Four Forest Restoration Initiative: Rim Country EIS

Fire Ecology & Air Quality Specialist Report

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Introduction/Project Information

The Four Forests Restoration Initiative (4FRI) Rim country EIS proposes ecosystem restoration efforts on 1,240,000 acres of land cross the ponderosa pine (*Pinus ponderosa*) forest located across the Mogollon Rim of Northern Arizona (Figure 1). Ponderosa pine and dry mixed conifer frequent-fire forest types are the target cover types for restoration within this project. Most frequent-fire forests throughout the Intermountain West have been degraded during the last 150 years. Many of these forests are now dominated by unnaturally dense thickets of small trees, and lack their once diverse understory of grasses, sedges, and forbs. Forests in this condition are highly susceptible to damaging, stand-replacing fires and increased insect and disease epidemics. Restoration of these forests centers on reintroducing frequent, predominantly low-severity surface fires—often after thinning dense stands—and reestablishing productive understory plant communities (Huffman *et al.* 2018). The purpose is to move the project area toward the desired conditions established in the land and resource management plans of the three forests found in the project area (Apache-Sitgreaves, Coconino, and Tonto National Forests).

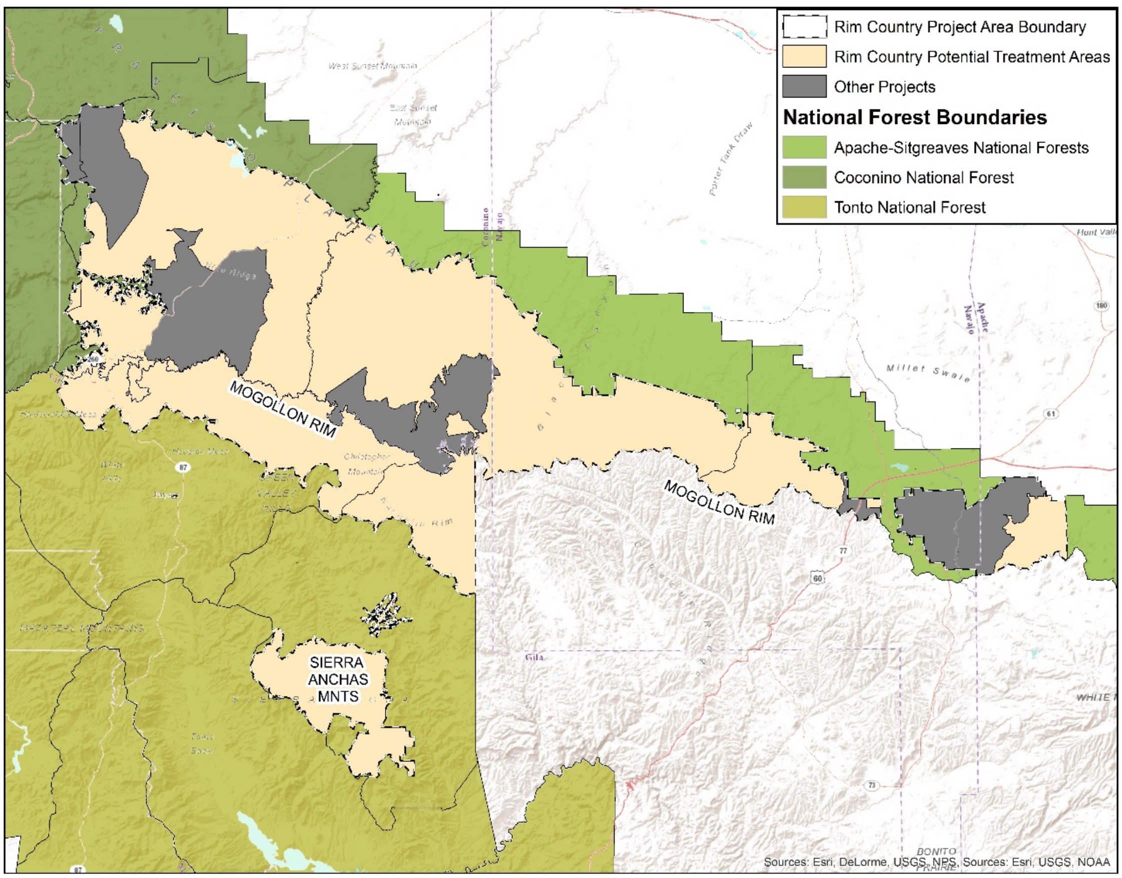

Figure 1: Project Area Location. Greyed out areas are those areas within the project area that have current NEPA projects, and are not being fully re-analyzed in this report.

One of the desired outcomes of the 4FRI restoration initiative is to reduce the risk of undesirable fire effects associated with stand replacing, high severity fire. Wildfires resulting in large-scale, high-severity fires where historically rare across the 4FRI landscape; however they are becoming more common due to uncharacteristic stand structure and prolonged drought (Covington and Moore 1994; Fulé et. al. 1997; Hessburg and Agee, 2003). These uncharacteristic wildfires pose a threat to human safety, highly valued resources and assets and ecosystem function. Increasing landscape heterogeneity decreases the likelihood of large scale high severity fires (Graham, et. al. 2004; Hessburg and Agee, 2005; Finney, McHugh and Grenfell 2005), increases opportunities for greater biodiversity (Strahan, 2015), and ultimately increases the opportunities for the necessary reintroduction of characteristic wildfire to fire prone areas (Hessburg et al. 2016; North et al. 2015b; Prichard et al. 2017; Thompson et al 2018).

In order to increase heterogeneity a broad range of prescribed fire and mechanical treatments will be needed to alter forest structure and allow for more characteristic large-scale, low-intensity fires to occur (Hessburg and Agee, 2005). Prescribed fire is effective at reducing subsequent wildfire severity and protecting adjacent areas especially on the lee side of treatments (Graham, 2003; Weatherspoon and Skinner, 1995; Finney, McHugh and Grenfell, 2005). However, prescribed fire alone is has some limitations in its ability to alter forest structure (Vaillant et. al., 2009), and may in some cases result in negative effects such as post fire mortality of old growth trees (Collins, et.al., 2014; Roccafort et al, 2015) and unpredictable fire behavior that is difficult to control (Zimmerman, 2003). Additional challenges to using fire (both wildfire and prescribed fire) on a landscape scale include narrow burn windows, smoke impacts, and 100,000s of thousands of acres of forests too overgrown to manage appropriately with fire alone. A combination of mechanical thinning and prescribed fire will help produce the desired heterogeneity; however mechanical treatment alone is not a substitute for prescribed fire. The ecological benefits of wildfire on the landscape expand well beyond reduction of wildfire severity. The nutrient cycling, vegetation regeneration and habitat formation resulting from wildfires cannot simply be replicated by mechanical treatments.

This report focuses on the effects of management actions proposed in each alternative in regards to fire behavior and fire effects. The effects of fire include smoke and emissions, which have ecological effects as well as effects on air quality.

Relevant Law, Regulation, and Policy

National Level Direction

Federal laws, regulations, and policies affecting fire and Air Quality in regards to the Rim Country analysis include:

<u>Organic Administration Act, June 4, 1897 (16 U. S.C.551):</u> This act authorizes the Secretary of Agriculture to make provisions for the protection of national forests against destruction by fire. Treatments proposed by Rim Country would support the intent of the Organic Administration Act by reducing the potential for undesirable fire behavior and effects.

<u>National Environmental Policy Act of 1970:</u> Compliance with this act requires analysis of proposed actions, including prescribed fire, so an analysis of the effects of prescribed fire as well as the resulting emissions are included as part of the documents.

<u>Clean Air Act (CAA), as amended 1977 and 1990</u>: This act provides for protection and enhancement of national air resources by regulating air emissions from stationary and mobile sources, including those from prescribed wildfire. The Act authorized the 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 six specific pollutants emitted in significant quantities throughout the country that may be a danger to public health and welfare. These pollutants were deemed 'Criteria" air pollutants, and include: Carbon Monoxide (CO), Lead (Pb) Nitrogen Dioxide (NO2), Ozone (O3), Particle Pollution 2.5 (PM2.5), Particle Pollution 10 (PM10), and Sulfur Dioxide (SO2). Areas that do not meet or "attain" the standards become non-attainment areas and must demonstrate to the public and the EPA how standards will be met 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, and other areas of special national or regional natural, recreational, scenic, or historic value. Some of these 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 Rim Country analysis is proposing prescribed fire on up to about 939,924 acres. To ensure compliance with the CAA, emissions from proposed restoration treatments were evaluated to determine the potential effects.

40 CFR 51 300-308 Federal Regional Haze Rule: Requires states to develop programs to assure reasonable progress toward meeting the national goal of preventing any future, and remedying any existing, impairment of visibility in mandatory Class I Federal areas which impairment results from manmade air pollution; and to establish necessary additional procedures for new source permit applicants.

Ominbus Public Land Management Act of 2009: Established the Collaborative Forests Landscape Restoration Projects. One of the purposes of the CFLRP is to "*facilitate the reduction of wildfire management costs, including through reestablishing natural fire regimes and reducing the risk of uncharacteristic wildfires…and demonstrate the degree to which various ecological restoration techniques affect …wildfire activity and management costs."* In addition projects should demonstrate how they "*reduce the risk of uncharacteristic wildfire, including through the use of fire for ecological restoration and maintenance and reestablishing natural fire regimes, where appropriate."*

Federal Wildland Fire Policy of 1995 (Updated in 2001): 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."
>
> It also states that wildland fire . . . "would be used to protect, maintain, and enhance resources and, as nearly as possible, be allowed to function in its natural ecological role as a disturbance factor in the ecosystem." (USDA and USDOI 2009)

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

- **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). Wildfires may be managed for suppression, resource objectives, or any combination of these, but they all are unplanned 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" includes pile burning, jackpot burning, broadcast burns or other wildland fires originating from planned ignitions to meet specific objectives identified in a written, approved, burn plan for which NEPA requirements (where applicable) have been met prior to ignition (NWCG 2009, FSM 5100).

Federal Land Assistance, Management and Enhancement (FLAME) Act of 2009

The challenge—and the potential—for wildland fire management in the 21st century is perhaps best described by the vision statement adopted by the Wildland Fire Leadership Council (WFLC):

"To safely and effectively extinguish fire, when needed; use fire where allowable; manage our natural resources; and as a Nation, live with wildland fire."

This vision frames the National Cohesive Wildland Fire Management Strategy effort (Cohesive Strategy) initiated by the Federal Land Assistance, Management and Enhancement (FLAME) Act of 2009. The Cohesive Strategy takes a holistic approach to the future of wildland fire management, and identifies three primary, national goals:

- Restore and Maintain Landscapes, making them resilient to fire-related disturbances.
- Create Fire-adapted Communities.
- Ensure safe, effective, and efficient Wildfire Response.

The Four-Forest Restoration Initiative (4FRI) is not intended to dictate any response to wildfires. However, the implementation of an action alternative would increase the decision space for Agency Administrators making decisions on how to manage wildfire, while reducing the potential for undesirable fire behavior and effects. The effects of planned ignitions (including pile burning, jackpot burning, and broadcast burning) are discussed. This document provides direction, consistent with the forest plans of the Apache-Sitgreaves, Coconino and Tonto National Forests regarding the use of planned ignitions in the areas proposed for treatment.

This report discusses potential effects of unplanned ignitions, but is not intended to provide any direction regarding the management of unplanned ignitions. This document is intended to provide direction, consistent with the forest plans of both the Apache-Sitgraves, Coconino and Tonto regarding the use of planned ignitions (prescribed fire) 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, funded by federal agencies in Arizona, and housed at ADEQ in the Air Quality Division. Planned ignitions implemented as treatments under the Rim Country would 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 (Achtemeier *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.* 2001)." Prescribed fire treatments proposed though the action alternatives are likely to increase Nuisance Smoke.

Arizona Revised Statute Title 18 Chapter 2 Article 15. Forest and Range Management Burns, regulates smoke emissions prescribed burning and to a lesser extent unplanned fires managed for resource benefit in the state of Arizona. This rule was update on March 15, 2004, and incorporates the necessary elements outlined in the Regional Haze Rule section 309 on for prescribed burning.

Agency Level Direction (USDA Forest Service)

USDA Forest Service Strategic Plan: FY 2015 – 2020. Direction in this document specifies the need to restore fire adapted ecosystems, while working with a range of partners. The priority stated is to *"reduce the risk from wildfire to communities and natural resources...working closely with landowners and other partners we will restore the natural role of fire while helping at-risk communities adapt to wildfire hazards."* Specifically, forest restoration is listed as a desirable means and strategy to decrease threats from wildfire, along with a goal of restoring degraded and at-risk watersheds.

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.

Land and Resource Management Plan Direction

Forest Plans provide specific goals, objectives, standards, and guidelines for management activities on National Forest lands. The Apache/Sitgreaves (USDA 2015), Coconino (USDA 2018) and Tonto National Forest (USDA 1985 (2011)) have developed forest-wide and location-specific standards and guidelines for reducing the risk of undesirable fire behavior and effects.

Forest plan direction addressing fire behavior, fire effect, air quality, and smoke ecology have been incorporated into this analysis as appropriate. General direction from each forests' Land Management Plan. Specific and specific relevant guidelines from the National Forest Land Management Plans is discussed below.

Apache-Sitgreaves National Forest (ASN)

The ASN Forest plan has a specific focus on the role of healthy ecosystems and on ecosystem diversity, particularly the distribution, complexity, and natural disturbance regimes (including fire) of watershed and landscape scale features, affecting terrestrial, aquatic, and riparian ecosystems. The ASN Forest Plan recognizes that ecological desired conditions may only be achievable over a long timeframe (several hundred years). A recurring theme through all management direction is for management actions reduce the negative effects of uncharacteristic fire effects and to restore wildfire to a more natural function.

Overall Ecosystem Health

Desired Conditions

Ecological components (e.g., soil, vegetation, water) are resilient to disturbances including human activities and natural ecological disturbances (e.g., fire, drought, wind, insects, disease, and pathogens).

Natural ecological disturbances return to their characteristic roles within the ecosystem. Wildfire, in particular, is restored to a more natural function

All Potential Natural Vegetation Types

Desired Conditions on a landscape scale (>1,000 acres) and at the mid-scale (100 – 1,000 acres), Guidelines, and Objectives:

Vegetative conditions are expected to be resilient to natural disturbances that are a part of the ecology of the area, including variations in climate. Specific to this report, "Natural fire regimes are restored and uncharacteristic fire behavior is minimal or absent on the landscape. Fire maintains and enhances resources and, as nearly as possible, is allowed to function in its natural ecological role."

Management Approach

Vegetation treatments are concentrated in priority 6th level HUC watersheds and areas identified in community wildfire protection plans, including regular treatments to maintain desired conditions in the Community-Forest Intermix Management Area terrestrial ecosystem survey.

