45					

Stratum Vegetation Departure: 55 | Stratum Fire Frequency Departure: 0 | Stratum Regime Departure: 11

Stratum Vegetation Condition Class: 2 | Stratum Fire Severity Departure: 22 | Stratum Regime Condition Class: 1

Stratum Fire Regime: I - Frequent Surface and Mixed | Stratum Departure: 33 | Stratum Fire Regime Condition Class: 1

Figure 91. Alternative B Landscape report with succession classes (2020)

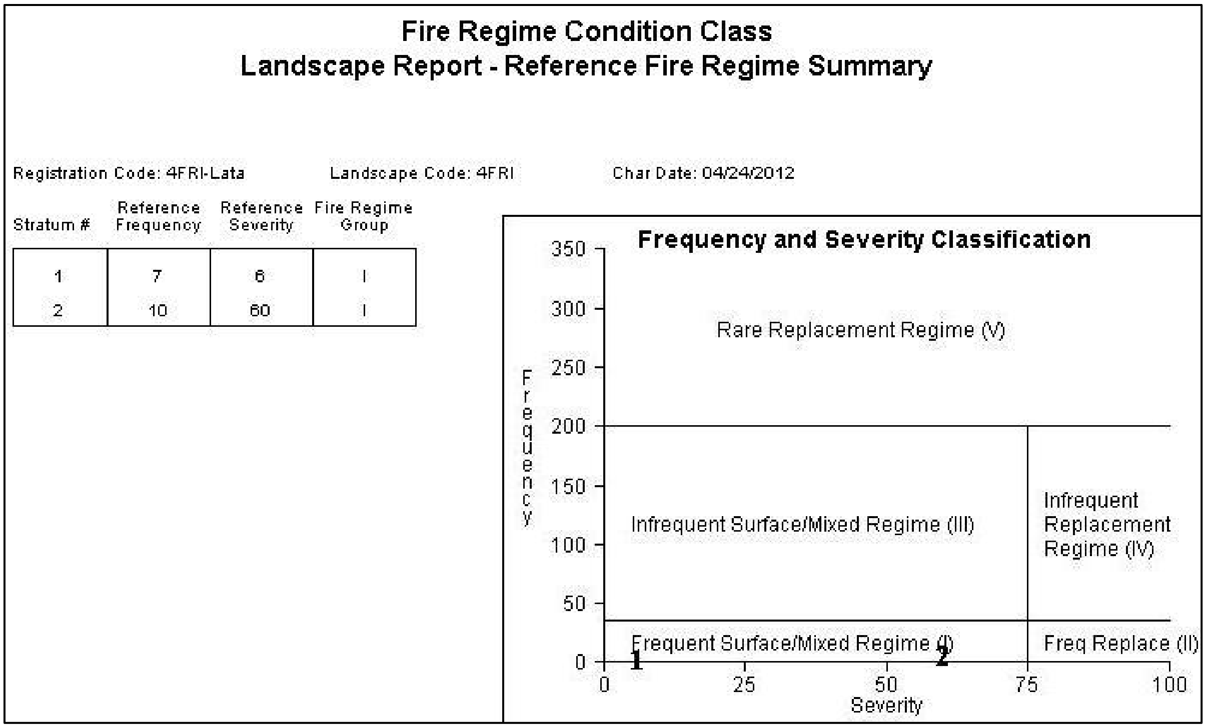


Figure 92. Alternative B Fire Regime summary (2020)

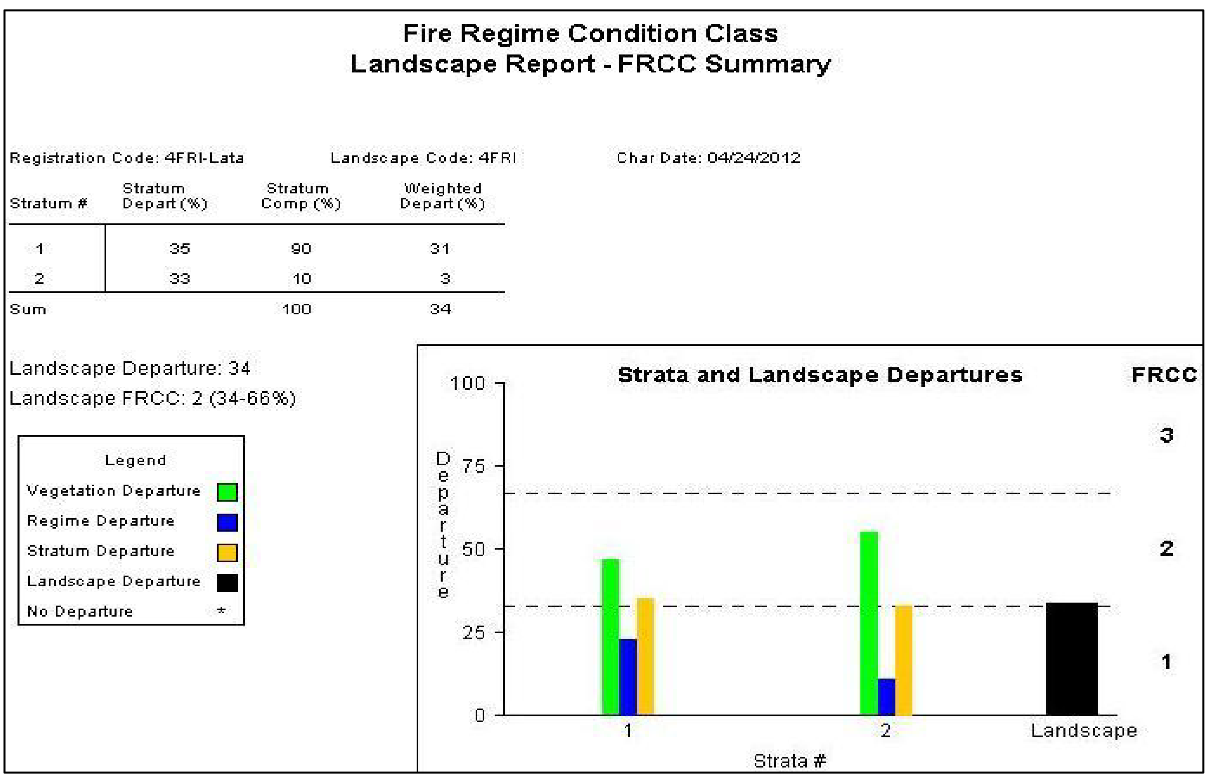


Figure 93. Alternative B Fire Regime/Condition Class summary (2020)

Table 121. Alternative B Fire Regime/Condition Class summary (2020)

Biophysical Setting (BpS Code)		FRG (I-V)	Condition Class 1 (Acres)	Condition Class 2 (Acres)	Condition Class 3 (Acres)	Total Acres
Ponderosa Pine (Colorado Plateau)	(PPIN5)	I	90874	393788	20194	504857
Mtn. Grassland With Trees	(MGRA2)	I	8414	43193	4488	56095
Total Acres			99289	436982	24682	560952

Fire Regime Condition Class
Landscape Report

version 3.0.3.0

Landscape

Registration Code: 4FRI-Lata   Landscape Code: 4FRI   Characterization Date: 04/24/2012

Examiner: Lata   Landscape Name: 4FRI-existing condition   Area: 560952 Acres

Lat: 35.000000   Lon: 112.000000   Datum: NAD83

Comment: Will add photos later

Biophysical Stratification

Num	Life-form	BpS	Species	Land-form	Slope Class	Insol Class	Elevation Low	Elevation High	Stratum Comp (%)	Ref Freq	Curr Freq	Ref Sev	Curr Sev	Strata Depart	Strata FRCC
1	CF	PPIN5							90	7	20	6	20	69	3
2	HU	MGRA2							10	10	1020	60	80	61	2
									100						

Figure 76. Alternative B Biophysical stratification (2050)

Fire Regime Condition Class
Landscape Report - Stratum Data

Registration Code: 4FRI-Lata   Landscape Code: 4FRI   Characterization Date: 04/24/2012

Stratum Num: 1   Biophysical Setting: PPIN5   Stratum Name: Ponderosa Pine (Colorado Plateau)

Stratum Composition (% of area): 90   BpS Lifeform: CF   Landform: Avg Slope Class: Insol Class:

Stratum Area: 504856 Acres   Species: Low Elevation: High Elevation:

Reference Frequency: 7   Current Frequency: 20   Latitude: Longitude: Datum: WGS84

Reference Severity: 6   Current Severity: 20   Reference Composition Source: D   Current Composition Source: R

Comments:

Succession Classes

Code	Upper Layer Lifeform	Majority Size	Dominant Species			Ref Comp	Curr Comp	Acres	Sim	Diff	Relative Amount	Stand FRCC	Stand Depart	S-Class Acres Departed from Reference
A						5	2	10097	2	-60	UNDER REP	1	0	-15145
B			DACRY3	PSEUD7	ABIES	5	31	156505	5	84	ABUNDANT	3	84	131262
C						15	7	35339	7	-53	UNDER REP	1	0	-40388
D			PIPO			65	6	30291	6	-91	TRACE	1	0	-297865
E			PIPO	PSEUD7	ABIES	10	49	247379	10	80	OVER REP	2	80	196894
U						0	5	25242	0	100	ABUNDANT	3	100	25242
					Total	100	100		30					

Stratum Vegetation Departure: 70   Stratum Fire Frequency Departure: 65   Stratum Regime Departure: 67

Stratum Vegetation Condition Class: 3   Stratum Fire Severity Departure: 70   Stratum Regime Condition Class: 3

Stratum Fire Regime: I - Frequent Surface and Mixed   Stratum Departure: 69   Stratum Fire Regime Condition Class: 3

Figure 77.Alternative B Landscape report with succession classes (2050)

Fire Regime Condition Class
Landscape Report - Stratum Data

Registration Code: 4FRI-Lata　Landscape Code: 4FRI　Characterization Date: 04/24/2012

Stratum Num: 2　Biophysical Setting: MGRA2　Stratum Name: Mtn. Grassland With Trees

Stratum Composition (% of area): 10　BpS Lifeform: HU　Landform:　Avg Slope Class:　Insol Class:

Stratum Area: 56095 Acres　Species:　Low Elevation:　High Elevation:

Reference Frequency: 10　Current Frequency: 1020　Latitude:　Longitude:　Datum: WGS84

Reference Severity: 60　Current Severity: 80　Reference Composition Source: D　Current Composition Source: R

Comments:

Succession Classes

Code	Upper Layer Lifeform	Majority Size	Dominant Species	Ref Comp	Curr Comp	Acres	Sim	Diff	Relative Amount	Stand FRCC	Stand Depart	S-Class Acres Departed from Reference
A	HERB			10	1	560	1	-90	TRACE	1	0	-5048
B				60	9	5048	9	-85	TRACE	1	0	-28608
C	HERB			30	80	44876	30	63	OVER REP	2	63	28047
D				0	0	0	0	N/A				0
E				0	0	0	0	N/A				0
U				0	10	5609	0	100	ABUNDANT	3	100	5609
			Total	100	100		40					

Stratum Vegetation Departure: 60　Stratum Fire Frequency Departure: 99　Stratum Regime Departure: 62

Stratum Vegetation Condition Class: 2　Stratum Fire Severity Departure: 25　Stratum Regime Condition Class: 2

Stratum Fire Regime: I - Frequent Surface and Mixed　Stratum Departure: 61　Stratum Fire Regime Condition Class: 2

Figure 78.Alternative B Landscape report with succession classes (2050)

Severity

Figure 97. Alternative B Fire Regime summary (2050)

Fire Regime Condition Class
Landscape Report - FRCC Summary

Registration Code: 4FRI-Lata　Landscape Code: 4FRI　Char Date: 04/24/2012

Stratum #	Stratum Depart (%)	Stratum Comp (%)	Weighted Depart (%)
1	69	90	62
2	61	10	6
Sum		100	68

Landscape Departure: 68

Landscape FRCC: 3 (67-100%)

Legend	
Vegetation Departure	green
Regime Departure	blue
Stratum Departure	yellow
Landscape Departure	black
No Departure	*

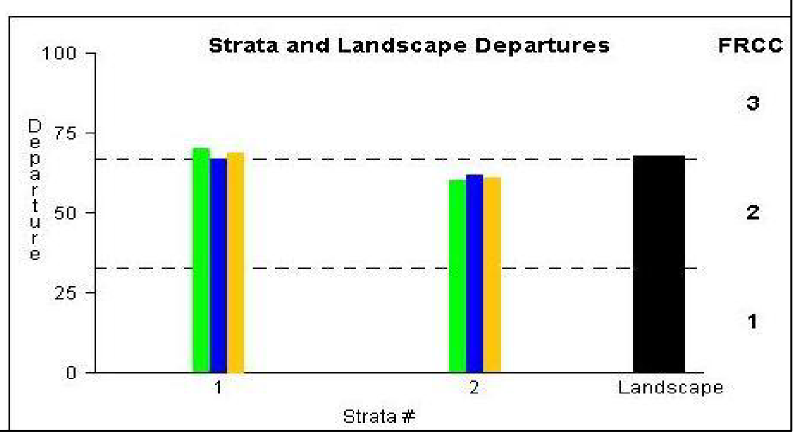


Figure 79.Alternative B Fire Regime/Condition Class summary (2050)

Table 122. Alternative B Fire Regime/Condition Class summary (2050)

Biophysical Setting (BpS Code)		FRG (I-V)	Condition Class 1 (Acres)	Condition Class 2 (Acres)	Condition Class 3 (Acres)	Total Acres
Ponderosa Pine (Colorado Plateau)	(PPIN5)	I	75729	247380	181748	504857
Mtn. Grassland With Trees	(MGRA2)	I	5610	44876	5610	56095
Total Acres			81338	292256	187358	560952

Fire Regime Condition Class
Landscape Report

version 3.0.3.0

Landscape

Registration Code: 4FRI-Lata   Landscape Code: 4FRI   Characterization Date: 04/24/2012

Examiner: Lata   Landscape Name: 4FRI-existing condition   Area: 560952 Acres

Lat: 35.000000   Lon: 112.000000   Datum: NAD83

Comment: Will add photos later

Biophysical Stratification

Num	Life-form	BpS	Species	Land-form	Slope Class	Insol Class	Elevation Low	Elevation High	Stratum Comp (%)	Ref Freq	Curr Freq	Ref Sev	Curr Sev	Strata Depart	Strata FRCC
1	CF	PPIN5							90	7	10	6	5	35	2
2	HU	MGRA2							10	10	10	60	65	22	1
									100						

Figure 80.Alternative C Biophysical stratification (2020)

Fire Regime Condition Class
Landscape Report - Stratum Data

Registration Code: 4FRI-Lata   Landscape Code: 4FRI   Characterization Date: 04/24/2012

Stratum Num: 1   Biophysical Setting: PPIN5   Stratum Name: Ponderosa Pine (Colorado Plateau)

Stratum Composition (% of area): 90   BpS Lifeform: CF   Landform: Avg Slope Class: Insol Class:

Stratum Area: 504856 Acres   Species: Low Elevation: High Elevation:

Reference Frequency: 7   Current Frequency: 10   Latitude: Longitude: Datum: WGS84

Reference Severity: 6   Current Severity: 5   Reference Composition Source: D   Current Composition Source: R

Comments:

Succession Classes

Code	Upper Layer Lifeform	Majority Size	Dominant Species			Ref Comp	Curr Comp	Acres	Sim	Diff	Relative Amount	Stand FRCC	Stand Depart	S-Class Acres Departed from Reference
A						5	8	40388	5	38	OVER REP	2	38	15145
B			DACRY3	PSEUD7	ABIES	5	25	126214	5	80	OVER REP	2	80	100971
C						15	30	151457	15	50	OVER REP	2	50	75728
D			PIPO			65	19	95922	19	-71	TRACE	1	0	-232234
E			PIPO	PSEUD7	ABIES	10	18	90874	10	44	OVER REP	2	44	40388
					Total	100	100		54					

Stratum Vegetation Departure: 46   Stratum Fire Frequency Departure: 30   Stratum Regime Departure: 23

Stratum Vegetation Condition Class: 2   Stratum Fire Severity Departure: 17   Stratum Regime Condition Class: 1

Stratum Fire Regime: I - Frequent Surface and Mixed   Stratum Departure: 35   Stratum Fire Regime Condition Class: 2

Figure 81.Alternative C Landscape report with succession classes (2020)

Fire Regime Condition Class
Landscape Report - Stratum Data

Registration Code: 4FRI-Lata   Landscape Code: 4FRI   Characterization Date: 04/24/2012

Stratum Num: 2   Biophysical Setting: MGRA2   Stratum Name: Mtn. Grassland With Trees

Stratum Composition (% of area): 10   BpS Lifeform: HU   Landform: Avg Slope Class: Insol Class:

Stratum Area: 56095 Acres   Species: Low Elevation: High Elevation:

Reference Frequency: 10   Current Frequency: 10   Latitude: Longitude: Datum: WGS84

Reference Severity: 60   Current Severity: 65   Reference Composition Source: D   Current Composition Source: R

Comments:

Succession Classes

Code	Upper Layer Majority Lifeform	Size	Dominant Species	Ref Comp	Curr Comp	Acres	Sim	Diff	Relative Amount	Stand FRCC	Stand Depart	S-Class Acres Departed from Reference
A	HERB			10	8	4487	8	-20	SIMILAR	1	0	-1121
B				60	23	12901	23	-62	UNDER REP	1	0	-20755
C	HERB			30	66	37022	30	55	OVER REP	2	55	20194
D				0	0	0	0	N/A				0
E				0	0	0	0	N/A				0
U				0	3	1682	0	100	ABUNDANT	3	100	1682
			Total	100	100		61					

Stratum Vegetation Departure: 39   Stratum Fire Frequency Departure: 0   Stratum Regime Departure: 4

Stratum Vegetation Condition Class: 2   Stratum Fire Severity Departure: 8   Stratum Regime Condition Class: 1

Stratum Fire Regime: I - Frequent Surface and Mixed   Stratum Departure: 22   Stratum Fire Regime Condition Class: 1

Figure 82.Alternative C Landscape report with succession classes (2020)

Fire Regime Condition Class
Landscape Report - Reference Fire Regime Summary

Registration Code: 4FRI-Lata   Landscape Code: 4FRI   Char Date: 04/24/2012

Stratum #	Reference Frequency	Reference Severity	Fire Regime Group
1	7	6	I
2	10	60	I

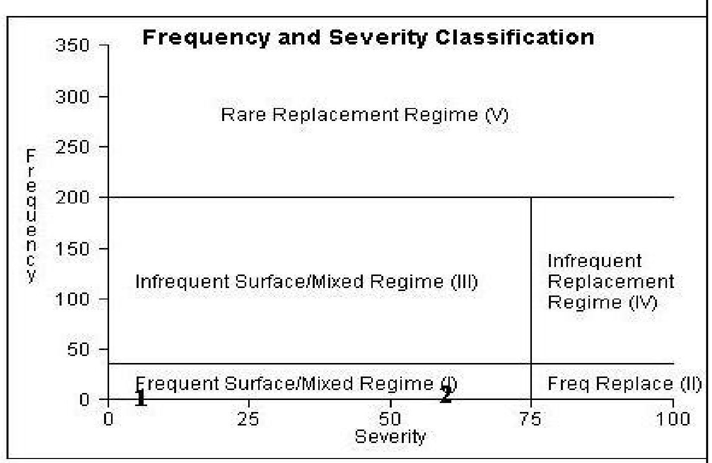


Figure 83.Alternative C Fire Regime summary (2020)

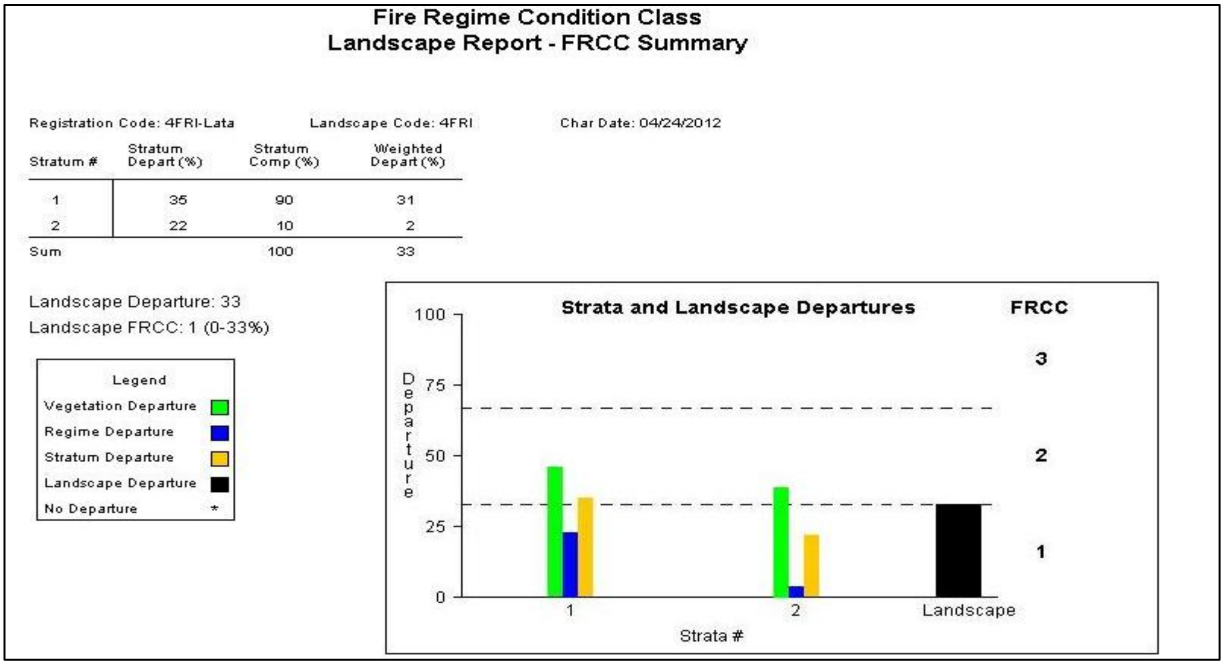
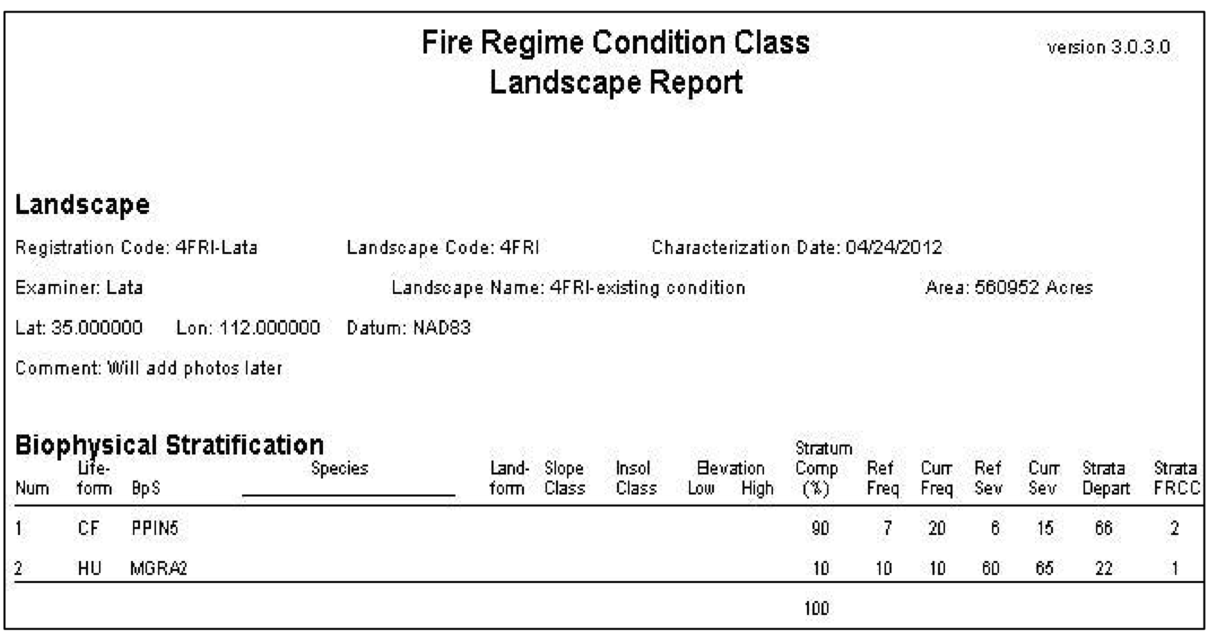


Figure 84.Alternative C Fire Regime/Condition Class summary (2020)

Table 123.Alternative C Fire Regime/Condition Class summary (2020)

Biophysical Setting (BpS Code)		FRG (I-V)	Condition Class 1 (Acres)	Condition Class 2 (Acres)	Condition Class 3 (Acres)	Total Acres
Ponderosa Pine (Colorado Plateau)	(PPIN5)	I	95923	408934	0	504857
Mtn. Grassland With Trees	(MGRA2)	I	17390	37023	1683	56095
Total Acres			113312	445957	1683	560952



Fire Regime Condition Class
Landscape Report

version 3.0.3.0

Landscape

Registration Code: 4FRI-Lata　Landscape Code: 4FRI　Characterization Date: 04/24/2012

Examiner: Lata　Landscape Name: 4FRI-existing condition　Area: 560952 Acres

Lat: 35.000000　Lon: 112.000000　Datum: NAD83

Comment: Will add photos later

Biophysical Stratification

Num	Life-form	BpS	Species	Land-form	Slope Class	Insol Class	Elevation Low	Elevation High	Stratum Comp (%)	Ref Freq	Curr Freq	Ref Sev	Curr Sev	Strata Depart	Strata FRCC
1	CF	PPIN5							90	7	20	6	15	66	2
2	HU	MGRA2							10	10	10	60	65	22	1
									100						

Figure 85.Alternative C Biophysical stratification (2050)

Fire Regime Condition Class
Landscape Report - Stratum Data

Registration Code: 4FRI-Lata   Landscape Code: 4FRI   Characterization Date: 04/24/2012

Stratum Num: 1   Biophysical Setting: PPIN5   Stratum Name: Ponderosa Pine (Colorado Plateau)

Stratum Composition (% of area): 90   BpS Lifeform: CF   Landform: Avg Slope Class: Insol Class:

Stratum Area: 504856 Acres   Species: Low Elevation: High Elevation:

Reference Frequency: 7   Current Frequency: 20   Latitude: Longitude: Datum: WGS84

Reference Severity: 6   Current Severity: 15   Reference Composition Source: D   Current Composition Source: R

Comments:

Succession Classes

Code	Upper Layer Majority Lifeform	Upper Layer Majority Size	Dominant Species	Ref Comp	Curr Comp	Acres	Sim	Diff	Relative Amount	Stand FRCC	Stand Depart	S-Class Acres Departed from Reference
A				5	3	15145	3	-40	UNDER REP	1	0	-10097
B			DACRY3 PSEUD7 ABIES	5	31	156505	5	84	ABUNDANT	3	84	131262
C				15	7	35339	7	-53	UNDER REP	1	0	-40388
D			PIPO	65	6	30291	6	-91	TRACE	1	0	-297865
E			PIPO PSEUD7 ABIES	10	51	257476	10	80	OVER REP	2	80	206991
U				0	2	10097	0	100	ABUNDANT	3	100	10097
			Total	100	100		31					