Community-Forest Intermix Background for Community-Forest Intermix

The Community-Forest Intermix Management Area consists of National Forest System (NFS) lands that are within one-half mile of communities-at-risk. Due to the threat of fire moving into or from developed areas, more intensive treatments (including regular maintenance) may be needed to reduce the risk of uncharacteristic wildfire and restore fire-adapted ecosystems. This management area may act as a zone in which fire suppression activities can be safely and effectively conducted. Likewise, it can act as a buffer to protect forest resources. The Community-Forest Intermix Management Area makes up a portion of the wildland-urban interface (WUI). The WUIs were identified in community wildfire protection plans (CWPPs) and may be located in several management areas. A WUI includes areas around human development at imminent risk from wildfire. Chapter 3. Management Area Direction Apache-Sitgreaves National Forests Land Management Plan 113

Desired Conditions for Community-Forest Intermix

• The Community-Forest Intermix Management Area is composed of smaller groups of trees that are more widely spaced than other forested areas. These conditions result in fires that burn primarily on the forest floor and rarely spread as crown fire.

As a result of forest management, most wildfires are low to mixed severity surface fires resulting in limited loss of structures or ecosystem function.

• These areas provide a safer firefighting environment than the general forest.

• Native grasses, forbs, shrubs, and litter (i.e., fine fuels) are abundant enough to maintain and support natural fire regimes, protect soils, and support water infiltration.

• The composition, density, structure, and mosaic of vegetative conditions reduce uncharacteristic wildfire hazard to local communities and forest ecosystems.

• Ponderosa pine and dry mixed conifer forest structure is similar to forest-wide conditions or is composed of smaller and more widely spaced tree groups than in the general forest.

• Wet mixed conifer and spruce-fir forests are growing in an overall more open condition than the wet mixed conifer forest outside of the Community-Forest Intermix Management Area. These conditions result in fires that burn primarily on the forest floor and rarely spread as crown fire.

• Where potential occurs, pure deciduous stands (e.g., aspen, Gambel oak) act as natural firebreaks and enhance scenery.

• Grasslands have less than 10 percent woody canopy cover.

• Piñon-juniper stands have open canopy conditions.

• The integrity of riparian areas is maintained.

Management Approaches

Treatments may occur more often than in other management areas. Both mechanized methods and prescribed fire may be used regularly. A higher degree of temporary ground disturbance may occur. The amount of snags and residual large coarse woody debris is generally lower than in the General Forest Management Area. In addition, forest openings are larger and basal areas are lower than in the General Forest Management Area. The management approach within this management area is to complete initial treatments to reduce fire hazard. Once initial treatments are complete, the focus is to maintain the investment and desired conditions primarily through prescribed fire and mechanical treatments. Other objectives may also be considered. Best available control technologies are used to limit smoke impacts from forest management activities. Forest managers coordinate with adjacent land management agencies and tribes to help reduce the impacts of prescribed fire programs on nearby communities. The forests work closely with adjacent landowners and communities, particularly their planning and zoning departments, to encourage new and existing developments to take into account measures to protect people, property, and natural resources from wildfire.

Fire Management

The Apache-Sitgreaves NFs' FMP provides for firefighter and public safety first; includes fire management strategies, tactics, and alternatives; and addresses values to be protected and public health issues. The FMP helps guide fire managers in wildland fire decisionmaking. When appropriate weather and fuel moisture conditions exist, use of wildland fire is a costeffective way to reduce the likelihood of uncharacteristic fire. The risk of uncharacteristic fire can be reduced when fires occur within historic fire regimes. To achieve ecosystems that are resilient to fire disturbance, vegetation structure needs to be more consistent with desired conditions. In addition to fire treatments, activities such as thinning and tree harvesting are needed to reduce tree density and canopy cover and support the natural fire regime. Strategic placement and design of these treatments is key to minimizing the impact from fire on values to be protected more efficiently because these activities are costly and there is limited capacity to implement them.

Desired Conditions

- Human life, property, and natural and cultural resource are protected within and adjacent to NFS lands.

- Wildland fires burn within the range of frequency and intensity of natural fire regimes. Uncharacteristic high severity fires rarely occur and do not burn at the landscape scale.

- Wildland fire maintains and enhances resources and functions in its natural ecological role.

- For all PNVTs, the composition, cover, structure, and mosaic of vegetative conditions reduce uncharacteristic wildfire hazard to local communities and forest ecosystems.

Management Approaches

To meet the plan's treatment objectives using prescribed fires, site-specific burn plans are developed which guide implementation. All prescribed fires are conducted in accordance with the Arizona Smoke Management Plan, administered by ADEQ, to comply with the Clean Air Act. Wildland fire is one tool in the process of restoring the forests' fire-adapted ecosystems; in areas departed from desired conditions, the use of fire is often most effective when combined with mechanical treatments that further restore forest structure34. Mechanical treatments are costly, so the capacity to implement such treatments across the landscape is limited. Strategic placement and design of mechanical treatments increases their effectiveness in protecting values to be protected. Wildland fire may be the only viable tool in areas such as steep rugged terrain or remote areas where mechanical treatments are not feasible. Objectives in these areas may include higher fire intensities and higher levels of mortality to achieve vegetation structural changes that would not occur through other means to move toward desired conditions. Fuels specialists and silviculturists, along with other resource specialists, work to ensure land management objectives are met. Joint silviculture prescriptions and burn plans may be produced.

Air Quality

Temporary decreases in air quality from management activities on the Apache-Sitgreaves NFs are primarily from prescribed fire. Wildfires also produce emissions and are subject to conformance with State regulations (see appendix D). The NAAQS pollutant of concern from wildland fire is fine particulate matter, both PM10 and PM2.5. Studies indicate that 90 percent of smoke particles emitted from wildland fires are PM10, and about 90 percent of PM10 is PM2.5. Because of its small size, PM2.5 has an especially long residence time in the atmosphere and penetrates deeply into the lungs.

Desired Conditions

Landscape Scale Desired Conditions (10,000 acres or greater)

•Air quality related values, including high quality visual conditions, are maintained within the Class I airshed over Mount Baldy Wilderness.

• Class II airsheds meet State of Arizona air quality standards including those for visibility and public health.

Guidelines

• During extended periods of burning, smoke should be monitored, in cooperation with the Arizona Department of Environmental Quality, for levels that may have impacts to human health from fine particulates

Management Approaches

• The Apache-Sitgreaves NFs participate with the State of Arizona in the air quality regulatory process. Specialists review air permit applications for new and modified industrial facilities to ensure that their air emissions do not adversely impact the air quality related values (e.g., visibility) of federally protected Class I wilderness areas. Forest managers consider impacts to Chapter 2. Forest wide Direction 20 Apache-Sitgreaves National Forests Land Management Plan Class I and II areas and follow State of Arizona permit and regulatory requirements for smoke production to help determine the management response for wildfires. Site-specific mitigation for fugitive dust is incorporated into ground-disturbing projects through implementation of best management practices (BMPs) and retention and replacement of ground cover.

Coconino National Forest (COF)

This plan does not include site-specific project and activity decisions, but provides guidance and direction for projects, including the Rim Country analysis. The COF forest plan is a framework for sustaining native ecological systems and guides management toward appropriate conditions that support native plant and animal diversity. The plan integrates forest restoration; watershed protection; resilience to changing climate; wildlife conservation; and social and economic values, goods, and services. The plan honors the continuing validity of private, statutory, or pre-existing rights.

All Ecosystems

Desired Conditions

As with most revised forest plans in Region 3, this LRMP provides direction to restore and/or maintain the natural fire regimes across the forest whenever practicable and appropriate.

It is important to recognize that the goal is that most acres would be managed towards the median of the range, but representation across the range is equally desired. However, it may be appropriate to have different desired conditions within a vegetation type, such as a lower density of vegetation in the WUI than outside of the WUI to achieve the desired fire behavior near property and human occupancy.

Management Approaches

Fire is essential for ecosystem function and for maintaining or moving toward desired conditions in ecosystems where fire is the primary natural disturbance. Primary natural disturbances in Desert Communities, Alpine Tundra, and riparian areas do not include fire, but rather include flooding, precipitation, temperature, wind, avalanches, and ultraviolet radiation. When used as a tool, fire can effectively restore forest structure when used alone or when combined with mechanical treatments. Mechanical treatments may be costly, so the capacity to implement such treatments across the landscape may be limited. Strategic placement and design of mechanical treatments increases their effectiveness in protecting values at risk.

In areas of high vulnerability to climate change, consider the following approaches to facilitate natural adaptation to changing conditions. Because many early-mid species or species characteristic of lower life zones are adapted for warmer and drier conditions, emphasize early-mid seral species or species from lower life zones over late-seral species and species of higher life zones. Consider managing tree basal area at the low end of the range of desired conditions to mitigate water stress.

Foster partnerships with the Rocky Mountain Research Station and other science organizations to identify and develop concepts, tools, and research opportunities applicable to ecosystem restoration and vegetation management on the Coconino NF.

Work with volunteer groups on projects that improve vegetation and ecosystem function.

Consider inclusions, landscape variability, and transition zones during project planning to support biodiversity at the fine and mid scales. Inclusions and variability could include individual species, such as alligator juniper or blue spruce, or microclimates, such as cool, moist sites in a more arid environment, or warm, dry sites surrounded by more arid conditions.

Wildland Urban Interface

In an effort to identify and protect community infrastructure, the Healthy Forest Restoration Act (2003) called for preparation of community wildfire protection plans to define the wildland-urban interface and establish priorities for wildfire preparedness and hazardous fuels reduction work in these areas. Currently, the Coconino NF has two community wildfire protection plans that cover over 1,494,900 acres on Federal, State, county, and private lands. Of this, approximately 1,304,152 acres are on NFS lands. These two community wildfire protection plans are for Flagstaff and surrounding communities (GFFP and PFAC 2005) and Blue Ridge Area and Mogollon Ranger District of the Coconino NF (Gatewood and Hampton 2009).

There are additional areas on the forest that meet the Forest Service Manual (Southwestern Region supplement) definition of wildland-urban interface (Region 3 supplement 5140). For the plan revision, wildland-urban interface is defined as follows:

> Wildland-urban interface (WUI) includes those areas of resident populations at imminent risk from wildfire, and human developments having special significance. These areas may include critical communication sites, municipal watersheds, high voltage transmission lines, church camps, scout camps, research facilities, and other structures that, if destroyed by fire, would result in hardship to communities. These areas encompass not only the sites themselves, but also the continuous slopes and fuels that lead directly to the sites, regardless of the distance involved. (FSM 5140.5)

During the last 10 years on the Coconino NF, the overall threats to community have decreased with notable increases and decreases in localized areas. Areas that have experienced effective treatments (they have greatly reduced departure and increased fire resilience) in intensive wildland-urban interface tend to have relatively low threat levels. Examples of this include areas adjacent to Flagstaff and Mountainaire. However, areas that have not had effective treatments remain at relatively high threat levels. Of particular concern are those areas that (1) have not received treatment and (2) are on the intensive end of the wildland-urban interface spectrum.

Desired Conditions

FW-WUI-DC

1 Firefighters are able to safely and efficiently suppress wildfires in the WUI.

2 Human life and property are protected. There is reduced fire hazard, intensity, and severity to human health, safety, infrastructure, communication sites, water supply, astronomical sites, and characteristic ecosystem function.

3 In forested ecosystems, WUI conditions result in fires that burn primarily on the forest floor and rarely spread as crown fire. Ladder fuels are nearly absent and crown base heights may also be higher than non-WUI areas to reduce the likelihood of fire reaching the tree canopy.

4 The WUI may have a higher frequency of disturbance from prescribed burning, wildfires managed for resource objectives, and/or vegetative treatments than the natural disturbance regime.

5 Conditions in the WUI, such as live and dead fuel loading, tree basal area, logs, and snags, are on the lower end of the range given in vegetation community desired conditions.

6 In forested vegetation communities, the area occupied by interspace with grass/forb/shrub vegetation is on the upper end of, or above, the range given in the vegetation community desired conditions. Trees within groups may be more widely spaced with less interlocking of the crowns than desirable in adjacent forest lands. Interspaces between tree groups are of sufficient size to discourage isolated group torching from spreading as a crown fire to other groups.

7 Forests in the WUI are dominated by early seral, fire-adapted species growing in a more open condition than the general forest.

8 When WUI intersects ERUs with a mixed- or high-severity fire regime, such as Interior Chaparral, Pinyon Juniper Evergreen Shrub, Pinyon Juniper Woodland, Mixed Conifer with Infrequent Fire, Spruce-Fir, and some portions of Mixed Conifer with Frequent Fire, characteristic ecosystem function is modified to promote low-severity surface fires.

9 Dead and down fuel load is between 1 and 10 tons per acre, depending on ERU, with lower amounts in frequent fire ERUs, and higher amounts in infrequent fire ERUs such as Mixed Conifer with Infrequent Fire, Spruce-Fir, and portions of Mixed Conifer with Frequent Fire. This light fuel load provides improved fire protection to the WUI, yet still meets desired conditions. This light fuel load applies even in ERUs with higher reference fuel loads, such as Mixed Conifer with Infrequent Fire or Spruce-Fir.

10 Fuel loading or tree densities at the higher end of the range may occur in areas where it provides for important fine-scale habitat structure or cover, as long as it meets the overall intent of protecting WUI values at risk.

Guidelines for Wildland-urban Interface

FW-WUI-G

1 While still remaining within the range of desired conditions, forest structure in the WUI should have lower tree density and lower levels of snags, logs, and coarse woody debris than non-WUI areas and be arranged spatially to reduce fire hazard and to increase suppression success.

Fire Management

General Description and Background for Fire Management

Wildland fire is any non-structure fire that occurs in vegetation or natural fuels. Wildland fire includes prescribed fires (planned ignitions) and wildfires. Wildfires include either unplanned human-caused fires or naturally caused fires. Wildfires may be concurrently managed for one or more objectives. Objectives are developed based on fuel conditions, current and expected weather, current and expected fire behavior, topography, resource availability, and values at risk. Objectives are also influenced by social understanding and tolerance, and adjoining governmental jurisdictions.

Objectives can change as the fire spreads across the landscape. Parts of a fire may be managed to meet protection objectives, while other parts are managed to maintain or enhance resources (wildfires managed for resource objectives). Site-specific analysis is conducted for prescribed fires and for any wildfire that extends beyond initial attack. For prescribed burns, the decision document is the signed National Environmental Policy Act (NEPA) decision. For wildfires, an analysis is performed using a tool like the Wildland Fire Decision Support System, and signed by the appropriate line officer.

Most of the vegetation on the Forest is adapted to recurrent wildland fires started by lightning from spring and summer thunderstorms. Fire plays a vital role in maintaining ecosystem health. Properly managed prescribed fire and wildfire are tools for maintaining and/or restoring vegetative composition, structure, and function where fire is a primary natural disturbance.

Desired Conditions

FW-Fire-DC

1 Public and firefighter safety is the highest priority in managing fire.

2 Wildland fires burn within the historic fire regime of the vegetation communities affected. High-severity fires occur where this is part of the historical fire regime and do not burn at the landscape scale.

3 Wildland fires do not result in the loss of life, property, or ecosystem function.

4 People understand that wildland fire is a necessary natural disturbance process integral to the sustainability of the ecosystems in which fire is the primary disturbance.

Guidelines

FW-Fire-G

1 WUI areas should be a high priority for fuels reduction and maintenance to reduce the fire hazard.

2 Fire management activities should be designed to be consistent with maintaining or moving toward desired conditions for other resources.

Management Approaches

Manage wildland fires forest wide for multiple resource management objectives[8] where conditions permit.

Integrate fire with other management tools to treat and restore vegetative composition, structure, and function in ecosystems where fire is a primary natural disturbance.