Stratum Vegetation Departure: 69   Stratum Fire Frequency Departure: 65   Stratum Regime Departure: 62

Stratum Vegetation Condition Class: 3   Stratum Fire Severity Departure: 60   Stratum Regime Condition Class: 2

Stratum Fire Regime: I - Frequent Surface and Mixed   Stratum Departure: 66   Stratum Fire Regime Condition Class: 2

Figure 86.Alternative C Landscape report (2050)

Fire Regime Condition Class
Landscape Report - Stratum Data

Registration Code: 4FRI-Lata   Landscape Code: 4FRI   Characterization Date: 04/24/2012

Stratum Num: 2   Biophysical Setting: MGRA2   Stratum Name: Mtn. Grassland With Trees

Stratum Composition (% of area): 10   BpS Lifeform: HU   Landform: Avg Slope Class: Insol Class:

Stratum Area: 56095 Acres   Species: Low Elevation: High Elevation:

Reference Frequency: 10   Current Frequency: 10   Latitude: Longitude: Datum: WGS84

Reference Severity: 60   Current Severity: 65   Reference Composition Source: D   Current Composition Source: R

Comments:

Succession Classes

Code	Upper Layer Majority Lifeform	Upper Layer Majority Size	Dominant Species	Ref Comp	Curr Comp	Acres	Sim	Diff	Relative Amount	Stand FRCC	Stand Depart	S-Class Acres Departed from Reference
A	HERB			10	8	4487	8	-20	SIMILAR	1	0	-1121
B				60	23	12901	23	-62	UNDER REP	1	0	-20755
C	HERB			30	66	37022	30	55	OVER REP	2	55	20194
D				0	0	0	0	N/A				0
E				0	0	0	0	N/A				0
U				0	3	1682	0	100	ABUNDANT	3	100	1682
			Total	100	100		61					

Stratum Vegetation Departure: 39   Stratum Fire Frequency Departure: 0   Stratum Regime Departure: 4

Stratum Vegetation Condition Class: 2   Stratum Fire Severity Departure: 8   Stratum Regime Condition Class: 1

Stratum Fire Regime: I - Frequent Surface and Mixed   Stratum Departure: 22   Stratum Fire Regime Condition Class: 1

Figure 87.Alternative C Landscape report (2050)

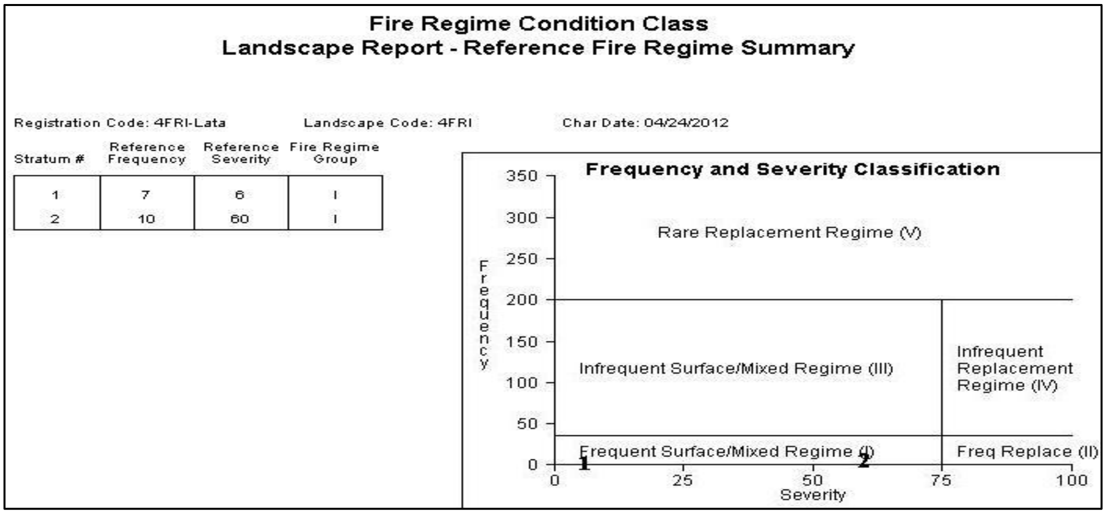


Figure 88. Alternative C Fire Regime summary (2050)

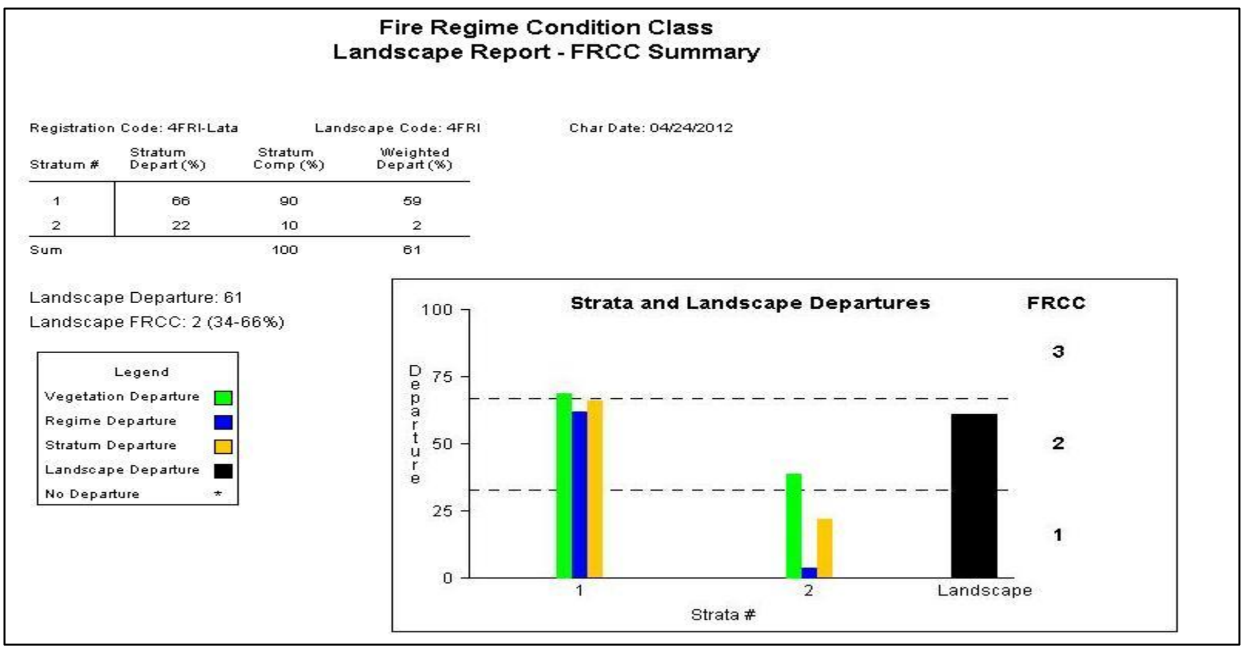


Figure 89. Alternative C FRCC summary (2050)

Table 124. Alternative C FRCC for ponderosa pine and grasslands (2050)

Biophysical Setting (BpS Code)		FRG (I-V)	Condition Class 1 (Acres)	Condition Class 2 (Acres)	Condition Class 3 (Acres)	Total Acres
Ponderosa Pine (Colorado Plateau)	(PPIN5)	I	80777	257477	166603	504857
Mtn. Grassland With Trees	(MGRA2)	I	17390	37023	1683	56095
Total Acres			98167	294500	168286	560952

Fire Regime Condition Class
Landscape Report

version 3.0.3.0

Landscape

Registration Code: 4FRI-Lata   Landscape Code: 4FRI   Characterization Date: 04/24/2012

Examiner: Lata   Landscape Name: 4FRI-existing condition   Area: 560952 Acres

Lat: 35.000000   Lon: 112.000000   Datum: NAD83

Comment: Will add photos later

Biophysical Stratification

Num	Life-form	BpS	Species	Land-form	Slope Class	Insol Class	Elevation Low	Elevation High	Stratum Comp (%)	Ref Freq	Curr Freq	Ref Sev	Curr Sev	Strata Depart	Strata FRCC
1	CF	PPIN5							90	7	34	6	7	52	2
2	HU	MGRA2							10	10	10	60	65	22	1
									100						

Figure 90. Alternative D Biophysical Stratification (2020)

Fire Regime Condition Class
Landscape Report - Stratum Data

Registration Code: 4FRI-Lata   Landscape Code: 4FRI   Characterization Date: 04/24/2012

Stratum Num: 1   Biophysical Setting: PPIN5   Stratum Name: Ponderosa Pine (Colorado Plateau)

Stratum Composition (% of area): 90   BpS Lifeform: CF   Landform: Avg Slope Class: Insol Class:

Stratum Area: 504856 Acres   Species: Low Elevation: High Elevation:

Reference Frequency: 7   Current Frequency: 34   Latitude: Longitude: Datum: WGS84

Reference Severity: 6   Current Severity: 7   Reference Composition Source: D   Current Composition Source: R

Comments:

Succession Classes

Code	Upper Layer Lifeform	Majority Size	Dominant Species			Ref Comp	Curr Comp	Acres	Sim	Diff	Relative Amount	Stand FRCC	Stand Depart	S-Class Acres Departed from Reference
A						5	9	45437	5	44	OVER REP	2	44	20194
B			DACRY3	PSEUD7	ABIES	5	25	126214	5	80	OVER REP	2	80	100971
C						15	26	131262	15	42	OVER REP	2	42	55534
D			PIPO			65	8	40388	8	-88	TRACE	1	0	-287768
E			PIPO	PSEUD7	ABIES	10	22	111068	10	55	OVER REP	2	55	60582
U						0	10	50485	0	100	ABUNDANT	3	100	50485
					Total	100	100		43					

Stratum Vegetation Departure: 57   Stratum Fire Frequency Departure: 80   Stratum Regime Departure: 47

Stratum Vegetation Condition Class: 2   Stratum Fire Severity Departure: 14   Stratum Regime Condition Class: 2

Stratum Fire Regime: I - Frequent Surface and Mixed   Stratum Departure: 52   Stratum Fire Regime Condition Class: 2

Figure 91.Alternative D Landscape report with succession classes (2020)

Fire Regime Condition Class
Landscape Report - Stratum Data

Registration Code: 4FRI-Lata   Landscape Code: 4FRI   Characterization Date: 04/24/2012

Stratum Num: 2   Biophysical Setting: MGRA2   Stratum Name: Mtn. Grassland With Trees

Stratum Composition (% of area): 10   BpS Lifeform: HU   Landform: Avg Slope Class: Insol Class:

Stratum Area: 56095 Acres   Species: Low Elevation: High Elevation:

Reference Frequency: 10   Current Frequency: 10   Latitude: Longitude: Datum: WGS84

Reference Severity: 60   Current Severity: 65   Reference Composition Source: D   Current Composition Source: R

Comments:

Succession Classes

Code	Upper Layer Majority Lifeform	Size	Dominant Species	Ref Comp	Curr Comp	Acres	Sim	Diff	Relative Amount	Stand FRCC	Stand Depart	S-Class Acres Departed from Reference
A	HERB			10	8	4487	8	-20	SIMILAR	1	0	-1121
B				60	23	12901	23	-62	UNDER REP	1	0	-20755
C	HERB			30	66	37022	30	55	OVER REP	2	55	20194
D				0	0	0	0	N/A				0
E				0	0	0	0	N/A				0
U				0	3	1682	0	100	ABUNDANT	3	100	1682
			Total	100	100		61					

Stratum Vegetation Departure: 39   Stratum Fire Frequency Departure: 0   Stratum Regime Departure: 4

Stratum Vegetation Condition Class: 2   Stratum Fire Severity Departure: 8   Stratum Regime Condition Class: 1

Stratum Fire Regime: I - Frequent Surface and Mixed   Stratum Departure: 22   Stratum Fire Regime Condition Class: 1

Figure 92.Alternative D Landscape report with succession classes (2020)

Fire Regime Condition Class
Landscape Report - Reference Fire Regime Summary

Registration Code: 4FRI-Lata   Landscape Code: 4FRI   Char Date: 04/24/2012

Stratum #	Reference Frequency	Reference Severity	Fire Regime Group
1	7	6	I
2	10	60	I

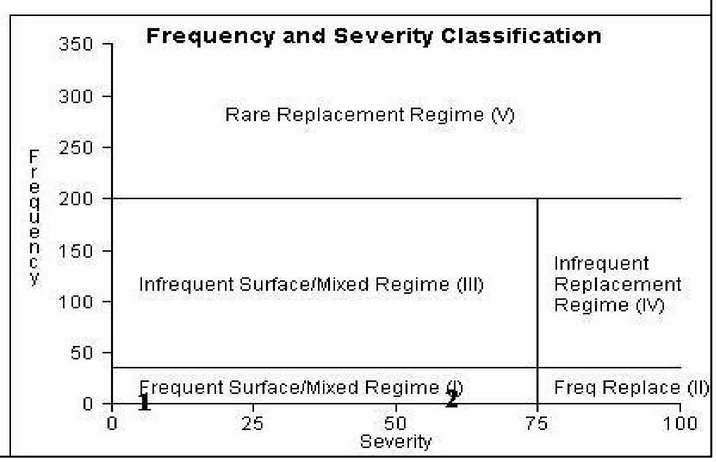


Figure 93. Alternative D Fire Regime summary (2020)

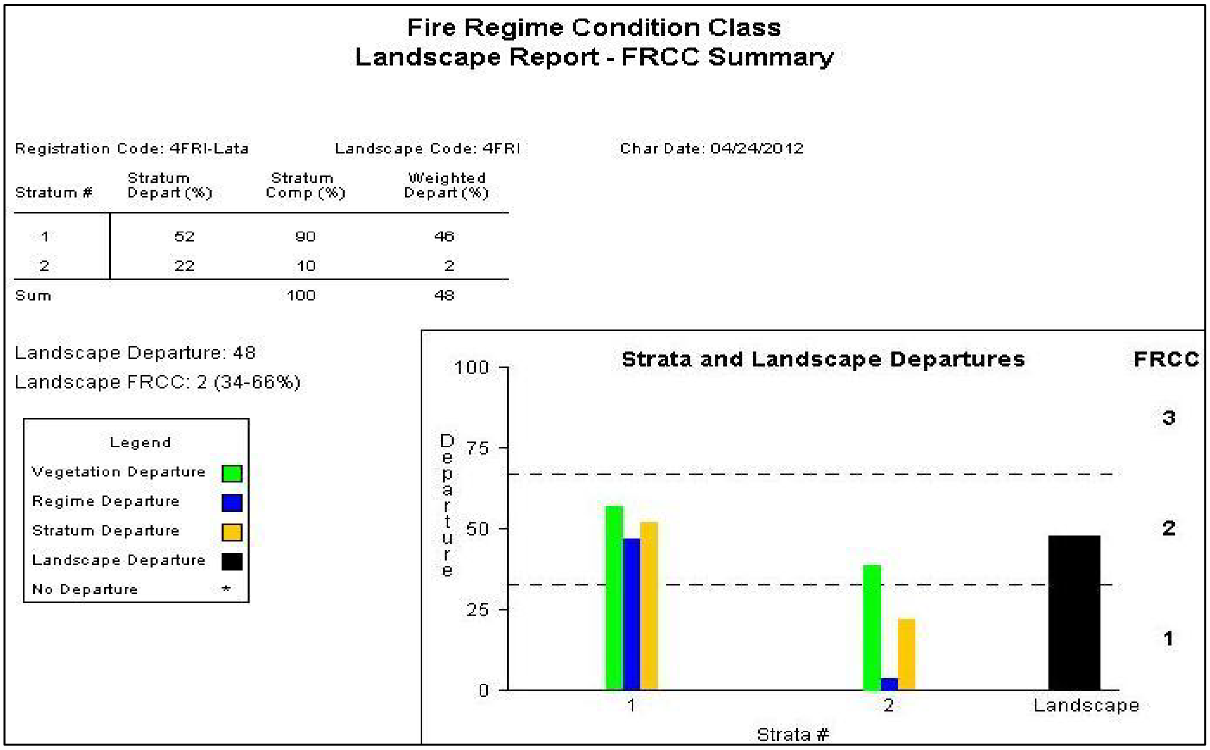
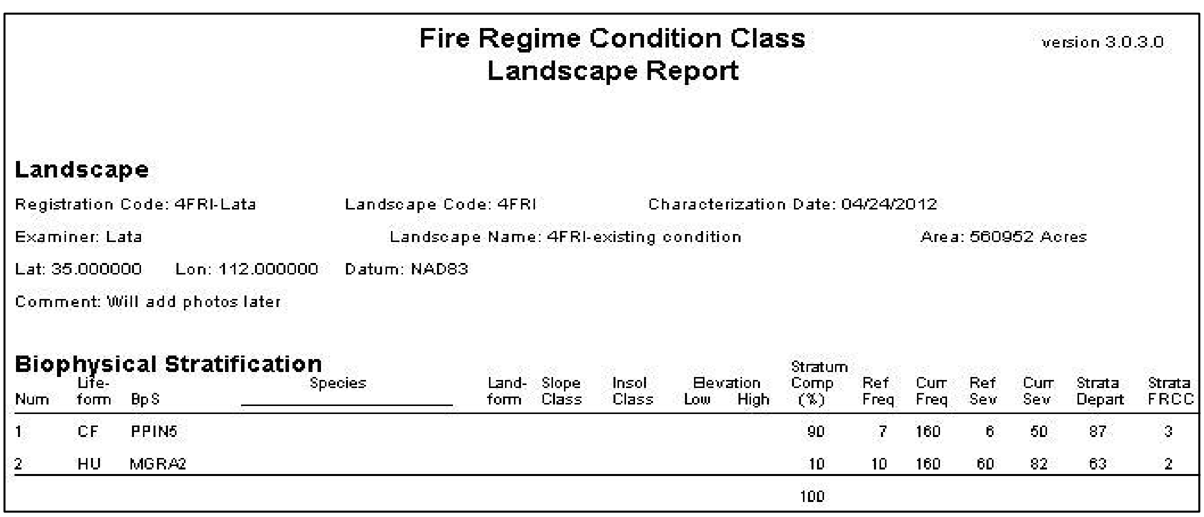


Figure 94.Alternative D Fire Regime/Condition Class summary (2020)

Table 125. Fire Regime Condition Class summary, Alternative D, 2020, for ponderosa pine and grasslands

Biophysical Setting (BpS Code)		FRG (I-V)	Condition Class 1 (Acres)	Condition Class 2 (Acres)	Condition Class 3 (Acres)	Total Acres
Ponderosa Pine (Colorado Plateau)	(PPIN5)	I	40389	413983	50486	504857
Mtn. Grassland With Trees	(MGRA2)	I	17390	37023	1683	56095
Total Acres			57778	451005	52169	560952


Fire Regime Condition Class
Landscape Report

version 3.0.3.0

Landscape

Registration Code: 4FRI-Lata — Landscape Code: 4FRI — Characterization Date: 04/24/2012

Examiner: Lata — Landscape Name: 4FRI-existing condition — Area: 560952 Acres

Lat: 35.000000 Lon: 112.000000 Datum: NAD83

Comment: Will add photos later

Biophysical Stratification

Num	Life-form	BpS	Species	Land-form	Slope Class	Insol Class	Elevation Low	Elevation High	Stratum Comp (%)	Ref Freq	Curr Freq	Ref Sev	Curr Sev	Strata Depart	Strata FRCC
1	CF	PPIN5							90	7	160	6	50	87	3
2	HU	MGRA2							10	10	160	60	82	63	2
									100						

Figure 114. Alternative D Biophysical stratification (2050)

Fire Regime Condition Class
Landscape Report - Stratum Data

Registration Code: 4FRI-Lata   Landscape Code: 4FRI   Characterization Date: 04/24/2012

Stratum Num: 1   Biophysical Setting: PPIN5   Stratum Name: Ponderosa Pine (Colorado Plateau)

Stratum Composition (% of area): 90   BpS Lifeform: CF   Landform: Avg Slope Class: Insol Class:

Stratum Area: 504856 Acres   Species: Low Elevation: High Elevation:

Reference Frequency: 7   Current Frequency: 160   Latitude: Longitude: Datum: WGS84

Reference Severity: 6   Current Severity: 50   Reference Composition Source: D   Current Composition Source: R

Comments:

Succession Classes

Code	Upper Layer Lifeform	Majority Size	Dominant Species			Ref Comp	Curr Comp	Acres	Sim	Diff	Relative Amount	Stand FRCC	Stand Depart	S-Class Acres Departed from Reference
A						5	0	0	0	-100	TRACE	1	0	-25242
B			DACRY3	PSEUD7	ABIES	5	40	201942	5	88	ABUNDANT	3	88	176699
C						15	2	10097	2	-87	TRACE	1	0	-65631
D			PIPO			65	2	10097	2	-97	TRACE	1	0	-318059
E			PIPO	PSEUD7	ABIES	10	40	201942	10	75	OVER REP	2	75	151457
U						0	16	80777	0	100	ABUNDANT	3	100	80777
					Total	100	100		19					

Stratum Vegetation Departure: 81   Stratum Fire Frequency Departure: 96   Stratum Regime Departure: 92

Stratum Vegetation Condition Class: 3   Stratum Fire Severity Departure: 88   Stratum Regime Condition Class: 3

Stratum Fire Regime: I - Frequent Surface and Mixed   Stratum Departure: 87   Stratum Fire Regime Condition Class: 3

Figure 95.Alternative D Landscape report with succession classes (2050)

Fire Regime Condition Class
Landscape Report - Stratum Data

Registration Code: 4FRI-Lata   Landscape Code: 4FRI   Characterization Date: 04/24/2012

Stratum Num: 2   Biophysical Setting: MGRA2   Stratum Name: Mtn. Grassland With Trees

Stratum Composition (% of area): 10   BpS Lifeform: HU   Landform: Avg Slope Class: Insol Class:

Stratum Area: 56095 Acres   Species: Low Elevation: High Elevation:

Reference Frequency: 10   Current Frequency: 160   Latitude: Longitude: Datum: WGS84

Reference Severity: 60   Current Severity: 82   Reference Composition Source: D   Current Composition Source: R

Comments:

Succession Classes

Code	Upper Layer Lifeform	Majority Size	Dominant Species	Ref Comp	Curr Comp	Acres	Sim	Diff	Relative Amount	Stand FRCC	Stand Depart	S-Class Acres Departed from Reference
A	HERB			10	0	0	0	-100	TRACE	1	0	-5609
B				60	5	2804	5	-92	TRACE	1	0	-30852
C	HERB			30	80	44876	30	63	OVER REP	2	63	28047
D				0	0	0	0	N/A				0
E				0	0	0	0	N/A				0
U				0	15	8414	0	100	ABUNDANT	3	100	8414
			Total	100	100		35					

Stratum Vegetation Departure: 65   Stratum Fire Frequency Departure: 94   Stratum Regime Departure: 60

Stratum Vegetation Condition Class: 2   Stratum Fire Severity Departure: 27   Stratum Regime Condition Class: 2

Stratum Fire Regime: I - Frequent Surface and Mixed   Stratum Departure: 63   Stratum Fire Regime Condition Class: 2

Figure 96.Alternative D Landscape report with succession classes (2050)

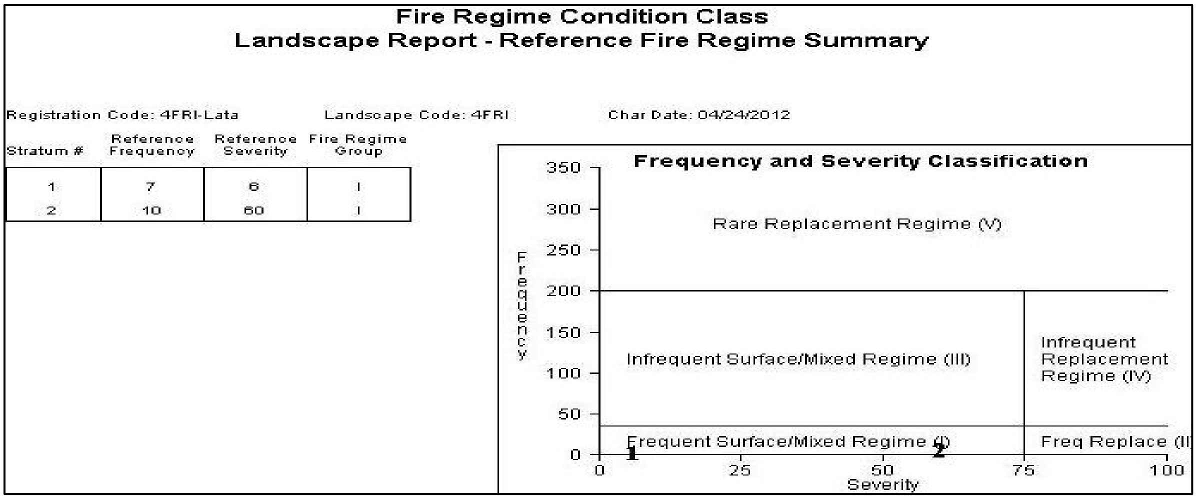


Figure 97.Alternative D Fire Regime summary (2050)

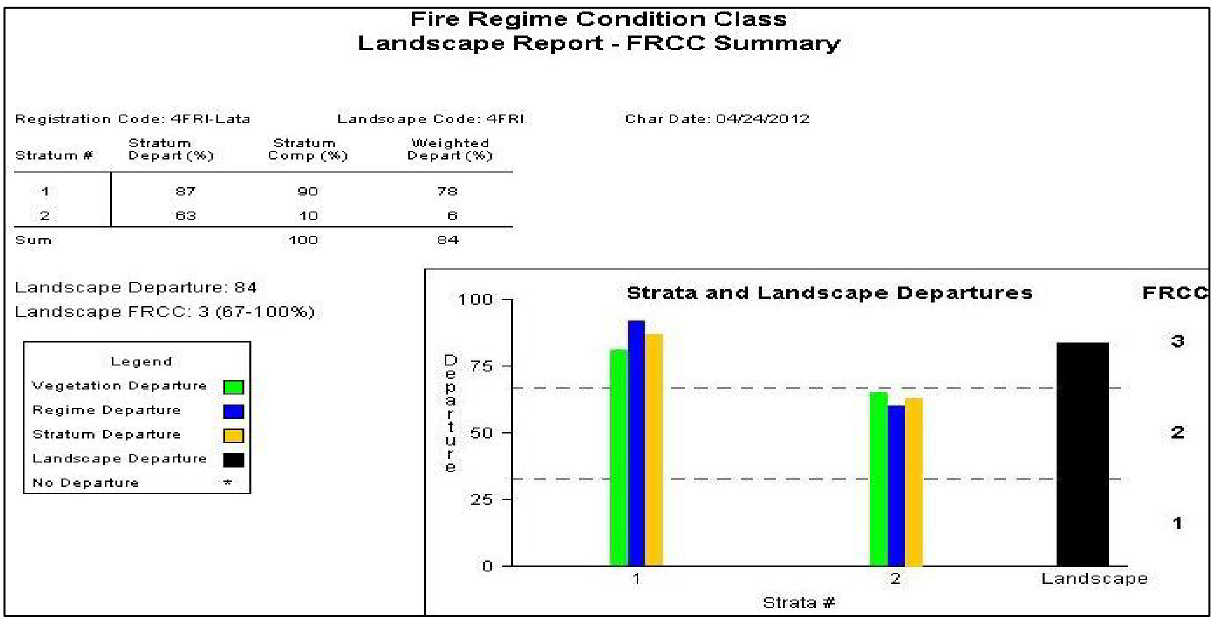


Figure 98.Alternative D Fire Regime/Condition Class summary (2050)