In all ROS classes and in wilderness, prescribed fire and wildfires managed for resource objectives can be appropriate tools to treat and restore vegetative composition, structure, and function where fire is a primary natural disturbance.

Coordinate with other jurisdictions such as communities, service providers (infrastructure), and Federal, State, county, and local entities regarding prevention, preparedness, planned activities, and responses to wildland fires. Notify the above regarding the upcoming and ongoing fire season and any prescribed fire activity.

Coordinate access for initial attack and suppression activities with responsible jurisdictions to reduce response times and address public and firefighter safety.

Encourage the development and implementation of community wildfire protection plans to promote public safety and to reduce the risk of wildfire on lands of other ownership.

Coordinate with stakeholders to increase public understanding of the necessity of wildland fire as a process integral to the sustainability of the vegetation communities in which fire is a primary natural disturbance.

Air Quality

Desired Conditions and Guidelines

Air quality will meet State and Federal air quality standards, including Class I airsheds, and fire management documents will identify smoke sensitive areas and Class I airsheds, and use best management practices (BMPs), design features, and mitigations to address concerns and issues. Night skies are clear and dark, providing for stargazing and professional astronomy.

Management Approaches

To promote public awareness and protection of human health and safety, notify stakeholders and the public in advance of potential air quality impacts through advanced notification using media as well as smoke warning signs along roads when visibility may be impacted. Coordinate with ADEQ during prescribed burns to comply with State and Federal regulatory requirements for impacts to Class I areas, and to ensure ADEQ is aware of potential smoke impacts to receptors.

Tonto National Forest (TNF)

The TNF Forest Plan was written in 1985, and was most recently amended in 2011. Forest Plan revision is underway, but is unlikely to be completed before the Rim Country analysis has been completed. For that reason, three non-significant forest plan amendments would be required on the Tonto NF to implement the management actions that would meet Rim Country goals and objectives. These amendments are described on page XX in the section on Effects common to all action alternatives.

Forest Plan Direction

Forest-wide

Standards and Guidelines

Within the forest-wide intent of improving ecosystem conditions while integrating as much as possible with concerns about hazardous fuel loading, there are few specifics on the type of mechanical activity that is allowed, and it can be combined with prescribed fire in all areas within the Rim Country analysis.

Fire Standards

The long term goal of fire management is to re-introduce fire back into fire dependent ecosystems, and allow it to resume its natural role. Fire will be recognized as a resource management tool and will be included within a management prescription where it can effectively accomplish resource management objectives. The priorities for managing wildland fire will be the protection of public and firefighter safety, property, natural and cultural resources to minimize negative impacts (p. 28 of 329, pdf numbering).

Fire management, including suppression activities, will be commensurate with resource values and objectives. The criteria for determining and managing Wildland and Prescribed Fires must meet agency direction.

In areas where it is not possible to allow fire to fully resume its natural role within an ecosystem, Prescribed Fire will be applied to meet management objectives (p. 38 of 329, pdf numbering). Wildland Fires in the Interface pose an immediate threat to life, property, and adjacent resources. Actively participate with all interested and potentially affected parties to develop strategic Interface management measures to reduce Wildland Fire threats to life, property and resources, address issues of Forest health, and provide for community partnerships including treatments of vegetation and fuels, and access needs. Wildland Fires threatening the Wildland/Urban Interface will have high suppression priority (p. 28 of 329, pdf numbering).

Mexican Spotted Owl Protected Activity Centers, and Steep Slopes in mixed conifer and pine-oak forests outside PACs with slopes greater than 40% that have not been logged within the past 20 years

Standards and guidelines

Use low severity prescribed fire in PACs as determined to be beneficial.

The current forest plan prohibits prescribed fire in the nest core, necessitating forest plan amendments to allow treatments to be proposed that would meet the intent of Rim Country as well as the MSO recovery plan (see page XX for details on forest plan amendments).

Mixed conifer and pine-oak forests MSO habitat

Standards and Guidelines

Encourage prescribed and prescribed natural fire to reduce hazardous fuel accumulation. Thinning is allowed as needed within diameter restrictions specified.

Other Forest and Woodland Types (MSO habitat)

Guidelines

Apply ecosystem approaches to manage for landscape diversity mimicking natural disturbance patterns, incorporating natural variation in stand conditions and retaining special features such as snags and large trees, utilizing appropriate fires, and retention of existing old growth in accordance with forest plan old growth standards and guidelines.

Goshawk habitat

Standards and Guidelines

Low severity prescribed fire is allowed, but no crown fire is allowed in PFAs or nest areas. Managing smoke and fire to minimize detrimental effects to the birds and their habitats is the basis for this standard/guideline.

Ponderosa Pine/bunchgrass Ponderosa Pine/Gamble Oak and Ponderosa Pine/Evergreen

Oak

Wildland Fire will be managed consistent with resource objectives. Wildland Fire not meeting management objectives will receive an appropriate suppression response. Fire management objectives for this area include: providing a mosaic of age classes within the total type which will provide for a mix of successional stages, and to allow fire to resume its natural ecological role within ecosystems. Wildland Fires or portions of fires will be suppressed when they adversely affect forest resources, endanger public safety, or have a potential to damage significant capital investments.

Old Growth

In allocating old growth and making decisions about old growth management, use appropriate information about the relative risks to sustaining old growth function at the appropriate scales, due to natural and human-caused events.

All riparian areas

Standards and Guidelines

Prescribed fire may only be used to achieve the objectives of allowing fires to play their natural ecological roles and to reduce unnatural fuel hazards.

Use prescribed fire to treat vegetation for water yield, forage, and wildlife habitat improvement.

Chaparral

Standards and Guidelines

Manage the chaparral type on a 30 year prescribed fire rotation on those sites managed for forage production and water yield and as needed to enhance natural regeneration. Fire may also be used to reduce fire hazard. Activity fuels and natural fuels will be reduced to manageable levels. Fuels management may include fuelwood harvest, chipping, piling, and/or prescribed broadcast burning.

Use prescribed fire for seedbed preparation to enhance natural regeneration and control of competing species such as juniper.

Issues/Indicators/Analysis Topics

The objective of the Four-Forest Restoration Initiative is to restore healthy ecological processes by manipulating the pattern, structure, and composition of ecosystem elements to improve ecological functions across the project area. Fire is a keystone process in healthy ponderosa pine ecosystems as well as grasslands, aspen, and other ecosystems within the analysis area. 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 project area towards the desired condition of having resilient forests and grasslands by reducing the potential for undesirable fire behavior and effects?

This addresses Issues 1: treatment effects in Mexican Spotted owl Protected Activity Centers and Issue 2: treatments in Goshawk habitat. Metrics used to evaluate differences between alternatives include:

Type of fire (surface or crown). Acres and percent area (quantitative measure) of each potential fire type following proposed treatments (details on pg. 30).

Fire Hazard Index is an indicator of the potential for negative fire effects and behavior, including fire intensity (suppression difficulty), fire severity (effects to vegetation), burn severity (soil effects), and second order fire effects (such as erosion). Details are on page 31.

Surface fuel loading (quantitative measure) for this analysis, includes all woody debris (>3” diameter = Coarse; <3” diameter = Fine), combined with litter and duff. These data were used to qualitatively evaluate potential fire effects (details on pg 32).

Question 2 (addresses Issue 5: Air Quality): What are the expected effects of smoke/emissions from prescribed fire? Metrics used to evaluate differences between alternatives include:

Surface fuel loading for this analysis, includes Coarse (>3” diameter) and Fine Woody (<3” diameter), litter and duff (quantitative measure). These data were used to qualitatively evaluate potential fire effects. The types of fuel (grass, pine needles, wood, etc.) affects the amount and kinds of emissions produced when they burn (Lutes *et al.* 2009). A minimum amount of litter and FWD is necessary for a fire to move across the surface, so changes in those fuel components were modeled, and mapped for a qualitative assessment.

Smoke/emissions (quantitative measure) were evaluated quantitatively by modeled emission quantities in pounds/acre for the most common stand condition under different treatment scenarios for prescribed fire. Emissions from wildfire were modeled and evaluated for all alternatives.

Assumptions and Methodology

In the analysis of this resource the following assumptions were made:

All mechanical treatments were modeled to have occurred in 2019, and all areas proposed for burning were modeled to have burned in 2024 and again in 2034. In reality, treatments would be spread out over the years of implementation, however, the modeled treatment times allow for a direct comparison of alternatives following full implementation of proposed management for each alternative. The specific timing of mechanical treatments would depend on the contract/contractor, road conditions, and numerous factors that are impossible to predict years in advance. Prescribed fire implementation depends on weather conditions, fuel conditions, other fires in the area, available resources, and multiple other variables that are impossible to predict weeks in advance. During the implementation period, untreated areas would be vulnerable to the effects as described in the Existing Condition and/or the Alternative 1 (no action), depending on the applicable time period. Modeling results presented do not include partial treatment, such as would be the case partway through implementation. Details on the treatments modeled can be found in the Silvicultural report (Moore 2019, this DEIS).

The prioritization of treatment areas will be a part of the implementation of Rim Country, though broad recommended methodology is presented here. Results were analyzed to compare the effectiveness of each action Alternative Against the “No-Action” Alternative (Alternative 1). Concepts that are necessary for a thorough understanding of this analysis are discussed when they are first presented. Additional information on modeling and concepts may be found in Appendix B and Appendix E respectively.

The discussion of effects assumes that all BMPs, design features, and mitigations described in Appendix C (page 188) are applied during implementation. Effects discussions are based on modeled fire behavior, modeled emissions, and proposed treatments for which the methods and assumptions are detailed in this section and in Appendices B and H and in the Silviculture Specialists' Report (Moore, this report).

Scales of analysis

The alternatives in this analysis are evaluated at multiple scales to ensure the expected effects are being considered in the appropriate context.

1. In order of decreasing size, with the largest first:

    a. **Rim Country Project Area:** This includes the entire area analyzed for treatment, including comprehensive restoration, at 1,240,000 acres. It includes large areas on which the Rim Country analysis is not recommending treatments. (Figure 1)

    b. **Hydrologic Unit Code (HUC):** Proposed treatments will be analyzed and evaluated at the 6th level HUC. In order to be included in this report, at least 30% of the watershed had to be within the Rim Country Project Area, resulting in 80 watersheds being analyzed. The watersheds range in size from 7,176 acres to 39,135 acres, with a mean size of 18,465 acres. (Figure 2, Table 1)

Table 1: HUC 6 watersheds with at least 30% of the watershed within the Rim Country Project Area

MAP LABEL	HUC ID	Watershed Name	Total Acres	Acres in RIM PA	Acres w/ RIM Treatments	% in RIM	% HUC being treated (PA)
1	150200050202	Upper Brown Creek	11,074	10,590	7,151	96%	65%
2	150200050205	Upper Rocky Arroyo	16,224	11,775	1,194	73%	7%
3	150200050308	Mortensen Wash	19,406	19,340	17,620	100%	91%
4	150200080304	Barbershop Canyon	13,408	13,408	13,320	100%	99%
5	150200080307	Leonard Canyon	29,521	29,533	28,372	100%	96%
6	150601030305	Gentry Canyon	7,820	5,267	4,948	67%	63%
7	150601030801	Reynolds Creek	10,046	8,424	8,247	84%	82%
8	150602020603	Double Cabin Park-Jacks Canyon	21,654	18,842	4,866	87%	22%
9	150602030202	East Verde River Headwaters	18,809	18,787	18,145	100%	96%
10	150602030203	Webber Creek	22,480	17,738	16,716	79%	74%
11	150200020403	Sepulveda Creek	11,404	5,118	4,971	45%	44%
12	150200080308	Cabin Draw	14,256	14,216	14,170	100%	99%
13	150200100104	Upper Chevelon Canyon-Chevelon Canyon Lake	17,063	17,073	15,331	100%	90%
14	150200100203	Bear Canyon-Black Canyon	16,896	15,689	15,568	93%	92%
15	150601030301	Bull Flat Canyon	14,357	4,988	4,987	35%	35%
16	150602020610	Red Tank Draw	36,113	11,634	2,301	32%	6%
17	150602030101	Upper Willow Valley	22,824	22,828	22,511	100%	99%
18	150602030106	Home Tank Draw	22,880	14,921	13,504	65%	59%
19	150602030206	Pine Creek	30,691	17,254	14,303	56%	47%
20	150200050106	Linden Draw	12,242	6,202	4,866	51%	40%
21	150200050302	W Fork Cottonwood Wash-Cottonwood Wash	18,780	18,584	18,013	99%	96%
22	150200050303	Upper Day Wash	12,169	11,513	10,741	95%	88%
23	150200080306	Upper Willow Creek	18,582	18,586	14,546	100%	78%
24	150200100105	Middle Wildcat Canyon	10,350	9,795	9,795	95%	95%
25	150200100109	Lower Wildcat Canyon	10,911	4,088	4,088	37%	37%
26	150200100301	Upper Potato Wash	12,956	10,781	10,775	83%	83%
27	150601050203	Christopher Creek	18,805	18,815	15,478	100%	82%
28	150602030105	Lower Willow Valley	30,865	30,044	25,518	97%	83%
29	150602030107	Upper West Clear Creek	14,446	11,030	10,723	76%	74%