Table 126. Alternative D Fire Regime/Condition Class summary (2050)

Biophysical Setting (BpS Code)		FRG (I-V)	Condition Class 1 (Acres)	Condition Class 2 (Acres)	Condition Class 3 (Acres)	Total Acres
Ponderosa Pine (Colorado Plateau)	(PPIN5)	I	20194	201943	282720	504857
Mtn. Grassland With Trees	(MGRA2)	I	2805	44876	8414	56095
Total Acres			22999	246819	291134	560952

Table 127. Alternative D Fire Regime/Condition Class summary (2050)

Biophysical Setting (BpS Code)		FRG (I-V)	Condition Class 1 (Acres)	Condition Class 2 (Acres)	Condition Class 3 (Acres)	Total Acres
Ponderosa Pine (Colorado Plateau)	(PPIN5)	I	25243	227186	252428	504857

Mortality and consumption modeling

Initial FVS runs were adjusted to improve the accurately of modeled post-treatment mortality. Several people conferred on how to produce accurate mortality including:

- Linda Wadleigh (Fire Ecologist, Regional Office)
- Tessa Nicolet (Fire Ecologist, Regional Office)
- Stephanie Rebain (Forest Management Service Center - FVS Group)
- Patti Ringle (Silviculturist, Flagstaff Ranger District, Coconino NF)
- Mary Lata (Fire Ecologist, 4FRI Core Team)
- Neil McCusker (Silviculturist, 4FRI Core Team)
- Mike Battaglia (Research Forester, Rocky Mountain Research Station, Ft. Collins, CO)

Input from persons listed above was considered and the decision was made to use the method most commonly used. For this method, FVS inputs define how much of a ‘burn unit’ actually burns (between 0 percent to 100 percent). For the initial burn in 2015, the area that burned was set at 70 percent, and for the 2019 burn it was set at 50 percent. Based on conclusions from the group listed above mortality was fixed in 2015 and the FFE default was used for 2019. This better represented actual conditions for groups/clumps because outputs were stand averages, and having FVS only ‘burn’ a portion of the stand would show less impact to the stand – as if only clumps or groups had burned. However, in the first run at assigning fuel models based on FVS outputs, it became obvious that modeled post-treatment surface fuels were out of alignment with structural characteristics. An actual burn would have consumed more of the surface fuels and small trees because it would have burned more of the area. To more accurately represent post-treatment conditions for surface fuels, shrubs, and trees <5” diameter, we assumed that 80 percent of the area burned in 2015 and 75 percent burned in 2019. This also provided more accurate numbers for those species that respond to fire/cutting by sprouting.

Post-treatment fuel model assignments

Fuel, fuel moisture, wind, and slope are assumed to be constant during the time for which predictions are to be applied. Because fires almost always burn under non-uniform conditions, the length of projection period and choice of fuel model must be carefully considered to obtain useful predictions. The more uniform the conditions are, the longer the projection time can be. The number of simulations for which fuel models needed to be assigned expanded from ~17 (in August of 2011) to 1,492 (February, 2012). During this time, the following process was developed to assign fuel models based on the following outputs from FVS and defined fuel model characteristics (Scott and Burgen 2005).

To more accurately assign post-treatment fuel models, the assumptions described in the previous section on Mortality and Consumption were applied as follows for each variable of interest for each simulation:

IF:

a = 2012 tons/acre = 120

b = 2015 tons/acre = 70

c = 2012 – 2015 = -50 tons/acre (amount consumed in the burn)

d = in 2012 70 of ‘a’ that was affected by the burn = 84 tons/acre

e = in 2012 30 of ‘a’ that was not affected by the burn = 36 tons/acre

SO,

c = 59 of d that was consumed (for first simulation with 70:30)

SO, for each simulation for which it was 80:20 (the ratio deemed more realistic for the second burn):

(a*. 7) = 84 tons/acre

59 of 96 tons/acre = 57 tons/acre

a*. 3 = 36 tons/acre

2012 – ((((2012 – 2015)/(2012 * . 7))*(2012 * . 7))+(2012 * . 3)) = 2015 value

FVS-FFE output data from the following categories was used/considered. Those in italics used the data adjusted for mortality, those in standard font did not.

- B = pj tpa<5”(Trees/acre less than 5” dbh of Pinyon/Juniper)
- C = pj tpa >5” (Trees/acre greater than 5” dbh of Pinyon/Juniper)
- D = potr tpa <5” (Trees/acre less than 5” dbh of aspen)
- E = potr tpa >5” (Trees/acre greater than 5” dbh of aspen)
- F = mc tpa<5” (Trees/acre less than 5” dbh of mixed conifer)
- H = cc (canopy cover ( ))
- I = cbh (feet)
- J = cbd (kg/m3 * 100)
- K = shb (tons/acre)
- L = quga tpa<5” (Trees/acre less than 5” dbh of Gambel Oak)
- M = quga tpa>5” (Trees/acre greater than 5” dbh of Gambel Oak)
- N = herb (herbaceous surface vegetation in tons/acre)
- = Litt (adj) (tons/acre)
- P = Duff (adj) (tons/acre)
- Q = Fines (Litt+1hr) (tons/acre)

- R = 1hr (adj) (1 hour fuels (<1/4” diameter) in tons/acre)
- S = 10hr (adj) (10 hour fuels (>1/4 and <1” diameter) in tons/acre)
- T = 100hr (adj) (100 hour fuels (<1” and >3” diameter) in tons/acre)
- U = 1000hr (adj) (1000 hour fuels (>3” diameter) in tons/acre)
- AA = Canopy Density (A, B, or C)

Fuel Model Characteristics considered (Scott and Burgen):

Fine fuel load (T/a)

- Potential FL (very dry)
- Potential ROS (very dry)
- Coarse fuel load (T/a)
- Species (deciduous vs. Conifer; aspen dominant)

Step 1: Apply formula to account for the difference in area between modeled area burned and the adjusted area (to account for a more complete burn) area burned for years 2015, 2020, and 2040. There was no rx after 2020 so, in order to account for the differences in surface fuels from the earlier burns, the 2040 Adjusted fuels were adjusted by the change between 2020 and 2020 Adjusted.

Step 2: Apply the formulas below to the appropriate data into the ‘first cut’ sheet to assign simulations to either: Timber, Shrub, or Grass based on the following criteria. This is an initial cut only, and as further classifications are completed in this process, simulations may be moved from their original assignation to other types.

Grass (GR) and grass/shrub (GS) fuel models:

CBH > 17.99 ft. And CC <30

Rational: A combination of CC and CBH can determine if crown fire is possible under most situations. CBH for initiation, CC for active vs passive. Surface fuels alone could produce sufficient surface fire intensity to initiate crown fire in some high canopy base heights but, for this first cut, if these criteria were met the simulation was classified as ‘GR’.

Shrub fuel models (SH):

CBH <17.99 ft, CC < 30

Rational: CC isn’t sufficient to be able to carry a fire through the canopy, so it isn’t a timber model (<30) but CBH may be low enough to initiate cf in whatever woody veg there is (CBH<17.99). This was a more challenging category, but it seemed to pick out PJ, Sage, and other potentially shrubby fuel types. This was just the first cut so simulations that fell into this category could be moved if further classification indicated it was better elsewhere (such as GS or TU).

Timber Litter (TL) and timber understory (TU) models:

CC > 29.99 (See assumptions below)

Rational: Observations in the field are supported by the stand data and modeling to show that CC affects surface fuel loading for all types (herbaceous, CWD, duff, litter), as well as the potential for crown fire. 30 is a common number used to define savanna vs. Forest (citation).

Assumptions:

- QUGA and POTR are deciduous and, therefore they, and their leaf litter, have different characteristics than ppine or mixed conifer
- PJ <5” MC <5” have more flammable morphology (lower and denser canopies) and have greater CBD than QUGA, so more QUGA <5” were deemed necessary to justify classification as having a shrub fuel component
- In 10 years, all stands had been rx burned twice and, all proposed mechanical treatment were completed.
- In stands where aspen dominates, the ecosystem is different. More cool season species, moister understory conditions much of the time as compared with conifers and oak. The dead/down component also appeared to be much higher in most aspen stands (in the FVS data) than in other species, so aspen was given a fuel model (186) of its own

Step 3: Assign models as per the formulas below. Note that simulations classified initially as ‘TL’ will be split into TL and TU (see below) before specific fuel models are assigned.

GR (grass)

101:
Only a little shrub/woody component. Litter was the differentiating factor. Spread rate moderate to low compared with other grass models, depending largely on the continuity of the fuel. Most of this would be in dry, open areas. Much of the herbaceous fuel would be discontinuous, so burns wouldn’t be 100. PJ and MC variables present in 102 classification made no difference for this classification, and were removed.

(Litter + 1 hr) <0.72 AND shrub < 0.25
OR
(litter + 1 hr) < 0.72 AND (tpa QUGA <5”) <300

102:
Greater fine fuel loading than 101, and fuels more contiguous. ROS moderate, may be high in wet years or small areas. This allows a small component of woody fuels (quga, pj, and/or mc).

((Litter + 1 hr) > 0.72 <2) AND shrub < 0.25 AND (tpa QUGA <5”) > 400 AND (TPA<5” mixed conifer and PJ) < 25

GS (grass/shrub)
SHB must be a component (see above), as well as greater fine fuel/litter loading than in the GR models.

121:
A minimum of .25 T/acre of shrub-like fuels, and a potentially greater (though still low) component of woody fuels in the form of 1 hr or small shrub-like trees (PJ, MC, quga). Less contiguous fuel than 122, but with very small areas of higher severity where there is a woody component, though not

contiguous.

(Shrub>0.35<0.79) AND ((litter + 1 hr) >0.9<1.7) AND ((tpa quga <5”)>160<300)
OR
(litter + 1 hr) >0.9 AND (TPA<5” mixed conifer and PJ) >25<40
OR
(litter + 1 hr) >0.9< 1.7 AND (tpa quga <5”)>300<500) AND (TPA mixed conifer and PJ <5”) <20

122:
Similar to 121, but greater fuel loadings. Overall fuels are more contiguous than 121. Woody fuels may be more frequent, but are still not contiguous. FL moderate and ROS high because mostly contiguous fuels.

(litter + 1 hr) > 1.5 AND shrub>0.75
OR
(litter + 1 hr) >1.2 AND (tpa quga >5”) > 500 AND (TPA<5” mixed conifer and PJ) >40

SH (shrub)
Shrub/PJ are the main component defining 141, 142, and 145.

141:
This is broad enough to include those areas with a number of small trees, but low fine fuel loading. Includes a fair amount of PJ. Fire behavior is expected to be low with spread being minimal without a strong wind. Flame length and ROS low, mostly because of discontinuous fuel.

CC<26 AND CBH < 17 AND (tpa all PJ) >10, (tpa PJ >5”) < 40; herbaceous > 0.17
OR
CC < 26 AND shrub > 0.75 AND (litter + 1 hr) >0.75<2. 1
OR
CC < 26 AND shrub > 0. 5 AND (litter + 1 hr) >0.75<2.1 AND (TPA<5” mixed conifer and PJ) >40

142:
Herbaceous <0.15
OR
Herbaceous <0.165 AND (tpa quga <5”) >300<400)

Low potential for spread without wind, almost no herbaceous fuel present, so wind is required for much spread. With sufficient wind, intensity is potentially high in places, but spotty and discontinuous. Includes a variety of fuel types, but picked up the higher fuel loadings of PJ.

145:
With much wind, this can produce high intensity fire and, as classified, included simulations with a moderately high component of QUGA <5” as well so, combined with the canopy characteristics, this is likely to produce a crown fire with high rates of spread and high flame lengths.

(TPA PJ<5”) > 200 AND CBH < 10 AND CC > 25

TU/TL
NOTE: in reviewing the TL models (after the original TL/TU split), the highest values for PJ<5”, MC<5” were reviewed and, if L5 was greater than 500, it was moved to TU. Any remaining TL models with CC<30 were moved to TU, and the lowest CC values were reviewed to see if any of

them should be moved to TU or GR/GS. The assumption was that a more open canopy would produce sufficient surface fuels to contribute to fire bx, and insufficient needle litter to really qualify as TL.

TU (Timber Understory)

This should be common across much of the 4FRI landscape with surface fire being the norm unless conditions are extreme. Herb or shrub component required. The shrub component may be represented by small MC or small PJ. Canopy should not be entirely closed in order to allow a surface fuel component of vegetation instead of just dead/down fuels, litter, and duff.

CC < 60 AND Canopy closure = A (open)

OR

CC < 60 AND Canopy Closure = A or B AND (herbaceous + shrub) > 0.4

OR

CC < 60 AND (herbaceous + shrub) > .75 AND (tpa quga <5”) >900 AND (TPA mixed conifer < 5” and PJ < 5”) >60

TL (Timber Litter)

Not as above.

161:

This picked up a lot of simulations, as it should. Some passive crown fire may occur in this fuel model, but spread rate and flame length are low. Surface vegetation, including herbaceous, shrubs, and small conifers is present. The canopy is open enough to assume that there will be at least a moderate amount of herbaceous fuels.