30	150602030306	Hardscrabble Creek	25,220	11,534	9,754	46%	39%
31	150200050101	Billy Creek	17,813	8,838	437	50%	2%
32	150200050309	Dodson Wash	21,403	9,289	7,554	43%	35%
33	150200100102	Long Tom Canyon-Chevelon Canyon	21,223	21,232	9,782	100%	46%
34	150200100107	Upper West Chevelon Canyon	16,731	16,729	16,043	100%	96%
35	150601030401	Parallel Canyon-Cherry Creek	14,640	13,831	13,831	94%	94%
36	150601050102	Rock Creek	16,312	7,531	7,331	46%	45%
37	150602030104	Clover Creek	9,924	8,927	3,158	90%	32%
38	150602030201	Ellison Creek	27,120	26,940	23,657	99%	87%
39	150200050103	Fools Hollow	7,176	3,662	294	51%	4%
40	150200080301	Miller Canyon	10,668	10,669	381	100%	4%
41	150200080303	East Clear Creek-Blue Ridge Reservoir	20,223	20,229	921	100%	5%
42	150200080309	Wilkins Canyon	13,406	13,415	13,324	100%	99%
43	150200080310	Lower Willow Creek	12,373	12,231	11,759	99%	95%
44	150200100204	Upper Pierce Wash	16,396	9,918	9,917	60%	60%
45	150200100205	Upper Brookbank Canyon	16,574	16,567	16,303	100%	98%
46	150601030404	Gruwell Canyon-Cherry Creek	23,994	8,461	8,455	35%	35%
47	150601030802	Workman Creek	12,877	7,517	7,339	58%	57%
48	150601050101	Buzzard Roost Canyon	14,016	13,938	13,882	99%	99%
49	150601050202	Gordon Canyon	17,973	17,718	14,813	99%	82%
50	150602030305	Upper Fossil Creek	25,829	12,382	11,993	48%	46%
51	150200080501	Windmill Draw-Jacks Canyon	27,293	27,301	21,239	100%	78%
52	150200080505	Hart Tank	21,638	8,278	5,856	38%	27%
53	150200050201	Ortega Draw	10,483	7,034	1,650	67%	16%
54	150200100103	Upper Wildcat Canyon	25,458	25,469	9,961	100%	39%
55	150200100106	Alder Canyon	15,598	15,609	15,304	100%	98%
56	150200100110	Durfee Draw-Chevelon Canyon	22,764	13,858	13,858	61%	61%
57	150200100202	Buckskin Wash	18,604	17,177	17,115	92%	92%
58	150601030803	Upper Salome Creek	19,063	17,112	17,051	90%	89%
59	150601050103	Upper Spring Creek	21,263	10,028	10,026	47%	47%
60	150601050204	Horton Creek-Tonto Creek	17,254	17,261	16,246	100%	94%
61	150602020604	Brady Canyon	17,922	16,043	2,583	90%	14%
62	150200080502	Tremaine Lake	30,804	25,268	24,965	82%	81%
63	150200080503	Dogie Tank-Jacks Canyon	22,084	21,859	20,078	99%	91%
64	150200050107	Bagnal Draw-Show Low Creek	17,704	7,573	6,692	43%	38%
65	150200050301	Stinson Wash	8,013	8,013	7,055	100%	88%
66	150200080102	Upper Phoenix Park Wash	19,257	12,685	12,593	66%	65%
67	150200080302	Bear Canyon	14,579	14,586	449	100%	3%
68	150200100108	Lower West Chevelon Canyon	16,845	8,476	8,476	50%	50%
69	150601050206	Bull Tank Canyon-Tonto Creek	22,095	12,257	11,175	55%	51%
70	150602030103	Toms Creek	8,520	8,122	7,423	95%	87%
71	150200050102	Porter Creek	25,078	24,095	6,746	96%	27%
72	150200050104	Show Low Lake-Show Low Creek	19,205	6,370	2,485	33%	13%
73	150200080101	Decker Wash	20,095	7,628	7,127	38%	35%
74	150200080305	Gentry Canyon	15,024	15,029	12,373	100%	82%
75	150200080311	East Clear Creek-Clear Creek	39,135	39,148	30,406	100%	78%
76	150200100101	Woods Canyon & Willow Spg. Canyon	16,685	16,691	452	100%	3%
77	150200100201	West Fork Black Canyon	8,660	8,662	8,662	100%	100%
78	150601030302	Canyon Creek Headwaters	25,788	21,065	13,322	82%	52%
79	150601050205	Haigler Creek	33,157	25,951	23,500	78%	71%
80	150602030102	Long Valley Draw	18,270	18,275	3,213	100%	18%

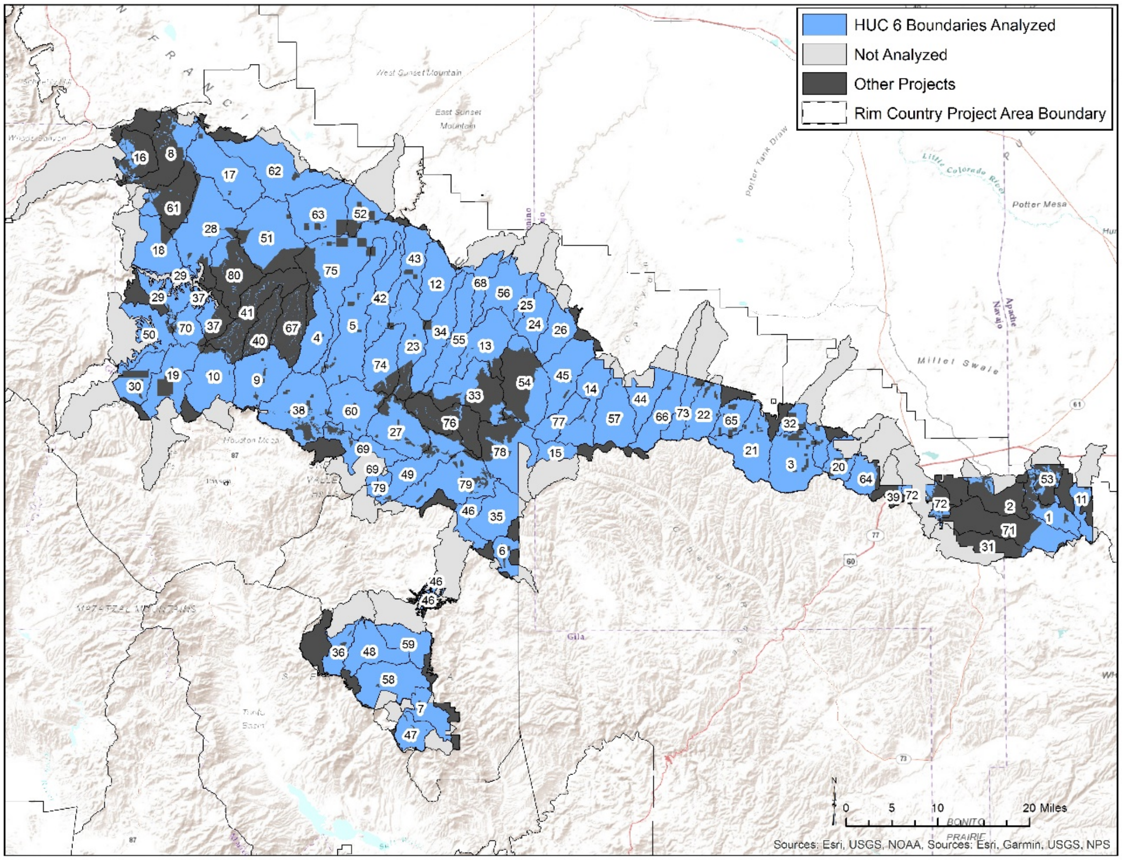

Figure 2: HUC 6 Boundaries. Dark gray areas are those areas within the project area that have current NEPA projects, and are not being fully re-analyzed in this report. Light gray areas are HUC 6 boundaries that fall outside the project area and were not analyzed in this report.

Metrics & Measures

Throughout this analysis, there are references to ‘undesirable fire behavior and effects’. Where it is legally and practically possible, ‘desirable’ fire behavior and effects align with reestablishing natural fire regimes, and that is the intent across the majority of the project area. Examples of where it is not possible to restore the natural fire regime include, but are not limited to, the following:

> *Example 1*: Mexican Spotted Owl habitat: Where there are nest cores, in particular, there is a need, legally and biologically, to manage those areas for denser vegetation than would have existed there historically. That means that, in most cases, fire will need to be less frequent than it would have been historically, and there is a desire to prevent high severity fire in those areas.

> *Example 2*: Proximity to infrastructure for certain vegetation types. Some of the ponderosa pine/evergreen oak and adjacent Chaparral/Madrean cover types historically would have had components of high severity fire as part of their natural fire regimes. Where these cover types occur on steep slopes above vulnerable assets, it may be necessary to manage these areas for lower severity fire.

The metrics used to evaluate the effectiveness of the alternatives in meeting the purpose and need of the project are described in detail below. A comparison of the outputs of these metrics between alternatives is displayed in Table 2.

Table 2: Brief description of the metrics used in this analysis.

Metric	Application	Issue/s Addressed	Assets and Resources Addressed
Fire Type	Indicates potential fire behavior at all scales analyzed. Crown fire is one an indicator of high severity fire.	Landscape and habitat resilience to wildfires burning under extreme conditions, vulnerability of values	Fire Management, Wildland Urban Interface, Old Growth Trees, Vegetation Cover Type, Watershed Response
Fire Hazard Index	See page 31 for details.	Landscape/habitat resilience to wildfires burning under extreme conditions, including both first and second order fire effects, and wildfire suppression difficulty.	Fire Management, Wildland Urban Interface, Vegetation Cover Type, Watershed Response
Total Surface fuel loading (Litter + Duff + Fine Woody Debris + Coarse Woody Debris)	Surface fuel loading is used to indicate potential for surface fire severity and intensity, particularly in areas where there may not be crown fire. It is also an indicator of potential emissions.	Potential for emissions and for high burn severity and high severity effects from both prescribed fire and wildfire from first and second order fire effects.	Old Growth Trees, Vegetation Cover Type, Watershed Response, Air Quality
Emissions	National Ambient Air Quality Standards for six pollutants: Carbon Monoxide (CO), Nitrogen Dioxide (NO_2), Ozone (O_3), Particle Pollution 2.5 (PM2.5), Particle Pollution 10 (PM10), and Sulfur Dioxide (SO_2) were modeled based on various treatment types, and discussed in context with each alternative.	Air quality concerns; particularly human health and visibility.	Air Quality

The effects of wildfire as quantified by the metrics and measures have direct implications for a variety of highly valued resources and assets. For this report, the resources and assets analyzed will be:

1. Fire management
2. Wildland Urban Interface
3. Old Growth Trees
4. Vegetation Cover Type
5. Air Quality

Fire Modeling

The intent of the fire modeling in this analysis is to identify the areas at greatest risk of undesirable fire behavior and first and second order fire effects, and what the expected effects would be for each of the alternatives.

One of the objectives of the Rim Country EIS is to reduce the likelihood of uncharacteristic wildfires, including large, high severity fires. Modeling fire behavior using conditions under which an uncharacteristic fire is known to have occurred allows for increased accuracy of post-treatment modeling results (McHugh, 2006). This analysis used the Rodeo/Chediski (RC) Fire, which was a large, complex fire that burned in 2002 on the Tonto and Apache-Sitgreaves National Forests, including about 100,000 acres within the Rim Country project area. The Rodeo fire was human caused, and was started on June 18 about 10 miles northeast of Cibecue on the lower slopes of the Mogollon Rim. The Chediski Fire was also human caused June 20 about 12 miles to the west of the Rodeo Fire. The fires merged and became the Rodeo/Chediski Complex which burned 468,638 acres before it was contained on July 6th. The fire effects were high, with 169,043 acres of high severity fire and 144,944 acres of moderate severity fire, in total accounting for 67% of acres burned. Vegetation within the fire perimeter still hasn't recovered in many of the areas that burned with moderate to high severity. The fire also burned 426 structures and homes. Over 30,000 people were evacuated from areas are within, adjacent to, or near the Rim Country Project area.

Conditions under which the RC Fire burned were extreme in regards to temperature, humidity, and fuel moisture. These are conditions that are likely to be more common in coming decades (Brown *et al.* 2004; Westerling *et al.* 2006). Modeled fire behavior assumes that every pixel within the dataset use for this modeling burned under the weather conditions recorded at the Heber RAWS at 1400 hours on June 25th, 2002 (Table 3). In a real wildfire, wind speeds and direction are erratic, and wind speeds recorded at a given point are unlikely to be representative of wind speed or direction across the fire area. Additionally, not all wind gusts are captured by weather stations. The maximum wind gust that occurred over the duration of the Rodeo/Chediski Fire was 36 mph. We used 20 mph in order to preserve the contrast in potential fire behavior as well as wind gusts.

Table 3: The weather conditions during the Rodeo/Chediski Fire (June 25th, 2002), and 97th percentile weather conditions from the Heber RAWS.

Variable	97th percentile weather	Rodeo-Chediski Observed Weather (percentile)	Inputs used for fire modeling (percentile)
Maximum Temperature (°F)	92	89 (94th)	89 (94th)
Minimum RH (%)	6	3 (99th)	8 (95th)

Maximum 20' steady wind (mph)	16	4 (<50th)	20
Maximum wind gust (mph)	29	6 (<50th) 36 (>99th)	n/a
1 hr fuel moisture (%)	1	n/a	3 (85th)
10 hr fuel moisture (%)	2	n/a	3 (90th)
100 hr fuel moisture (%)	4	n/a	5 (95th)

Data for modeling fire behavior is based on a landscape file which describes the fuel and topographic characteristics of an area, at a 30x30 meter (0.22 acre) resolution. The landscape file was created using a combination of Landfire 2014 data (LF1.4.0), Lidar data (see Appendix B for additional information on LiDAR data processing), USFS stand data (Moore, this report) and satellite imagery (NAIP, USFS Resource Photography). Existing condition fuel models were assigned based on a combination of Landfire Existing Vegetation Type (EVT), canopy cover, canopy height and past disturbance. The predominant Landfire EVT was modified in order to match the FSVeg stand vegetation cover type, while non-burnable surfaces and riparian corridors were left unmodified regardless of stand vegetation cover type. Lidar data was used to create canopy cover and canopy height rasters. Mapped disturbances including mechanical treatments, prescribed fire and wildfire from 2008 – 2017 were used to further modify fuel model assignments. See Appendix B for more detailed information on LCP creation.

Fire behavior for alternative future conditions used outputs from the Forest Vegetation Simulator Fire and Fuels Extension (Dixon 2003; Rebain 2016) to adjust data for modeling the effects of actions, or no actions, proposed in the alternatives. Post-treatment landscape files were modified from the existing conditions using the percent of change to canopy characteristics output from FVS-FFE. The resulting stand characteristics informed the assignation of post-treatment fuel models using the Landfire Total Fuel Change tool (LFTFC v0.160). Details of the process for updating existing conditions and assigning post-treatment fuel models for modeling fire type are included in Appendix B.

Fire Type

In ponderosa pine and most of its associated vegetative communities, the expected type of fire is a good indicator of the health and resilience of the ecosystem. Crown fire in ponderosa pine is lethal to the tree, therefore the amount and distribution of crown fire activity is an important indicator of the health of a frequent fire forest. Fire types include active crown fire, conditional 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 top-kill, 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 type of 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. In the fire modeling used, Conditional Crown Fire was combined with Active Crown Fire.

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.

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 under worse conditions. 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, or maintain/improve grassland structure.

Fire type was evaluated at the Rim Country project area level and at the 6th level hydrologic unit code (HUC) and in order to facilitate an analysis of specific fire effects in different areas. Watershed impacts from fire increase with the proportion of the watershed burned at high severity (Cannon 2010; Neary 2011). Therefore, fire type is considered at all scales in those areas proposed for thinning and/or prescribed fire.

Fire Hazard Index (FHI)

Five datasets were used to identify areas of high probability for severe fire effects, extreme behavior and a complex fire management environment. These datasets are crown fire potential, fire intensity, heat per unit area, slope, and soils with high erosion potential.

As a general rule, the amount and size of plants top-killed by fire increases with an increase in either the rate of heat energy released (fire intensity) or total amount of heat energy released (heat/unit/area). Estimates of the rate and amount of this heat release are thus important descriptors of fire behavior (Wade 2013).

Fire intensity is directly related to the suppression strategies, with direct attack becoming less effective as intensity increases. This holds true for both forested and non-forested systems. Therefore, while fire type will only be undesirable for forested landscapes, the FHI can be undesirable on any burnable landscape.

Steep slopes (> 30%) not only increase fire behavior, they are also difficult to thin via mechanical treatments. Fire suppression on these slopes is ineffective and presents additional hazards to the fire fighters.

Soils with high erosion potential have a greater chance of initiating a post fire debris flow, especially when found on steep slopes. With vegetation cover gone following a wildfire, these soils are more likely to erode than those with a lower erosion potential.

The FHI classified the landscape as shown in Table 4 below. Further details are included in

Appendix B.

FHI was evaluated at the Rim Country project area level and at the 6th level hydrologic unit code (HUC) and in order to facilitate an analysis of specific fire effects in different areas. Resource impacts and fire management responses will change with the proportion of the watershed in high hazard classes. Therefore, FHI is considered at all scales in those areas proposed for thinning and/or prescribed fire.

Table 4. Fire Hazard Index scores used to identify the need for treatment for resources, values and assets

Rating	Comments
1 – very low	Conditions are such that expected fire behavior will have minimal negative impacts to resources and suppression efforts, where needed, are expected to be very effective
2 – low	From a fire perspective, areas where crown fire is expected will not pose a threat to soil stability. Areas of high erosion potential are not expected to burn with active crown fires or high intensity conditions. Use of ground resources for suppression efforts becomes increasingly difficult.
3 – Moderate	Either extreme fire behavior resulting in difficult to control fires, or moderate soil severity. Presence of steep highly erodible soils may coincide with crown fire and higher intensity fires. Control of wildfire by suppression efforts will be difficult.
4 – High	These areas have the highest expected levels of all the fire behavior metrics. Control of wildfire by suppression efforts will be difficult and complex.
5 – Very High	These areas have the highest expected levels of all the fire behavior metrics, as well as steep slopes and highly erodible soils, making them prone to adverse second order effects such as debris flows. Control of wildfire by suppression efforts will be difficult and complex.

Surface Fuel loadings

In this analysis, total surface fuel loading includes fine dead woody debris (FWD) ≤ 3 inches in diameter (FWD), dead coarse woody debris (CWD) > 3 inches in diameter, litter, and duff. FWD and litter contribute significantly to fire behavior as well as fire effects, while and CWD and duff are mostly of interest in regards to fire effects (both direct and indirect). All three forest plans provide specific direction on desired conditions for CWD, but are silent or do not quantify any other components of surface fuel loading. As such, in this analysis, CWD, FWD, litter, and duff were combined as "total surface fuel loading" in tons/acre, which is evaluated both qualitatively and quantitatively regarding potential fire effects. Recommended surface fuel loadings are estimates, based on the best available science and expert opinion (Ottmar 2015) on the interaction of surface fuel loading with fire behavior and fire effects

Fuel loadings were evaluated at the Rim Country project area level and the 6th level hydrologic unit code (HUC) and in order to facilitate an analysis of specific fire effects in different areas.

Water, soil and wildlife impacts from wildfire are also related to surface fuel loadings. Additionally, fuel loadings have direct influence on wildfire emissions, and therefore will be discussed in those sections as well.

Emissions Modeling

Air impacts are felt, seen, and measured by the concentration of emissions at a given location. There are no reliable methods of predicting concentrations at specific locations years in advance of a prescribed fire. This analysis does not attempt 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 and non-treatment scenarios using the First Order Fire Effects Model (Kean and Lutes). Fuel loadings were calculated for a representative Ponderosa Pine stand using FVS. The resulting modeled emissions shows the relative differences that the same piece of ground would be expected to produce before, during and after treatments.

For a landscape analysis, changes in those fuel components which produce the greatest percentages of emissions when they burn were modeled, and mapped using Forest Vegetation Simulator (Moore, this report). The components include litter, duff, FWD and CWD>3 inches (Lutes *et al.* 2009), which were combined into a single total surface fuel loadings metric in tons per acre. Details may be found in Appendix D.

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 the action alternatives, and hence, Air Quality is not expected to be a primary driver in selecting one alternative over another.

Some comparison between alternatives can be made by looking at the indirect effects of management activities that reduce the likelihood of active crown fire and heavy surface fuel loading. Active crown fire and heavy surface fuel loading produce large quantities of emissions that may be 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.

Affected Environment and Existing Conditions

Existing and desired conditions are discussed as follows:

1. Background and history of the Rim Country area
2. Summary of fire ecology, current condition, and desired condition across the Rim country

project area for each cover type and metric used.
3. Surface fuel loading effects on fire behavior, fire effects, and air quality
4. Emissions: Air Quality and Smoke Ecology

The Rim Country project area is about 1.24 million acres, encompassing portions of the Apache-Sitgreaves, Coconino, and Tonto National forests. The majority of the Rim Country project is a large, contiguous area along the Mogollon Rim, with a spatially separate area south of the Rim in the Sierra Anchas Mountains (Figure 1).

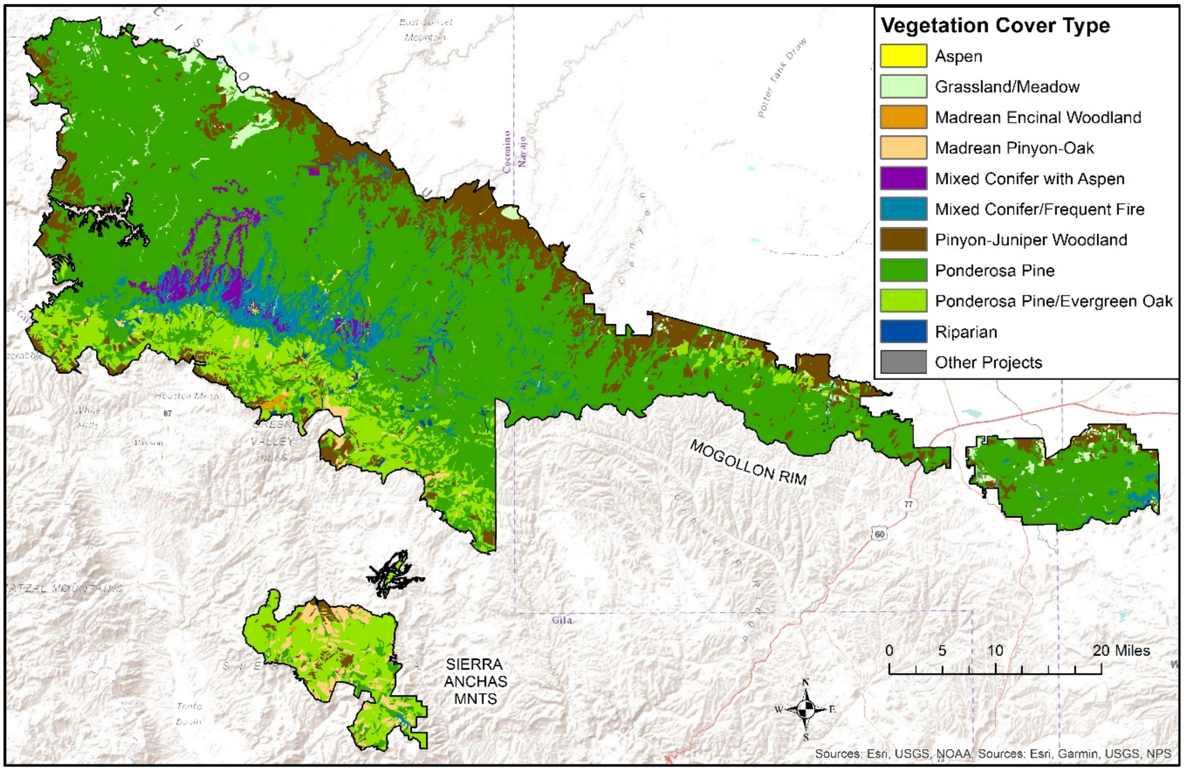

Figure 3: Vegetation Cover Types are based on stand boundaries and were defined using the Ecological Restoration Units dataset.

In regards to fire, the Rim Country landscape is a temporal and spatial mosaic made up of a complex mix of cover types (Figure 3) and fire regime groups (Table 5). The cover types have different fire hazards associated with them throughout the year. The typical climate of the project area includes conditions favorable for frequent early summer fires (Harrington and Sackett 1992), with rainfall minimums occurring in May and June, and some areas averaging less than 0.5 inches during those months. 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 thunderstorms; July and August are the wettest, warmest months. A second dry season occurs in the fall. While the majority of fires in the project area are in the spring dry season, fires have been reported in all cover types in every month of the year due to inter-annual variability in weather (FOD dataset).

Table 5: Fire regime groups adapted from (Barrett *et al.* 2010)

Group	Frequency	Severity	Severity Description	Cover types that would be affected by treatments proposed under 4FRI	Acres of FRG within Project Area

I	0 – 35 years	Low to mixed	Stand replacement is less than 25% of the dominant overstory vegetation.	Most ponderosa pine, dry mixed conifer, savannas	1,142,310
II	0 – 35 years	High	High severity replaces greater than 75% of dominant overstory (grasslands).	Grasslands. Grasses and forbs are the dominant species. Greater than 75% of these are likely to be top-killed by fire.	5,483
III	35 - 100 years	Mixed to Low	Generally mixed-severity; may also include low severity fires.	Some mixed conifer, chaparral, some pinyon/juniper, Madrean Pinyon/Oak Woodland.	70,823
IV	35 - 200 years	High	High severity.	Seral aspen, some wet mixed conifer, some aspen	12,296
V	200+ years	High or any severity	Any severity may be included, but mostly replacement severity; may include any severity with this frequency	Some of the Piñon/Juniper, wet mixed conifer, some aspen.	6,386

Background and Historic Conditions

Across the Rim Country landscape, the disruption of Fire Regimes over the last century is largely responsible for the deteriorating health of the ecosystems in Northern Arizona (Covington 1994). In the latter part of the 19th century, unsustainable practices in fire management, grazing, and logging began to change the structure and composition of landscapes, making them more homogenized. As a result ecological functions are now impaired across the landscape of northern Arizona (Leopold 1924; Covington 1994; Heinlein *et al.* 2005; Rodman *et al.* 2017).

Fire is a keystone process affecting the ecological functions of large areas. As Europeans settled into the area, roads and trails increasingly broke up the continuity of surface fuels and contributed to the reduction of the frequency and size of wildfires (Covington and Moore 1994). Long periods without fire changed the species composition and fuel structure of southwestern ecosystems (Swetnam 1990b; Huffman 2017). There are about 800,000 acres of cover types targeted for restoration in Rim Country that historically were maintained by frequent fires.

Logging removed much of the large tree component across the landscape, allowing younger and smaller trees to survive in unnaturally dense stands (Covington and Moore 1994; Swetnam and Baison 1996).

The disruption of historical fire regimes by introduced ungulates has also been well documented for southwestern ecosystems. Montane grasslands were utilized as summer range for large numbers of sheep and cattle (Leopold 1924). Grazing at such intensities removed much of the fine fuels that had competed with pine seedlings for water, nutrients and light, and had also maintained the light, flashy fuels that produced frequent, cool surface fires, with short residence times. 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.

Fire Occurrence & Fire Regime

There is little doubt that fires, started by lightning or by Native Americans, were frequent before

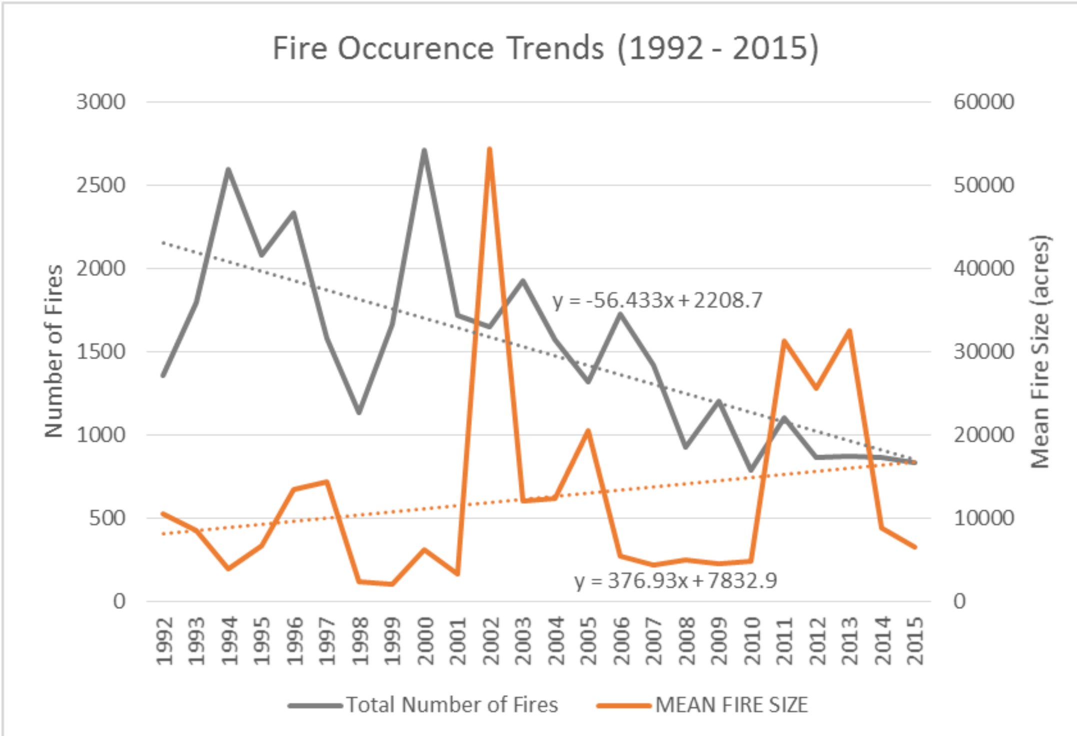

Figure 4: Trends in Mean Fire Size and Total Number of Wildfires from 1992-2015

the arrival of the Europeans and in the early years of settlement. Fire scars from stumps collected at various sites in Arizona showed the highest fire frequency average interval of 4.8 years between fires, while the longest average interval between fires exhibited by any sample tree was 11.9 years (Weaver 1951). A 1910 report on what would be the Coconino National Forest stated that over 80% of the yellow pine type (*Pinus ponderosa*) had been burned over one or more times, but that the fires usually destroyed only a small amount of standing timber (Drake 1910). Only two stand replacing fires were noted: the Escudilla fire of July, 1951, which destroyed most of the timber on 19,000 acres and the 21,000 A Dudley Lake fire of June, 1956 (Cooper 1960).

The number of fires reported in and adjacent to the project area has decreased over the last 25 years (1992 – 2015), while the average size has increased (Figure 4). Some of these fires became large in spite of efforts to suppress them, and some grew large because of management objectives. While fire size is certainly an indicator of the trends in wildfire, it is primarily those areas that burn with uncharacteristic severity that are of concern.

Currently, the number of acres burning with high severity is much larger than historic data indicates was typical of ponderosa pine in the southwest (Weaver 1951; Covington 1994; Swetnam and Betancourt 1998; Westerling *et al.* 2006). Of the annual acres burned by large fires, about 73% burned at low severity on average, and 27% burned at moderate to high severity. One outlier to this pattern was found in 2002, which is when the Rodeo- Chediski fire burned (see discussion on page 29). While the annual acres burned by large fires has increased since 1992 (Figure 5), the proportion of acres burned in each severity class has remained about the same (Figure 6), with no significant trend found. If these patterns continue into the near future (10 years), the total acres of high severity fire will increase proportional to fire size increases.