(tpa pj <5” + mixed conifer <5”) < 152 AND (quga <5”) <1500

162:

This fuel model is intended to pick up the moderate amount of fuel loading and passive crown fire potential in areas not well represented by 161 or 165. It is generally a humid climate model, so fuel moistures were modeled lower for this than for the other TU models. Spread rate is moderate because of more contiguous fuel than 161, crown fire is more likely than in 161, but not as likely as 165. Flame lengths can be moderate, depending on burning conditions.

(tpa pj <5” + mixed conifer <5”) > 150 < 500

OR

(tpa quga <5”) > 1500 < 3000 AND (tpa pj <5” + mixed conifer <5”) > 150 < 500

165:

Higher fuel loading, with potential for undesirable fire effects. Lots of ladder fuels, good potential for crown fire initiation. Rate of spread and flame length moderate.

(tpa pj <5” + mixed conifer <5”) > 500 AND (tpa quga <5”) >3000

TL (Timber Litter)

Timber litter is the primary carrier of the fire. Canopies are mostly closed, and/or surface fuel loading other than dead/down woody debris, litter, and duff is minimal.

181:

Light surface fuel loading because of low surface productivity, or recent burns. Canopy cover may be lower in this fuel model. Flame length and rate of spread should be low as litter is the primary carrier of the fire. Surface fuels may be discontiguous in places.

Duff < 1.5 AND (litter + 1 hr) > 0.75 < 2.75 AND (potr < 5” + quga < 5” + potr > 5” + quga > 5”) < 50 AND (tpa pj < 5” + tpa mc <5”) <50)

182:

Surface fuel loading is low to moderate, with contiguous fuels prevalent. One aspect of the fuel model picks up areas with higher deciduous components (excluding those dominated by aspen). In general, this fuel model picks up low to moderate surface fuel models in a wide variety of pine and pine oak forests.

(tpa quga <5”) >450 AND (tpa quga >5”) >75 AND (100 hr + 1000 hr) <12

OR

(tpa all potr + tpa all quga) >50 AND duff <6 AND (litter + 1 hr) > 1 < 7 AND (tpa pj <5” + tpa mc <5”) < 50 AND (100 hr + 1000 hr) <12

183:

Fuel model 183 has low to moderate fuel loading. Canopies are mostly open, and canopy base heights moderately high. These should be areas that have been thinned and/or have had fire in the last 10 years so that fire behavior produces mostly low severity effects that are beneficial to the ecosystems.

Duff > 1.5 < 6.7 AND (1 hr + 10 hr) < 7 AND (tpa potr < 5” + tpa mc <5”) <50.85 AND (tpa PJ <5” + tpa mixed conifer <5”) <50 AND ((100 hr + 1000 hr) AND (litter + 1 hr) < 7.1

184:

High surface fuel loading (23 – 30 tons/acre) with a CWD (>3”) component averaging 9 tons/acre. Canopies are more open than the ‘higher’ timber litter models though so, although surface effects have potential to be negative, heat can escape upwards in most simulated areas with less scorch/damage to the canopy. Spread rate and flame lengths would be low to moderate, with the range depending on the openness of the stand (mid-flame wind).

(100 hr + 1000 hr) >12<16 AND (tpa PJ <5” + tpa mixed conifer <5”) <50 AND 1 hr >0.1<1.4 AND duff < 15 AND (litter + duff) <11

185:

Fuel model 185 represents high fuel loading, with a mix of fuel sizes. Surface fuel loading exceeds 21 tons/acre, with over 7 tons from litter and 1 hour fuels. Closed canopies may contribute to excessive scorch and negative surface and soil effects even when no crown fire occurs.

CC > 60 AND (100 hr + 1000 hr) < 13 (100 hr + 10 hr) >6 AND (litter + 1 hr) > 7 AND (tpa PJ <5" + tpa mixed conifer <5") < 50

OR

(100 hr + 1000 hr) >7<12 AND (litter + 1 hr) >7 AND duff >4<10

186:

This fuel model, in this analysis, represents stands dominated by aspen. Fire would be of mixed severity most of the time, lower flammability than the surrounding grasslands and conifer forests most of the time. For many of the simulations of aspen stands (7 out of 20), large CWD exceeds 14 tons/acre, and for 9 out of 20, fine dead surface fuels (litter and 1 hr) exceed 8 tons/acre. However, litter in aspen burns differently than in conifers, and is less flammable than oak so flame lengths would be low and ROS moderate except under extreme conditions.

(tpa potr <5")>600 AND (tpa potr >5") >50

187:

Fuel model 187 has high surface fuel loading, with a high component of large CWD sufficient to cause high severity surface effects in the event of a fire burning in extreme conditions. Crown fire is possible, but not necessary to cause high severity effects to soils and vegetation, since they could come from high quantities of surface fuels burning hot. Surface fuel loading ranges from 26 tons/acre to 57 tons/acre.

(100 hr + 1000 hr) > 15. 99 AND (tpa pj <5" + tpa mixed conifer <5") <50

188:

This fuel model picks up mostly closed canopy pine where there has been no fire for decades. Surface fuel loads are high, but dominated by litter/duff/1 hr fuels with only a low to moderate load of dead/down CWD. Unless/until crown fire is initiated, flame lengths are low and ROS is moderate to low. These areas have high potential for high severity effects in ponderosa pine because of contiguous canopies and surface fuel loads sufficient to scorch canopies where there is no crown fire. Surface fuel loading ranges from 20 to over 32 tons/acre and in most simulations, duff loading exceeds 15 tons/acre.

Duff > 15 AND (100 hr + 1000 hr) <15.99

OR

CC > 45 < 60 AND (litter + 1 hr) > 7.5 AND (tpa pj <5" + tpa mixed conifer <5") <50 AND 1000 hr < 8 AND (tpa quga <5") <300

Step 4: Review simulations to ensure they make sense. If there are duplicates assigned, or no fuel model assigned (these should constitute less than 10 of all simulations), review variables and assign fuel model. Simulations may be moved from one category to another if perusal of the variables and the formula do not place it in an appropriate category.

Crowning and Torching Indices

This modeling was done with FVS-FFE (Forest Vegetation Simulator – Fire & Fuels Extension).

Prescribed fire parameters for burns were the same as for the alternatives under Environmental Consequences. For the post-treatment maintenance burns (2029, 2039, and 2049), modeled parameters were the same as for the 2019 burn.

Regeneration is an important component in long-term fire modeling because of the potential for regeneration to mature into ladder fuels. Regeneration rates were set at 50 for the 2016 burn and at 100 for the 2029 burn. This was based on the premise that the bare mineral soil that is exposed following a fire is a beneficial seed-bed for ponderosa pine and would promote regeneration.

Fire Priority Ranking

Areas showing active or passive crown fire and high or extreme levels of surface fire intensity in timber fuel models were given points according to the matrix below (Table 128). Those areas of high probability of crown fire or high intensity surface fire occurring on slopes greater than 40 were given one additional point. Additionally, those areas identified on soils with high erosion hazard were given one additional point. Total points possible are 7.

Table 128. Fire prioritization process with hazards (fire behavior) and risks

Crown fire Hazard	Active	3	Highest priority. High mortality, high severity likely.
	Passive	2	High severity effects are localized.
High intensity surface fire	>4000 (extreme)	2	High intensity, high severity, 100 percent mortality is likely in ponderosa pine and negative surface effects are likely.
	1000 – 4000 (high)	1	Indicates flame lengths of <11 ft, good potential for high severity effects, but not always stand replacing. Control limited to indirect attack.
Slope >40		1	When combined with high severity fire, there is high potential for negative impacts to onsite resources (seed bank, soil, etc) as well as potential downslope effects (debris flows, etc).
High Risk of Erosion		1	When combined with high severity fire, these soils are at a high risk of erosion by wind or water

Table 129 shows how the spatial component of the scoring was laid out. Soils with erosion characteristics are not shown. Scoring is shown below, with the highest priority as a ‘7’, indicating extremely negative consequences should a high intensity crown fire burn on a slope greater than 40 on highly erodible soils.

Table 129. Scoring used for prioritizing risks and hazards attributed to potential fire effects

Priority (1 to 7)	Risks and Hazards
1	high intensity
2	passive cf OR extreme intensity OR high intensity + >40 slope OR high intensity + erosion risk
3	active cf OR passive cf + >40 slope OR passive cf + high intensity OR

	passive cf + erosion risk
4	passive cf + extreme intensity OR passive cf + high intensity + >40 slope OR passive cf + high intensity + erosion risk OR active cf + >40 slope OR active cf + erosion risk
5	active cf +extreme intensity OR active cf + high intensity + >40 slope OR passive cf + extreme intensity + >40 slope OR active cf + high intensity + erosion risk OR passive cf + extreme intensity + erosion risk OR active cf + >40 slope + erosion risk
6	active crown fire + extreme intensity + >40 slope OR active crown fire + extreme intensity + high erosion risk
7	active crown fire + extreme intensity + >40 slope + erosion risk

According to this process, scores of two or greater indicate high probability of severe effects/behavior. It does not preclude severe fire effects that could occur if a fire of high intensity did not crown, but scorched a sufficient amount of crown to cause mortality. An average score was calculated for every mechanical treatment stand. Stands with an average score of two or greater and stands with ≥50 acres of high probability of severe effects/behavior (scores between 2 and 7) were identified as high fire priority stands.

Table 130. Fire priority ranking by Restoration Unit and acres

Restoration Unit	Fire Priority Ranking								
	1	2	3	4	5	6	7	Total	Acres
1	9	12	14	7	87	13	0	37	57,681
3	23	19	13	11	90	9	1	31	46,843
4	47	25	22	8	90	9	1	28	47,187
5	34	41	29	9	89	8	3	22	17,398
6	29	104	67	15	96	4	0	8	3,430
All	26	22	18	9	89	10	1	29	172,539

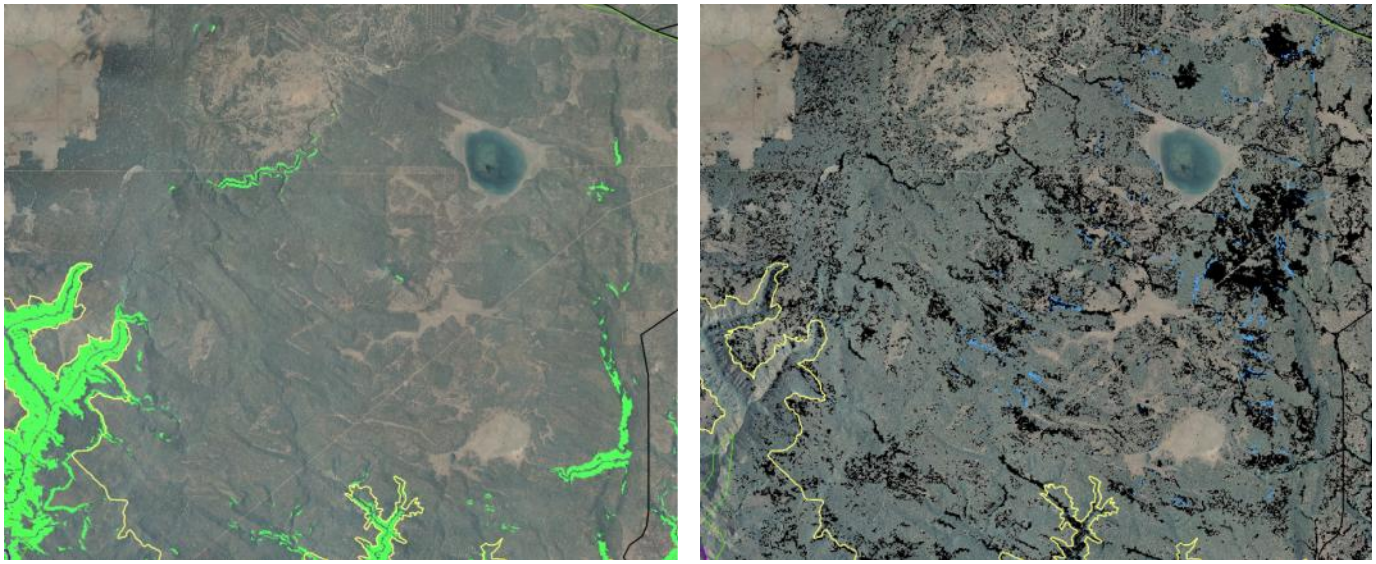


Figure 99.Left: slopes greater than 40 percent are shown in green. Right: Fireline intensities: black (high) and blue (very high)

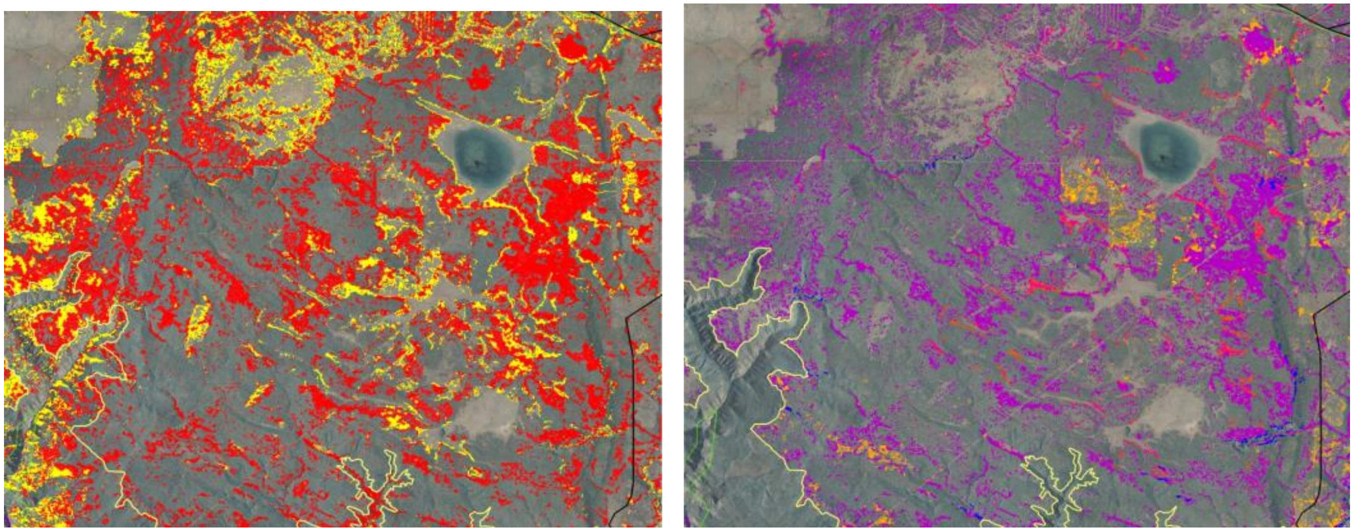


Figure 100. Left: red denotes active crown fire, yellow is passive crown fire. Right: Blue is highest priority, purple is second highest priority and yellow is the lowest priority

Ignition Density

One additional analysis that was conducted to determine where the greatest concerns were regarding fire was an analysis of where ignitions have occurred. All fires were included, whether they were just a snag, or thousands of acres. They were considered by lightning ignitions, human ignitions, and the two combined. The intent is to provide a spatial picture of where fires were more likely to start (Figure 101). Human ignitions were most frequent near roads, towns, and recreation areas. Lightning ignitions were most numerous near high points and cinder cones. These data represent only those fires that fire personnel responded to, and are likely to omit many fires that were never reported.