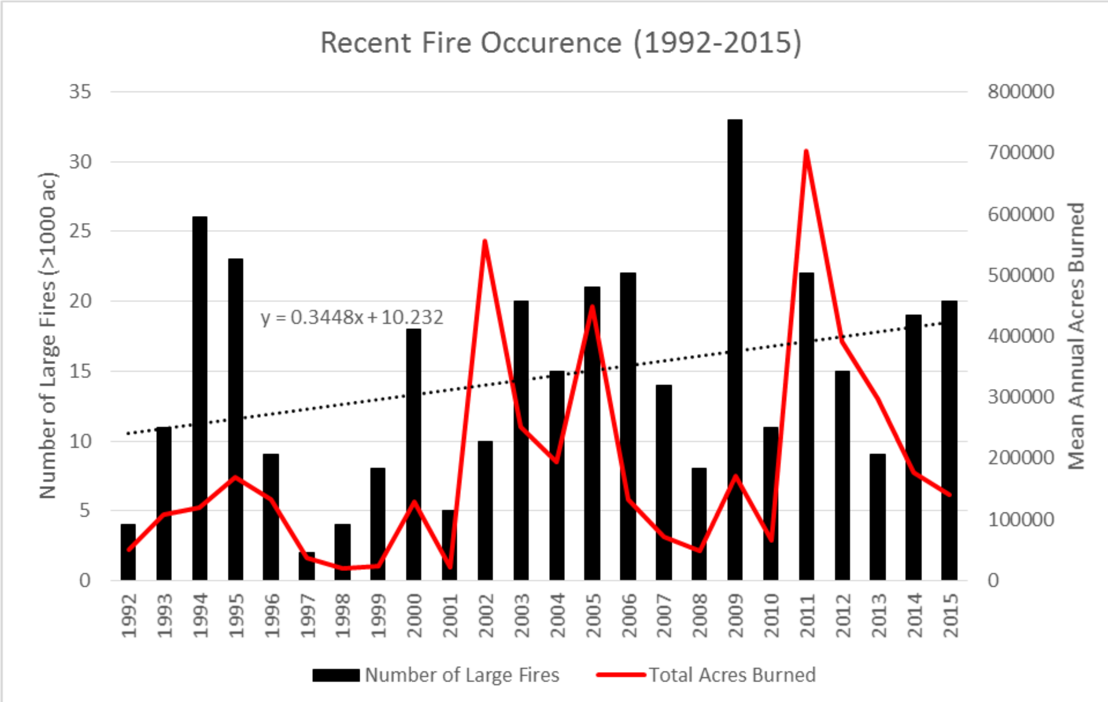

Figure 5: Trends in the Number of Large Fires (>1,000 ac) and Total Acres Burned from 1992 – 2015 within the Arizona/New Mexico Mountains Ecoregion

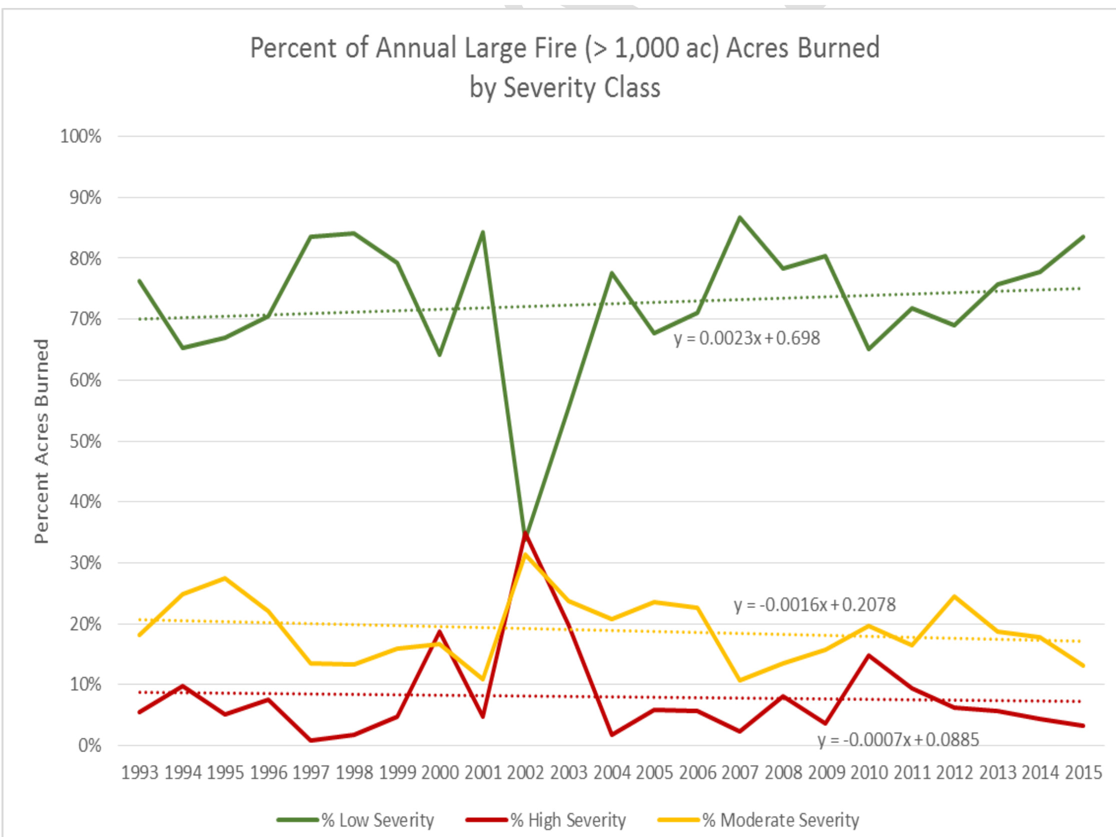

Figure 6: Percent of Annual Large Fires Burned by Severity Class.

Figure 7: Locust dominated area in the Sierra Anchas where the Coon Creek Fire produced high severity effects in 2000.

Areas of high severity fire can have detrimental impacts that extend far from the actual fire perimeter both temporally and spatially. Many of the areas that burned under high severity have been slow to regenerate and remain open with excessive CWD in areas dominated by herbaceous vegetation and/or shrubs. In the Sierra Anchas area of the Tonto National Forest, high severity fires in ponderosa pine has resulted in large areas being dominated by New Mexican Locust (*Robinia neomexicana*) (Figure 7). Where there is high surface fuel loading, high severity fires can consume enough soil organic matter and nutrients that it is 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 have severe, long term effects on areas downstream, downslope, and adjacent to the burned area. 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. See the soils specialist report for more detail.

Current conditions inhibit the survival and recruitment of large trees by fueling increasingly extensive high severity 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; Strom and Fulé 2007b; Kuenzi *et al.* 2008). Figure 8 shows dense forest conditions (numerous trees with dense, contiguous canopy fuels) that occur within the project area and would support high severity fire. Even without crown fire, a surface fire burning though this area could do enough damage to trees to cause widespread mortality (Van Wagner 1973).

Of the 349 large fires (> 1,000 acres), 283 were stared by lightning and the remaining 66 were caused by humans (Short 2017). Two of these human caused fires, the Rodeo Chedisky (~468,864 acres) fire of 2002 and Wallow (~538,050 acres) of 2011, were some of the most destructive fires in the history of Arizona. The largest lightening ignited fires include the Whitewater Baldy fire (297845) of 2012, the Humbolt fire (248,310) of 2005 and the Silver fire (234,000) of 2013. These fires mostly burned in ponderosa pine.

Figure 8: Conditions in dry mixed conifer in the project area that could easily support high severity fire.

Fire Return Interval (FRI)

Fire Return Interval (FRI) can be used as a coarse indicator of how departed an area is in regards to the fire regime. The FRI calculated for this analysis does not take into account seasonality, severity, size, spatial complexity, or other important characteristics of a fire regime. However, particularly when combined with cover type/s, and severity, it is a useful indicator for evaluating how far an area has departed from a sustainable fire regime.

Fire Return Interval is a component of the fire history of an area. The Mogollon Rim, and the Sierra Anchas areas have a high density of ignitions, both lightning and human. In the past 31 (1987 – 2017) years, 850,215 acres of the 1,238,658 acre project area burned, for a mean annual acres burned of 27,426 acres. In addition to wildfire, 242,028 acres of Rx fire have occurred in the project area from 1995 – 2018 for another 10,084 acres per year. Prescribed fire is often focused on areas strategic to values at risk, and therefore is concentrated on the landscape, rather than distributed throughout (Figure 9). Taken together, the mean fire return interval for the entire project area is 33 years.

For Montane Ponderosa Pine forest types, the recent FRI is 38 years (Table 6: Vegetation cover types targeted for restoration, and their desired and current fire regimes across the project area.). This is almost double the desired maximum average for maintenance burning in ponderosa pine on the Mogollon Rim. The FRI is 59 years for Ponderosa Pine-Evergreen Oak, 65 years for dry mixed conifer, and 113 for grasslands in the project area. These FRIs represent an average that includes areas that have burned much more frequently and areas that have burned at a much longer frequency. These higher than desired fire return intervals have contributed to the degree of departure from historic conditions that puts over 51% of the area proposed for treatment area at risk of moderate to high severity fire effects based on recent severity proportions.

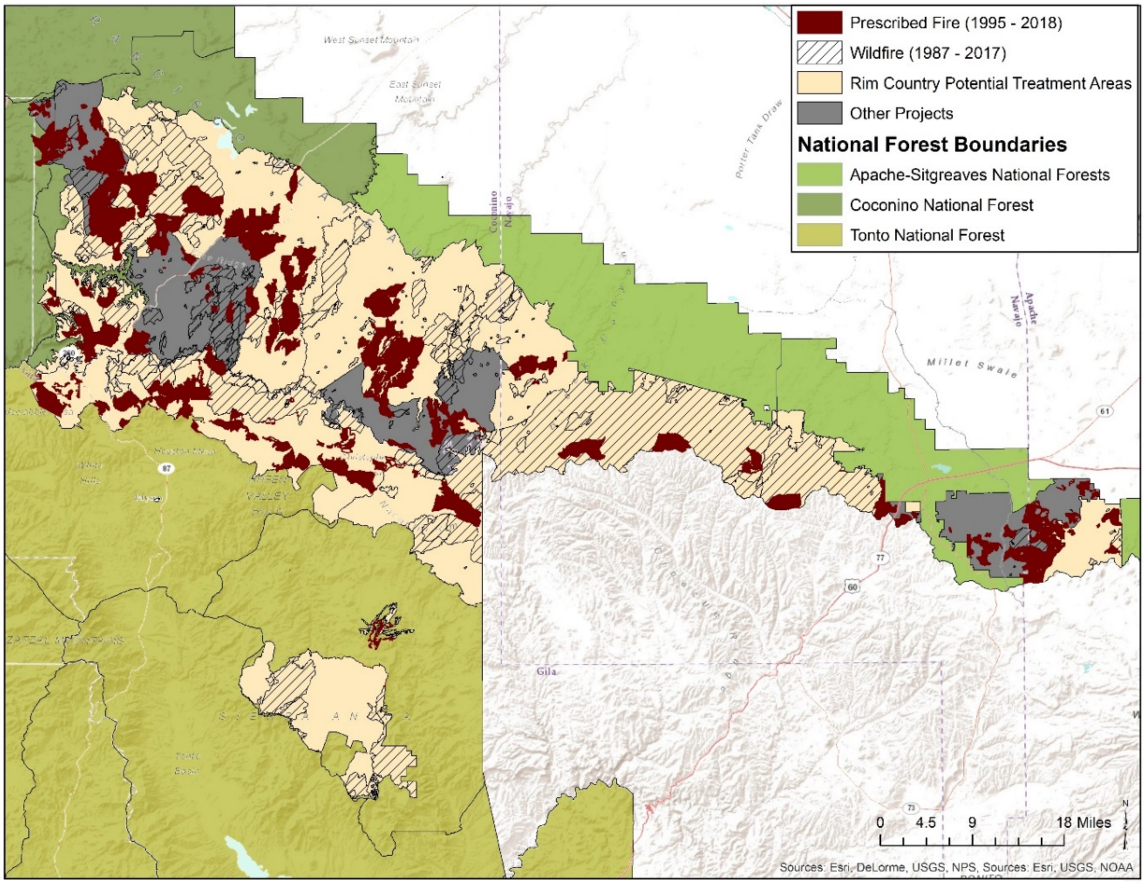

Figure 9: Location of recent Wildfire (1987 – 2017) and Prescribed Fire (1995 – 2018) within the project area.

Surface fuels and canopy characteristics

The ability of a forest to maintain its adapted resilience to fire depends, in part, on how close it is to threshold conditions that would support a fire of an intensity and severity to which it is not adapted. In frequent fire systems in which the fire regime has been interrupted, those conditions generally result from excessive surface and canopy fuels.

Canopy characteristics

The specific characteristics that determine the likelihood of crown fire initiation are canopy cover, canopy base height, canopy bulk density, and canopy height. While there are no specific desired conditions for these canopy characteristics, they are important variables to be addressed in proposed treatments. Generally speaking:

Canopy cover

Canopy Cover affects the ability of fire to move from the canopy of one tree to the canopy of another, thus is a significant component in differentiating the potential for a stand to transition from passive to active crown fire. Additionally, tree canopies shade the surface, affecting surface vegetation which defines fuel structures and affects fuel moisture. Canopy cover also affects

Table 6: Vegetation cover types targeted for restoration, and their desired and current fire regimes across the project area.

Cover type	Acres of cover types	Natural Fire Regime	Fire Return Interval		High Severity Fire			Average Annual Acres burned +	Average annual acres needed to burn to meet desired conditions
			Desired (average)	Current+	Desired	Recently Burned w/ Mod - High Severity++	*Potential to Burn with Mod - High Severity		
Ponderosa Pine (montane)	543,058	1	2 – 22 (12)	38	< 20 (<5% active crown fire)	51% (27% High)	78% (23% active crown fire)	14,495	~45,000
Ponderosa Pine – Evergreen Oak**	146,445	1, 3	1 – 60 (7)	59	< 25 (with <10% active crown fire)	57% (29% High)	69% (36% active crown fire)	2,477	~20,000
Dry Mixed Conifer	47,993	1, 3	2 – 61 (15)	65	< 20 (with <7% active crown fire)	51% (19% High)	77% (54% active crown fire)	743	~3,200
Aspen	1,436	4	5 - 150	739	N/A	N/A	48% (17% active crown fire)	2	~15
Grasslands	43,000	2	2 – 40 (12)	113	<10%	35% (12% High)	10% (<1% active crown fire)	379	3,600
Riparian	9,931	Related to, but not the same as, adjacent cover types.							

+ Average calculated across all stands with that cover type for the past 30 years (1987 – 2017) for wildfire plus the past 24 years (1995 – 2018) for prescribed fire

++Data from Monitoring Trends in Burn Severity from 1992 – 2015

**Evergreen Shrub Subclass included in acres, but not in desired condition

*Based on modeled fire behavior under extreme fire weather conditions surface wind speed, which, in turn, affects surface fire intensity and rate of spread. Across the project area, canopies have become much more closed, resulting in elevated potential for crown fire and decreased surface vegetation.

Canopy base height

Canopy base height is the lowest height of the part of the tree canopy which could support sufficient flames to propagate fire up into the rest of the crown (Scott and Reinhardt 2005). Canopy base height is a critical factor in crown fire initiation. In the last century, ladder fuels have effectively lowered the functional canopy base height as small trees and shrubs now provide ‘ladders’ by which flames can climb into tree canopies.

Canopy bulk density

Canopy bulk density is the mass per volume of the crown of a tree. Denser canopies have more fuel, and can burn with a higher intensity (longer flame lengths). They will ignite more easily than sparser canopies if fire reaches them and it is the primary component determining conditional crown fire.

Canopy height

Canopy height is the height of the top of the canopy of a forest. Its primary effect on fire behavior is spotting potential. Taller trees are likely to spot further than shorter trees if their crowns are burning.