When ignition density was evaluated with the priority rating, it was determined that the majority of areas with high ignition potential were already rated as very high priority by the fire priority rating.

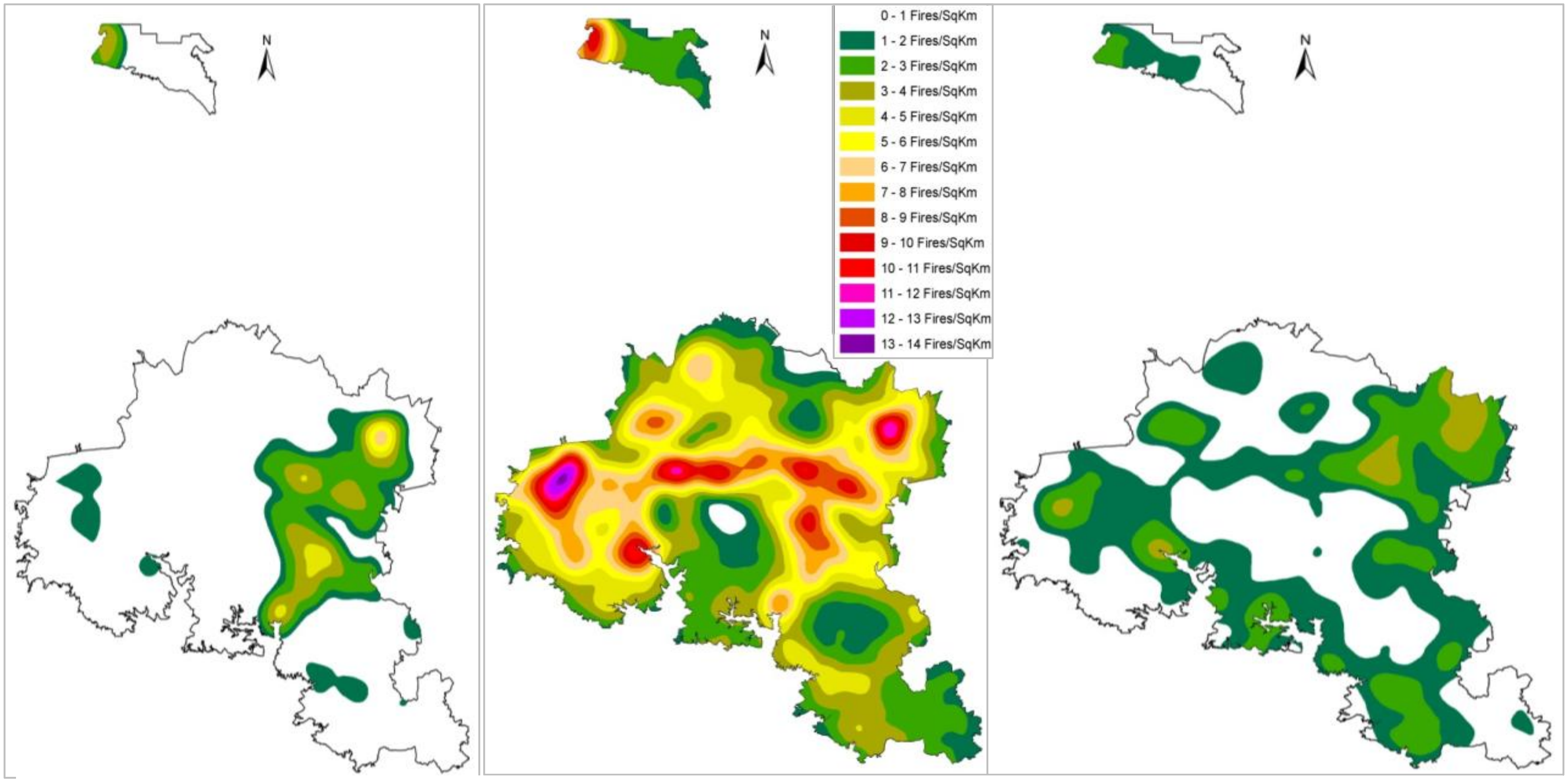


Figure 101. Ignition density from 1985 through 2005. Left - lighting fires. Right: Human started fires. Center: all fires

Modeling Assumptions

A lower intensity was modeled for prescribed burning in PACs because there is generally higher fuel loading and, in order to obtain the desired effects from a prescribed fire, more moderate conditions would be required to keep the fire severity at desired levels.

Modeled fire data for existing condition were modified with a change detection process developed by ForestERA (ForestERA 2010) to more accurately represent existing conditions since the base data had not been updated in 2009 and 2010.

This analysis uses running averages of acres treated by planned and unplanned fire for each alternative as a fixed number per year in order to make broad comparisons between alternatives. In reality, there are wide fluctuations in the number of acres treated each year which depend on weather, resource availability, public tolerance, funding, and logistics.

Outputs were modeled with 2010 data representing existing conditions because that was the most up-to-date data when the analysis began.

Conditions modeled for prescribed burning in PACs represented a ‘cooler’ burn, with higher fuel moisture to represent the lower severity fire that would be implemented in these areas.

All mechanical treatments were modeled to have occurred in 2012

Prescribed burns were modeled in 2015 and 2019 except for aspen for which only the 2015 burn was modeled.

Thinning parameters were modeled to assume 15 percent of stems cut are left on site, and 10 percent of the branchwood from those stems are also left onsite. This is what would be expected wherever there would be mechanical treatments, except where it would need to be modified to meet desired conditions.

Savanna is classified as ‘forested’, despite the fire type generally being overwhelmingly surface fire in a healthy savanna. The ‘All Pine’ designation in the analysis includes the 45,469 acres of savanna restoration for all Alternatives, so it should be assumed that over 35,000 acres of the surface fire indicated for the ponderosa pine in each Action alternative is in the 45,469 acres of savanna.

FRCC: The assumption is that ‘large trees’ = old trees for this analysis, thus, it likely over-predicts CC1 acres.

Appendix E – Design features and mitigation

Table 135. Design features and mitigation measures for all action alternatives

Design Criteria No.	Description	Purpose		Comment or Purpose
		Forest Plan Compliance	Specialist Recommendation	
FE1	Burn unit size, as well as strategic placement, would be a consideration in designing units and implementation prioritization (Finney et al. 2003).		X	Arrangements of large treatment areas are more effective at reducing fire behavior than arrangements of smaller ones. Larger burn blocks, when possible, would also be mitigation for emissions by increasing the potential number of acres that could be burned in a burn window. Larger burn units would produce more smoke when prescribed fires are implemented, but for a shorter duration.
FE2	Prescribed fire (pile, broadcast, and jackpot burning) would occur in accordance with Arizona Department of Environmental Quality (ADEQ) requirements.	X		Regulatory requirement.
FE3	Emission Reduction Techniques (see FE8) would be utilized when possible to minimize impacts to sensitive receptors of burn unit(s). Project design for prescribed fire and strategies for managing wildfires should incorporate as many emission reduction techniques as feasible, subject to economic, technical, and safety criteria, and land management objectives. Decision documents (which define the objectives and document line officer approval of the strategies chosen for wildfires) should identify smoke-sensitive receptors, and include objectives and courses of action to minimize and mitigate impacts to those receptors as feasible.		X	ERTs are recommended by the ADEQ as techniques that can be effective for minimizing impacts to sensitive receptors.

Design Criteria No.	Description	Purpose		Comment or Purpose
		Forest Plan Compliance	Specialist Recommendation	
FE4	As needed, the burning of hand piles or machine piles would occur when conditions are favorable and risk of fire spread is low. Piles would be located far enough away from residual trees and shrub patches to minimize canopy scorch or damage to ponderosa pine or large oak (>6”dbh) where it is not desirable. Individual piles or groups of piles may have fireline cut around them if necessary to meet objectives.		X	Prevent undesirable impacts.
FE5	Firelines would be used to facilitate broadcast burns or pile burning operations as needed: (1) Firelines may consist of natural barriers, roads and trails, or may be constructed as needed. Line construction may consist of removing woody and/or herbaceous vegetation, removing surface fuels, pruning, or cutting breaks in fuels by hand, ATV (drag lines), or a dozer as needed, (2) Fireline width would be determined as adjacent fuels and expected fire behavior dictate, assuming compliance with the requirements of cultural, wildlife, and other resource areas, (3) Constructed firelines would be rehabilitated, which may include pulling removed material back into the lines, hand constructing water diversion channels and/or water bars, laying shrubs or woody debris in the lines following burning, or other methods appropriate to the site, and (4) Fireline construction would be coordinated with wildlife.		X	Facilitate broadcast burns or pile burning operations.
FE6	Mechanical treatments following broadcast burns would occur after surface vegetation has recovered sufficiently to minimize impacts from the mechanical treatments (generally 1 to 3 years). Prescribed fire treatments following mechanical treatments would occur after there has been adequate surface vegetation recovery that fuel loads are sufficient to meet the objectives of a prescribed burn.		X	Minimize impacts from mechanical treatments on vegetation and soil.
FE7	Prescribed fires may be conducted before or after mechanical treatments. The sequencing of prescribed fires and mechanical treatments would be decided on a site-specific basis, depending on the site, burn windows, available resources, thinning schedules, etc.		X	Increase the flexibility for implementing both prescribed fire and mechanical treatments.

Design Criteria No.	Description	Purpose		Comment or Purpose
		Forest Plan Compliance	Specialist Recommendation	
FE8	The following ADEQ emissions reduction techniques (ERTs) would be used when practicable to minimize impacts to sensitive receptors: pre-burn fuel removal, mechanical processing, increased burning frequency, aerial/ mass ignition, high moisture in large fuels, rapid mop-up, air curtain incinerators, burn before green-up, backing fire, maintain fireline intensity, underburn before litterfall, isolating fuels, concentrating fuels, mosaic/jackpot burning, moist litter and duff, burn before large activity fuels cure, and utilize piles.		X	Reduce emissions from prescribed fire.
FE9	Mitigation and design features for smoke impacts include: (1) Reducing the emissions produced for a given area treated, (2) Redistributing/diluting the emissions through meteorological scheduling and by coordinating with other burners in the airshed. Dilution involves controlling the rate of emissions or scheduling for dispersion to assure tolerable concentrations of smoke in designated areas, and (3) Avoidance uses meteorological conditions when scheduling burning in order to avoid incursions of wildland fire smoke into smoke sensitive areas. Also see FE8 for ERTs.			See FE9.
FE10	When prescribed burns are conducted in areas with, or near known populations of invasive weeds, follow-up monitoring would be conducted. Also see Botany B4.		X	Detect new weed infestations before they spread.
FE 11	See Rangeland Management: R1, R4, and R5.		X	Prevent damage or loss of infrastructure.

Design Criteria No.	Description	Purpose		Comment or Purpose
		Forest Plan Compliance	Specialist Recommendation	
FE12	When practicable, damage or mortality to old trees, large trees would be mitigated by implementing prescription parameters, ignition techniques, raking, wetting, thinning, compressing slash, or otherwise mitigating fire impacts to the degree necessary to meet burn objectives and minimize fireline intensity and heat per unit area in the vicinity of old trees. Trees identified as being of particular concern (e.g. trees with known nests or roots for herons, eagles, osprey, or other raptors, occupied nest cores, or critical areas in PACs) would be managed in accordance with wildlife design features (see wildlife). Prepare old trees 1 year or more before a burn if possible.		X	Old trees and large trees are rare components and are under-represented across the project area. Implementing mitigation measures when possible is a critical component of restoration on a landscape scale. Large trees that are not old are not as susceptible to damage from fire. Mitigation measures that can be implemented a year or more before a burn, such as thinning or raking, may improve the health of the tree, improving its response to fire.
FE13	Mitigation measures and design features for wildlife species including Mexican spotted owl, golden eagle, bald eagle, pronghorn, northern goshawk, bats, northern leopard frog, turkey, deer, and other wildlife can be found in the wildlife section.			
FE14	Aspen, Gambel oak, pine-sage: fire effects would be managed primarily by implementing prescriptions, and ignition techniques to meet objectives in pine/sage systems. In Gambel oak, avoid lighting near the bases of large oak boles.		X	To serve as a detriment to ungulates would be inclined to browse on young aspen.
FE15	Concerned/interested public will be given as much warning as possible in advance of prescribed burns via notices, press releases, email lists, public announcements, phone lists, or other notification methods as appropriate.		X	To provide advanced notice for publics concerned about potential impacts from emissions resulting from prescribed fires.