Surface fuels

Wildland fuels are composed of various categories, including live and dead, small and large, and so on. Each plays a different role in fire behavior and effects. Coarse Woody Debris (CWD: diameter >3 inches) and duff are the highest contributors to total emissions in prescribed fires because prescribed fires are mostly surface fires, and little of the canopy fuels are consumed. Litter is a necessary component of fires in frequent fire systems because, particularly in dry, frequent fire forested systems, litter is what allows a surface fire to spread. Most of the heat produced by fine woody debris (FWD: <3 inches in diameter) and litter goes upwards. Duff and CWD can smolder for a long time, transferring excessive 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. High burn severity (fire effects to soil) is far more likely as the heat transferred to the soil can consume or kill soil biota and other organic matter in soil that is critical to soil function and productivity (Valette *et al.* 1994; Neary *et al.* 2005 (revised 2008); Lata 2006).

Litter and FWD are necessary components of surface fuel loading, providing continuity to carry a fire across the surface. Dry litter combusts relatively quickly during the flaming stage with little smoldering or smoke produced. It is a major component of surface fire intensity and behavior. CWD is an important contributor to healthy forest soils, and many habitat types. It’s common for significant amounts of CWD to be consumed during the smoldering phase, generating more emissions that can impact air quality than fuels burning in the flaming combustion phase. Duff can also be a significant source of emissions and plays a role in feeder root structure. Duff and CWD can smolder for long periods of time, causing temperature impacts to the soil and generating large amounts of low buoyant smoke for weeks (Covington and Sackett 1984).

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. Generally, the litter layer contributes to fire *intensity*, while the duff layer contributes to fire *severity,* (Sackett and Haase

1996; Hood 2007).

Historically, fine surface fuel loads were made up primarily of herbaceous material and fire burning though it would move relatively quickly, with a short residence time and a high rate of consumption. Repeated fires would consume coarse woody debris a little at a time, allowing natural recruitment of more from branches or snags to maintain equilibrium based mostly on fire frequency. (Covington and Sackett 1984).

Decades of fire suppression have allowed litter and duff layers to accumulate to levels that cause a multitude of problems that include (but are not limited to) fire behavior, direct and indirect fire effects, fire effects on soil productivity, interception of precipitation, nutrients locked up in organic matter, changes to soil chemistry, emissions, and physical suppression of surface vegetation contributing to a decrease in species diversity (Covington and Sackett 1984; Moir and Dieterich 1988; Neary *et al.* 2005 (revised 2008); Abella *et al.* 2007; Varner *et al.* 2007).

Currently, across much of the project area, surface fuels are dominated by needle litter and duff that has accumulated over years to decades and is more closely packed than herbaceous fuel. Fire burning through these fuels will have a longer residence time than in herbaceous fuels, and the lower layers may smolder for extended periods, transferring more heat to the soil, roots, and boles of trees (Lutes *et al.* 2009, Valette *et al.* 1994; Sackett and Haase 1996). Conversely, litter that has accumulated for just a few years, will burn almost completely, and quickly, with little detrimental impact from heat (Covington and Sackett 1992; Sackett and Haase 1998; Garlough and Keyes 2011).

Litter and duff cones have accumulated around the base of many large and/or old trees in the project area and are likely to cause, or contribute to, undesirable mortality (Egan 2011). Prescribed fire can produce fire behavior that is less likely to cause lethal damage.

These fuel 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 on site.

Wildfire Management

Initially, and through most of the 20th century, wildfires burning in frequent fire regimes in the Southwest were relatively easy to suppress. Fuels were mostly light and flashy, and forests were open with high canopy base heights, and suppression was a common response. Many areas were increasingly overgrazed to the point where some areas couldn’t burn at all and/or fires were easy to suppress. Settlers saw fire as a threat, and actively suppressed it whenever they could. The subsequent accumulation of fuel, through litter-fall, logging debris, and development of ladder fuels that can initiate crown fire (Covington and Moore 1994) made fire suppression more difficult. Surface fuel loading changed from light flashy fuels to compact needle litter, duff, and dead/down woody debris. Forests continued to grow denser, woody species increasingly encroached into non-forested areas, and shrubby species established and matured beneath increasingly dense canopies. This increased the severity of fire’s effects, as well as the intensity of fire behavior. As wildfires became more difficult to suppress, firefighting technology, tactics, strategies, equipment and support improved dramatically, allowing suppression forces to succeed in suppressing all but the most intense and extreme fires. Most of the acres that burn now are from fires that have such extreme behavior that they overwhelm firefighting forces.

Wildland Urban Interface

The Wildland Urban Interface (WUI) is the line, area, or zone where structures and other human development meet or intermingle with undeveloped wildland or vegetative fuels ((NWCG) 2018). It is that portion of the landscape where structures and vegetation are sufficiently close that a

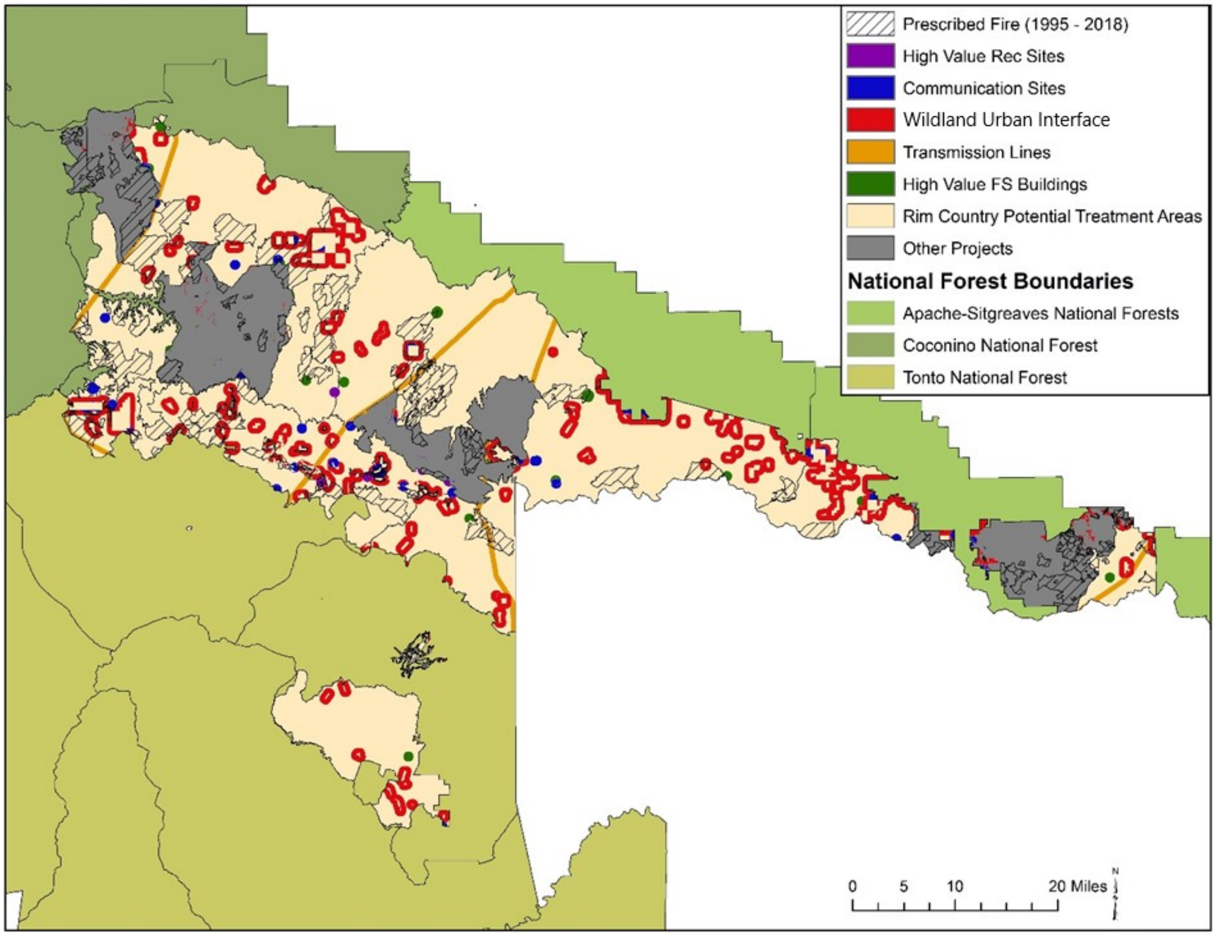

Figure 10: Wildland Urban Interface, as defined and mapped by this project. Recent prescribed fires are shown by hashed polygons.

wildland fire could spread to structures, or a structure fire could ignite vegetation. WUI areas are scattered across the project area, though areas of the greatest concern are relatively focused around towns or along travel ways. For this analysis, the wildland urban interface is defined by a 0.5 mile buffer surrounding non-Forest Service lands where structures are present (Figure 10). Other critical infrastructure (Transmission Lines and Communication sites) and high value Forest Service Infrastructure (Buildings and Recreation Sites) were also included within the WUI for this project.

Large and/or old trees

Large and/or old trees in the project area increase structural diversity, improving habitat for birds, insects, and other animals. Old trees have greater genetic diversity than even-aged groups of young trees, and provide forests a better chance of adapting to changing climate conditions and other environmental stressors (Minard 2002). Large and/or old trees 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 and/or old trees have been linked to fuel accumulation resulting from a century of fire exclusion (Sackett *et al.* 1996; Covington *et al.* 1997c). Some of these fuels are deep duff and organic soil layers at the surface. They often burn with low intensity by smoldering combustion and, although temperatures are lower than in flaming combustion, residence times are much longer so more heat is transferred to cambiums, roots, and soil (Ryan and Frandsen 1991; Hartford and Frandsen 1992; Hood 2010a).

Crown damage is an important factor in the mortality of old trees for which the death is attributed to fire (Fowler and Sieg 2004; Haase and Sackett 2008; Hood 2010b). The proximity of dense young trees and ladder fuels is problematic because it is so wide spread. In the transitional pine areas various species of juniper and oak are components of the forest, often centuries old. The overtopping of these trees by ponderosa pine allows a buildup of needles in the crotches and forks. This can lead to greater mortality and/or damage to very old trees when highly flammable needle accumulations burn than would occur without the needle accumulations.

Vegetation Cover Types

The ecology and fire history for each vegetation cover type within the Rim Country project area is discussed in depth in the appendices. Below is just the discussion for the three primary target cover types: Ponderosa Pine (Montane), Ponderosa Pine – Evergreen Oak, and Dry Mixed Conifer.

Ponderosa Pine (Montane)

This cover type includes all ponderosa pine other than the ponderosa pine/evergreen oak and transitional pine described in the next section. There are about 543,058 acres of this kind of ponderosa pine forest within the area being considered for restoration treatments.

Fire Ecology

Ponderosa pine forests are widespread in the Southwest occurring at elevations ranging from 6,000-7,500 ft on soils from igneous, metamorphic, and sedimentary parent materials with good aeration and drainage, and across elevational and moisture gradients. The dominant species is Ponderosa pine (*Pinus ponderosa* var. *scopulorum*). Other trees, such as Gambel oak (*Quercus gambelii*), pinyon pine (*Pinus edulis*), and juniper (*Juniperus* spp.) may be present. There is sometimes a shrubby understory mixed with grasses and forbs, although this type sometimes occurs as savannah with extensive grasslands interspersed between widely spaced clumps or individual trees. Canopy cover in the savanna areas is between 10 and 30%.

Historically, once fires ignited in ponderosa pine forests, they could burn until extinguished by rain, or until they ran out of fuel, which typically occurred when they reached an area that had recently burned. Fires could burn for months and cover thousands of acres (Swetnam and Betancourt 1990; Swetnam and Baison 1996; Swetnam and Betancourt 1998). Effects from these long burning fires would vary as conditions changed over the weeks or months they burned. As a result, most ponderosa pine in the southwest burned every 2 to 22 years as mostly low-severity, often area-wide fires (Weaver 1951; Cooper 1960; Deterich 1980; Swetnam *et al.* 1990; Swetnam and Baison 1996; Covington *et al.* 1997a; Fulé *et al.* 1997; Heinlein *et al.* 2005; Kaib 2011).

Open stands of ponderosa pine under a frequent fire regime are capable of supporting a contiguous understory of up to 1,600 pounds per acre of herbaceous fuels in frequently burned stands. These high levels are the result of frequent surface fires cycle nutrients, scarify seeds for many species via smoke and/or heat effects, increasing germination (Huffman and Moore 2004; Abella *et al.* 2007; Lata 2015), and reduce competition from woody reproduction. Frequent, surface fires kill small trees, but most grasses and forbs are only top-killed, and mature trees escape damage because of their high crowns and thick bark.

During drier, warmer, windier conditions, fires would have burned at higher intensities, but would still have produced primarily low severity effects in the ponderosa pine forests of the southwest (Swetnam and Baison 1996; Fulé *et al.* 2004; Roccaforte *et al.* 2008). Ecological processes, including 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 (Moore *et al.* 1999; Allen *et al.* 2002b). Numerous documents (Drake 1910; Leopold 1924; Cooper 1960; Brown and Davis 1973; Dahms and Geils 1997) 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" (Plummer 1904) (in Dahms et al.1997).

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 does not easily ignite 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. New resin ducts develop around wounds to help protect trees although, if the wound doesn't heal before the next fire, the additional flammable resin deposits around wounds can make an individual tree susceptible to fire damage and can enlarge existing fire scars.

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 would regenerate (Swetnam and Dieterich 1985). This regeneration cycle required seed production, establishment, and survival to an age at which the young tree could successfully compete and endure surface fires. When single or small groups of trees died and fell, they were inevitably consumed by surface fires, producing severe but localized fire effects that reduced grass competition, and created favorable microsites for seedling establishment (Cooper 1960).

History

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. " (Dahms and Geils 1997). In a report written in 1910 by Willard M. Drake, Acting Forest Supervisor of the Coconino National Forest wrote: “…Western Yellow Pine, (*Pinus ponderosa*) is the characteristic species generally forming in this type a nearly pure and often very open stand of mature timber with few young trees in the mixture. Only in very scattered areas do the crowns form anything like a continuous cover…”

Although the popular early descriptions of the ponderosa pine forest call attention to the park-like stands, there are some descriptions which refer to areas with dense cover (Woolsey 1911). An accurate picture of the pre-settlement ponderosa pine forest would probably describe a mosaic of mostly open, grass savanna and clumps of large, yellow-bark ponderosa pine and open forest with an occasional dense patches or stringers of small, blackjack pines (young ponderosa pine). Ponderosa pine naturally regenerate infrequently, but when they do, they reproduce with an overabundance of seedlings and a high rate of juvenile mortality (Pearson 1931).

Extensive stand-replacing fires are unreported in the documentary records prior to circa 1950 (Cooper 1960; Allen *et al.* 2002a). Ponderosa pine does not sprout, so crown fire generally produces 100 percent mortality. 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 very little crown fire, passive or active (Roccaforte et al. 2008, Covington 2002). Modeled historic conditions in Southwestern ponderosa pine indicate that up to 17% of the area may have supported active crown fire with windspeeds of 43 mph (Roccaforte et al. 2008), with less under conditions close to those modeled for this analysis for montane ponderosa pine.

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 Rim Country, patches of high severity, mostly in the form of passive crown fire, would generally have been less than 50 acres in size under those conditions modeled for Rim Country. These patches would 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 and spread.