Daily Burn Accomplishment Form

Contact Number:	
Contact Name:	

Updated 10/18/05

Please submit accomplishment forms the day following ignition. Submit only one accomplishment for per burn for each ignition date.

BURN NAME:	
BURN NUMBER:	
IGNITION DATE: (MM/DD/YY)	
ACREAGE TREATED: Area for which management objective(s) were achieved.	
ACREAGE BURNED: Area blackened for broadcast burns only, not to exceed the	
ACREAGE ERT(s) USED: Area in which emission reduction techniques were used.	
BURN LOCATION: (TT/RR/SS or SS-SS)	
BURN DURATION: (Hours)	
IGNITION DURATION: (Minutes) Non-piled Activity fuels only	
DEAD FUEL MOISTURE: (%) 10 hour	
DEAD FUEL MOISTURE: (%) 1000 hour	
DUFF FUEL MOISTURE: (%) (OPTIONAL) Natural fuels only	
FUEL MOISTURE METHOD: 1) NFDRS 2) Measured 3) Both	
DAYS SINCE LAST RAINFALL: Non-piled activity fuels only.	
SNOW-OFF DATE: (MM/YY) Non-piled activity fuels only.	
PRIMARY EMISSION REDUCTION TECHNIQUE: (Select the primary ERT	

1. Pre-Burn Fuel Removal	2. Mechanical Processing	3. Ungulates	4. Burn More Frequently
5. Aerial / Mass Ignition	6. Rapid Mop-Up	7. Windrow Burning	8. Air Curtain Incinerators
9. Burn Before Green Up	10. Backing Fire	11. Maintain fire line intensity	12. Isolating Fuels

DIURNAL PLUME CHARACTERISTICS:

REMARKS:

FUEL INFORMATION (BROADCAST BURNING)

PRIMARY FUEL TYPE: 1)Ponderosa 2)Ponderosa /Grass 3)Juniper 4)Mixed Conifer 5)Grass			
PRIMARY NFDRS FUEL		**FIRE REGIME CONDITION**	
HARVEST DATE: (If Applicable)		**PRIMARY DUFF TYPE:** 1) Black (Litter Type), 2) Red (Rotten	

SOUND AND ROTTEN **(Woody Fuels Only –** Do not		***ROTTEN*** **(Woody fuels only –** Do not include	
0.0 – 0.25 IN FUELS:		**>3.0 IN FUELS:** (T/A)	
0.26 – 1.0 IN FUELS:		***OTTHER (Do not include these fuels in any other***	
1.01 – 3.0 IN FUELS:		**STUMP 20+ IN FUELS:**	
SOUND **(Wood fuels only –** Do not include piles		**SHRUB /BRUSH FUELS:**	
3.01 – 9.0 IN FUELS:		**GRASS /HERB FUELS:**	
9.01 – 20 IN FUELS:		**AVERAGE LITTER DEPTH:**	
>20.0 IN FUELS:		**AVERAGE DUFF DEPTH:**	

FUELS

NUMBER OF PILES PER ACRE: Provide the average number of piles per acre.	
TONS OF PILES PER ACRE: Provide the average fuel loading per acre	
SOIL IN PILES: (%)	

PRIMARY SPECIES: (>50%) 1) Ponderosa Pine, 2) Douglas Fir, 3) Cottonwood, 4) Aspen, 5)	
PRIMARY SPECIES: (%)	
SECONDARY SPECIES: (<50%) 1) Ponderosa Pine, 2) Douglas Fir, 3) Cottonwood, 4) Aspen, 5)	
SECONDARY SPECIES: (%)	
QUALITY: 1) Clean, 2) Dirty, 3) Real Dirty	
DIMENSIONS: (FT) Provide the average width and height of round piles, as well as the	**W H L**
PACKING RATIO: 1) Ponderosa Pine <10 IN, 2) Short needle conifer,	

Limitations to prescribed fire

Prescribed fire, is a critical component of restoration in ponderosa pine and its associated vegetation types (grasslands, oak, PJ, aspen). In order to implement fire as a restoration tool and a maintenance tool on the landscape level, it will be necessary to plan prescribed burns on a larger scale to the degree possible. Limits relating to emissions were discussed in Air Quality and Smoke Effects on page 76. Restrictions across the proposed treatment areas and adjacent areas will dictate how burn units can be organized and delineated. Across the proposed treatment area, there are specific spatial and temporal restrictions that differ by species (specifics are listed in Appendix E and in the Wildlife Specialists' Report). These limitations, when combined with others such as National Ambient Air Quality Standards, resource availability, social constraints, climate, highway safety, and thinning contract obligations, will make it a challenge for fire managers to implement the proposed acres of prescribed fire needed to meet the purpose and need and restore the spatial and temporal patterns of the fire regimes within the treatment areas.

Restrictions for prescribed include the following:

- No burning: Under Alternatives B and D there are PACs and core areas where no prescribed fire is allowed. A PAC is 600 acres, and a core area is at least 100. This means that the restricted area must be blocked out of burn units. PAC boundaries do not often follow roads, rocky ridges, or other areas that would make natural fire breaks. That means that much more than the 600 acre PAC could not be burned. The blocked out area could remove over 1,000 acres from a prescribed fire unit, depending on the setting of the PAC/core area.

- Spatial restrictions: Desired conditions within the PAC and/or Core Areas differ from the surrounding area. That requires that, as above, the area be blocked in some manner in order to produce the appropriate fire behavior within the PAC or core area. Fire behavior and effects required in these areas are usually much reduced from that in the surrounding area so that, within a burn unit blocked to include a PAC or core area, the NON-PAC and core areas would not receive the fire and behavior most beneficial to them.

- Additional spatial and timing restrictions apply for other species. Both temporal and spatial restrictions differ from species to species, with some overlap in time and space.

- Restrictions also apply outside of some designated habitat, as well as within that addresses potential smoke impacts. These are generally buffers within which fire may not be allowed in order to reduce potential smoke impacts within the designated habitat.

- There are self-imposed social limits that are fairly standard, such as not burning on homecoming weekends, not burning on the 1st day of deer hunting, etc.

- Legal limits are set by the Arizona Department of Environmental Quality to ensure compliance with the Clean Air Act.
- Burn windows must meet prescriptions.
- Social limits are imposed, generally based on emissions.
- Logistical limits are set by the capacity of firefighting resources available.

Appendix F – Smoke and emission modeling details

The most common stand conditions across the 4FRI area are VSS3 and VSS4. Forest Vegetation Model outputs from three simulations were used as inputs to model potential emissions. The First Order Fire Effects Model (FOFEM) was used to model emissions because, though it doesn't produce concentrations at sensitive receptors, the temporal and spatial scales of modeling for this stage of 4FRI suggest that trying to predict where smoke will end up and at what concentrations is premature. That modeling will be done as burn plans are written for the implementation stage of 4FRI. The objective of this modeling is to compare and contrast expected emissions outputs for different treatment options.

The three simulations included:

1. BurnGHawk_4AB: (a burn only treatment in VSS4AB stands)
2. FA_UEA_4ABSS 45 - 55: (Foraging area, uneven age management in VSS4AB single story stands)
3. FA_UEA_4ABMS 45 - 55: (Foraging area, uneven age management in VSS4AB multi story stands)

To represent burn only treatments, outputs from #1 were used. To represent mechanical and fire treatments combined, outputs from #2 and #3 were averaged, including weighting for the difference in acres (Table 136). In order to compare apples to apples, BurnGHawk_4AB existing conditions were used for all modeling change between years were determined for #'s 2 and 3 and averaged (weighted as before). These changes were then applied to the applicable treatment. This allowed the comparison of different treatments on the same stand, rather than using different stands and comparing numbers that started at different points.

Stands were modeled in FVS based on their proposed treatments, so these stands were not equivalent to begin with. The burn only stand started out with 24 percent lower fuel loading.

Table 136. Inputs used for emissions modeling

Prescribed Fire-Only							Mechanical Treatment Before Prescribed Fire					
Fuels tons/acre	**Existing Condition WildFire**	**1st burn**	**2nd burn**	**3rd burn**	**4th burn**	**Wildfire After Treatments**	**Mechanical only Wild Fire**	**1st burn**	**2nd burn**	**3rd burn**	**4th burn**	**WildFire After Treatments**
Litter	2.55	2.55	1.13	1.23	1.18	1.23	2.67	2.67	2.85	3.05	3.80	3.05
1 hour	0.23	0.23	0.09	0.08	0.09	0. 08	0.23	0.23	0.20	0.18	0.18	0.18
10 hour	1.23	1.23	0.55	0.60	0.74	0. 60	1.35	1.35	1.41	1.48	1.36	1.48
100 hour	1.53	1.53	0 92	0.96	1.11	0. 96	1.66	1.66	1.74	1.83	1.70	1.83
1000+ hour	3.36	3.36	1.79	1.92	2.19	1.92	3.58	3.58	3.06	2.62	2.83	2.62
Duff	3.30	3.30	3.32	2.84	2.44	2.84	2.66	2.66	2.28	1.96	2.26	1.96
Herb	0.22	0.22	0.22	0.22	0.23	0.22	0.23	0.23	0.23	0.23	0.23	0.23
Shrub	0.26	0.26	0.26	0.27	0.27	0.27	0.26	0.26	0.26	0.26	0.26	0.26
Foliage	12.21	12.21	10.96	10.71	10.69	10.71	11.86	11. 86	11.60	11.35	11.46	11.35
Branch	21.74	21.74	20.05	20.09	20.50	20.09	21.26	21.26	20.85	20.45	20.29	20.45
Total fuels	**33.95**	**33.95**	**31.01**	**30.80**	**31.19**	**30.80**	**45.76**	**33.13**	**33.13**	**32.45**	**31.79**	**31.79**
Moist 10 hour	3	6	6	6	6	3	3	6	6	6	6	3
Moist 1000+	12	20	20	20	20	12	12	20	20	20	20	12
Moist Duff	20	60	60	60	60	20	20	60	60	60	60	20
Log Rotten	20	20	15	10	8	15	20	20	15	10	8	10
Duff Depth	0.40	0.40	0.40	0.34	0.30	0.40	0.40	0.20	0.27	0.24	0.3	0.40
Log Loading Distribution	Center											
Crown Burn	60	19	6	10	5	30	60	6	6	13	5.00	30
Season	Summer											
Conditions	Very Dry	Dry				Very Dry	Dry					Very Dry

Appendix G – General concepts used for this analysis

Fire Effects

Fire Effects refers to the responses of an ecosystem to a fire, and are dependent upon a myriad of variables including but not limited to: soil temperature and moisture before, during, and after a fire; fire behavior; long and short term weather before and following the fire; season of burn; time since last burn; and so on. Fire effects may be beneficial, detrimental, or both. They are classified as either 'First Order Fire Effects' or 'Second Order Fire Effects', with the primary difference being the temporal immediacy to the fire. Both kinds may be long or short term. Generally, first order effects, with the exception of smoke effects, are on site. Second order fire effects may be on or off site, such as sediment deposition downslope from a high severity burn. Second order effects are generally more complex than first order effects because the longer time period allows far more variables to play a role. This makes them more difficult to predict and, therefore, more difficult to address in advance. Table 131 lists some first and second order fire effects, but is intended only to give examples so only a few are shown in each order.

Table 131. Examples of First and Second Order Fire Effects

First Order Fire Effects (direct effects)	Second Order Fire Effects (indirect effects)
• Amount of fuel consumed • Amount of bare, mineral soil exposed • Scorch and char height • Decreased surface albedo • Oxidation of some minerals in the soil • Creation of hydrophobic soil • Immediate mortality	• Erosion • Sediment deposition • Longer term mortality (ex: large and/or old trees and shrubs may take years to die, though the catalyst was a fire). • Increased surface vegetation • Increased shrub vigor

Canopy Characteristics

The structure of the canopy affects wind speed at the ground. A more open canopy (less closure, higher CBH) allows faster wind at the surface which can increase fire intensity and rate of spread. Surface fire intensity is directly related to crown fire initiation (Omi and Martinson 2002). Figure 3 shows an area of the Schultz Fire a few months after the burn. Yellow arrows show what the crown base height was before the fire. Blue arrows show what the crown base height will be after the 'red' needles fall. Flames must be at least half as tall as the crown base height to initiate crown fire.

- Affects heat dissipation. Closed canopies will trap heat beneath the canopy, increasing the potential for scorch and mortality. Open canopies allow heat to dissipate upwards with little damage to tree crowns. Other canopy measures may combine with CC to augment or minimize the effects.

- Regulates insolation by shading (or not) the surface. The amount of sunlight at the surface directly affects fuel moisture and temperature at the surface, as well as the potential for surface fuels to grow.

- Contiguous canopy cover can support active crown fire. The more open the canopy is, the less chance of active crown fire.

Figure 102. Canopy base heights before and after the Schultz Fire (2010)

In order for a crown fire to initiate, a surface fire must be intense enough to ignite branches that can propagate fire to the upper levels of the canopy. Flame lengths must be approximately ½ the canopy base height to initiate crown fire, though additional variables also come into play, such as needle moisture and wind speed (Van Wagner 1973). In order for a passive crown fire to become an active crown fire, canopy fuels must be contiguous enough and wind speed high enough for the fire to spread from one tree crown to another. Low and moderate intensity fires can effectively raise canopy base height to levels that make crown fire initiation less likely, as well as decreasing canopy bulk density, decreasing the potential for active crown fire (Figure 103).