Ponderosa Pine – Evergreen Oak & Transitional pine (PPEO)

The ponderosa pine/evergreen oak (PPEO) cover type in this analysis includes vegetative associations which have been referred to by various classifications and names, including transitional pine, Arizona highlands, Ponderosa Pine/Evergreen Oak ERU, Mogollon highlands, various Madrean fringe types (Fleischner *et al.* 2017; Wahlberg *et al.* 2017 (in draft); Huffman *et al.* 2018). In order to be consistent, this analysis will use the broadest classification, ‘Ponderosa Pine/Evergreen Oak’ (PPEO) to refer to this broad cover type, with more detailed discussion as needed to include unique characteristics.

PPEO occurs in the mild climate gradients of central and southern Arizona, particularly below the Mogollon Rim, where warm summer seasons and bi-modal precipitation regimes are characteristic. These vegetation types occur at a biogeographic crossroads, contributing to a tremendous ecological diversity in this part of the Rim Country project area. (Fleischner *et al.* 2017). Generally, PPEO occurs from 5,500 –7,200 feet and is dominated by ponderosa pine. PPEO can be distinguished from montane ponderosa pine by well-represented evergreen oaks. It may also include pinyon pine (*Pinus edulis*) and alligator juniper (*Juniperus deppeana*) as co-dominant species (Brown 1994a; Wahlberg *et al.* 2017 (in draft)). In places, ponderosa pine forests co-occur with interior chaparral and Madrean woodland communities (Huffman *et al.* 2018), sometimes as inclusions, and sometimes as more extensive adjacent types, often aspect-driven. Wahlberg *et al.* (2017 (in draft)) describe an 'Evergreen Shrub Subclass' within the PPEO that favors high shrub cover and higher fire severity than in the matrix PPEO forest. These transitional forests commonly occur on xeric sites, and rather than the herbaceous communities typical of montane forests, shrubs presently dominate the understories of many transitional ponderosa pine systems. Much less is known about these ecosystems compared to the montane ponderosa communities, yet transitional forests are important components of biodiversity on southwestern landscapes. Because transitional forests occur at the environmental limits of ponderosa pine, they are vulnerable to rapid changes in terms of tree mortality as the climate warms and periodic droughts become more frequent and severe (Huffman *et al.* 2018).

Fire Ecology

Research in other areas pine/shrub systems found that moderate intensity fires tend to favor pine, while less frequent fire favors the sprouting species. This poses a challenge for management and for proposed restoration treatments.

PPEO forests differ from montane ponderosa pine by site potential, typically favoring high shrub cover, and by higher fire severity, and more even-aged conditions characteristic of mixed-severity fire regimes. Some high-density evergreen shrub patches exhibit infrequent, high severity fire (fire regime IV; stand replacement at 35-200 years). Areas where this pattern was persistent are likely to be identified as Interior Chaparral.

PPEO averages greater fire severity than the montane ponderosa pine forests above the Mogollon Rim, and greater patchiness with less horizontal uniformity and more even-aged conditions. Site potential, fire history, and the importance of perennial grasses versus shrubs in the understory vary, affecting forest structure and the disturbance regime (Wahlberg *et al.* 2017 (in draft)). Understory shrubs include manzanita (*Arctostaphylos* sp.), turbinella oak (*Quercus turbinella*), skunkbush sumac (*Rhus trilobata*), and mountain mahogany (*Cercocarpus montanus*).

History

It is well understood that 20th century fire exclusion in montane ponderosa pine forests has led to substantial increases in tree establishment and associated changes in ecological function (Covington and Moore 1994; Fulé *et al.* 1997; Moore *et al.* 1999; Savage and Mast 2005; Strom and Fulé 2007a). Much less is known about historical changes associated with modern land use in the PPEO. Some species in the PPEO are often growing at their environmental limits and thus can be under high levels of stress within ecotones, thus these zones where communities intergrade are often dynamic and fluctuate in composition over relatively small spatial and temporal scales. It appears that cover of long-lived sprouting shrubs has increased in many transitional ponderosa pine forests as a result of fire exclusion (Huffman *et al.* 2018).

Historical fire regimes in pine forest communities co-occurring within interior chaparral and Madrean evergreen woodland appear to have been characterized by frequent, low-severity surface fires similar to those widely reported for montane ponderosa pine forests of the Southwest.

Frequent fires likely kept forests in open structural conditions and limited establishment and regeneration of sprouting woody species. As was prevalent in other southwestern ecosystems, unregulated livestock grazing in the late 19th and early 20th centuries apparently reduced abundance of herbaceous plants in ecotone communities (e.g., in both ponderosa pine forests and chaparral shrublands), and interrupted fire regimes. Intensive harvesting of ponderosa pine for mining materials in the mid-1800s undoubtedly contributed to later shifts in forest structure at some sites. Fire regime interruption in the Southwest appears to have allowed shrubs as well as young trees to increase in abundance within transitional pine forests. Similarly, less frequent fire in adjacent shrublands allowed ponderosa pine trees to establish and expand into these communities. Active fire suppression beginning in the mid- 1900s likely exacerbated structural shifts of both pine forests and shrublands. The ultimate effect of these anthropogenic influences has been to encourage broader, more complex ecotones, with ponderosa pine trees found overtopping shrubs on both historical forest sites as well as historical shrubland sites. Additionally, research indicates that fire exclusion due to historical intensive livestock grazing and tree harvesting has led to a broadening of ecotone boundaries, with shrubs increasing within pine forests as well as coniferous trees expanding into chaparral and evergreen woodlands. (Huffman *et al.* 2018).

Mixed Conifer

"Mixed Conifer" includes a wide range of vegetation types and fire regimes. Mixed conifer has been classified into warm/dry, or cool/moist (Romme *et al.* 2009; Korb *et al.* 2013; Wahlberg *et al.* 2017 (in draft)), which can also be distinguished by their natural fire regimes. In this analysis, mixed conifer will be referred to as WMC (Mixed Conifer with Aspen, or Wet Mixed Conifer) or DMC (Mixed Conifer - Frequent Fire, or Dry Mixed Conifer).

Historically, mixed conifer in the southwest had highly diverse composition and structure. This diversity was largely driven by topography, with the scale of the mosaic of cover types dependent on the scale of topographic variation. Ridgetops and low elevation sites were (and largely still are) characterized by open stands dominated by ponderosa pine and had frequent surface fires. South and west-facing slopes likely were similar, but were less open and had less ponderosa and more Douglas-fir, aspen and white fir. These stands likely also were characterized by frequent surface fires. North and east-facing slopes were likely more dense and had still less ponderosa and more white fir, as well as Engelmann spruce and subalpine fir, especially at higher elevations. Douglas fir (*Pseudotsuga menziesii*) tends to dominate drier sites where ponderosa pine does well. *Abies concolor* tends to dominate cooler sites, such as upper slopes at higher elevations, canyon sideslopes, ridgetops, and north and east-facing slopes which burn somewhat infrequently. *Picea pungens* is most often found in cold, moister locations, often occurring as smaller patches or frost bands within a matrix of other associations. As many as seven conifers can be found growing in the same stand.

Tree species found in mixed conifer forests exhibit a wide range of tolerance to shade and low severity fire; these traits are often related (Strahan *et al.* 2016). Those species adapted to establish and grow in low light conditions below other trees often have thin bark and are easily killed by fire (Evans *et al.* 2011). Conversely, ponderosa pine is well adapted to fire, having thick, insulating bark. On the ground, there is a gradient of biotic and abiotic factors, with some sites being clearly wet or dry mixed conifer, and many sites in a grey area between that can be difficult to identify clearly as one or the other, either in existing condition or historic condition (Figure 11). This is particularly true where the disturbance cycles have been interrupted, and vegetation is significantly departed from historic conditions. Some sites have become so dominated by shade-intolerant species that their classification as DMC was changed to WMC (Margolis and Malevich 2016). Below are descriptions of WMC and DMC as they apply to this analysis.

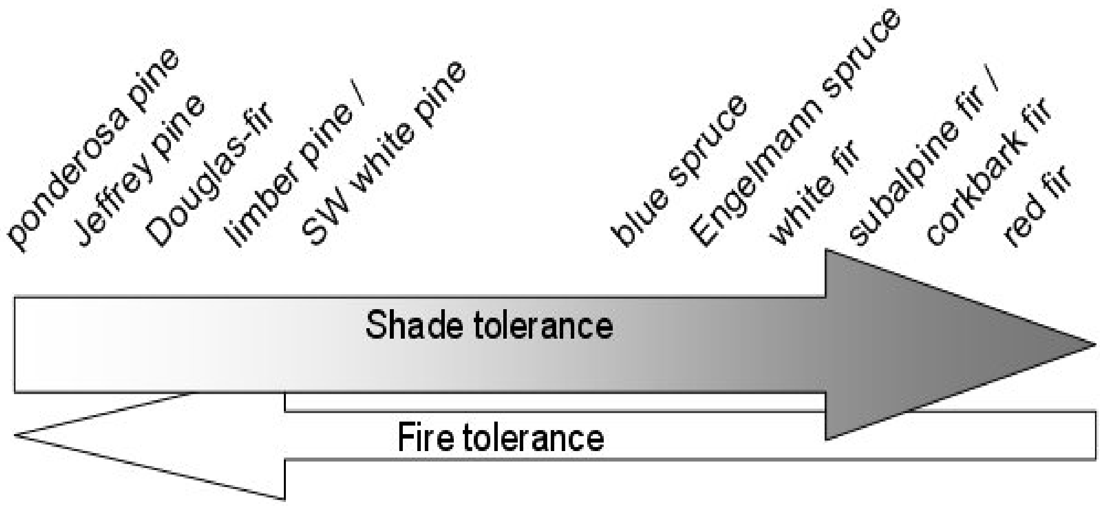

Figure 11: Relative shad and fire tolerance of common tree species in mixed conifer forests (from (Burns *et al.* 1990))

Mixed Conifer with Frequent Fire (Dry Mixed Conifer)

Dry Mixed Conifer (DMC) covers approximately 63,000 acres within the area proposed for treatment in Rim Country. It generally occurs at elevations between 6,000 and 10,000 feet, with some variability depending on aspect. DMC is generally situated between ponderosa pine or pinyon-juniper woodlands below wetter mixed conifer or and spruce-fir forests above. Historically, DMC was dominated by ponderosa pine (*Pinus ponderosa* var. *scopulorum*) in an open forest structure (Reynolds *et al.* 2013; Rodman *et al.* 2016; Huffman *et al.* 2018), with minor occurrence of aspen (*Populus tremuloides*), Douglas-fir (*Pseudotsuga menziesii*), white fir (*Abies concolor*), and Southwestern white pine (*Pinus strobiformis*). Species vary in relation to elevation and moisture availability and are mainly shade intolerant trees. In lower elevations and drier areas, Douglas-fir, Gambel oak, ponderosa pine, piñon, and juniper may co-dominate. In higher elevations and moister areas, ponderosa pine may co-dominate with Rocky Mountain Douglas-fir, aspen, white fir, southwestern white pine, and Rocky Mountain juniper. The understory can be composed of a wide variety of shrubs, grasses, sedges, rushes, and forbs depending on the soil type, aspect, elevation, disturbance history, and other factors (Wahlberg *et al.* 2017 (in draft)).

Fire Ecology

Historical fire regimes were probably similar to those widely reported for montane ponderosa forests of the Southwest. Frequent surface fires likely kept forests in open structural conditions and limited the abundance of woody understory species. A 2015 study that included areas on the Black Mesa Ranger District of the Apache-Sitgreaves National Forest, fire return intervals ranged from about 2 to 60 years, averaging about 12 (Heinlein *et al.* 2005; Huffman *et al.* 2015). Available evidence in DMC forests suggests that high severity patches would have been generally been less than 60 acres, with the larger patches being less common (Huffman *et al.* 2015; Yocom Kent *et al.* 2015).

History

Tree establishment patterns compared with widespread fire dates did not suggest historical high-severity fires at the site level. Strong evidence of high-severity fire at finer scales was lacking, though spatial locations of 'young' plots suggested the possibility of historical high-severity disturbances. The historical fire regime on this landscape was one of high frequency, low-severity fires (Huffman *et al.* 2015). This would have supported a finer grained pattern of vegetation than is currently present. Current conditions show a coarser pattern that would be more consistent with a less frequent, mixed to high severity fire regime, increasing the susceptibility to stand-replacing fire, even where such regimes were uncommon historically (Abella and Springer 2014; Rodman *et al.* 2016). Fire and drought tolerance have decreased since pre-settlement times, driven largely by increases in the relative importance of white fir (*Abies concolor*) and southwestern white pine (*Pinus strobiformis*), but also shifts from shade intolerant species to shade tolerant species (Strahan *et al.* 2016).

Emissions and Air Quality

Wildland fire emissions can cause adverse health effects and/or become a nuisance, but are fundamental to the disturbance ecology associated with healthy ecosystems that are adapted to frequent fire. Fire will occur in the project area in some form, regardless of the decision made based on this EIS, so air quality impacts are evaluated for all the alternatives. Air quality within the project area currently meets EPA air quality standards.

Wildfire vs. Prescribed Fire

Smoke is inevitable in the airsheds of fire adapted ecosystems, such as those of Northern Arizona. Federal land managers have the role of protecting and meeting air quality standards while simultaneously allowing fire, as nearly as possible, to function in its natural role in the ecosystem (USDA and USDOI 1995). Smoke and visibility impairment from wildland fire that closely mimics what would occur naturally is generally viewed as acceptable (Peterson 2001).

Currently, prescribed fires are regulated and their emissions are monitored and regulated in the same manner as emissions sources that are more controllable (such as dust, vehicle emissions, smoke from wood-burning stoves, industrial emissions, etc.), and included in air quality assessments used to approve burn plans. Smoke impacts from wildfire can be more difficult to mitigate 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 how to manage a wildfire, or whether to ignite a prescribed fire is whether the potential benefits of the wildfire outweigh all of the smoke impacts. Prescribed fires and wildfires both create smoke, but differ in the amount, timing, and predictability of these events (Table 7). Most wildfires in the southwest occur between late April and mid-September. Currently, most prescribed fires are implemented in the early spring or late fall.

Fire managers are able to manage smoke impacts to some degree by implementing prescribed fire and when ventilation conditions are favorable. It may be possible to minimize burning and/or hold a fire in check on days when reduced emissions are needed. It can be advantageous to blackline a burn unit well in advance of burning the entire unit to take advantage of burn windows with good ventilation. Various Emissions Reductions Techniques (ERTs) are utilized and documented as a standard part of implementing prescribed fires. (see Appendix C: Design features, Best Management Practices, and Mitigation). A 'Daily Burn Accomplishment Form' is completed and submitted for each day a burn is being implemented (see Appendix C: Design features, Best Management Practices, and Mitigation).

Table 7. 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 (other than smoke), such as downstream flooding or damage to infrastructure outside the fire perimeter	Low, but present	Low to very high
Threat to human life and property	Low, but present	Low to very high

Activities on prescribed fires and wildfires in an airshed are coordinated between fire managers, working with the Arizona Department of Air Quality, to either spread high emission producing events from multiple wildland fires 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 concentration and duration of smoke impacts.

Actual smoke impacts are dependent on numerous factors, some predictable, some less so. Air quality impacts are more closely related to ventilation parameters, live and dead fuel moisture, wind direction and speed, fuel chemistry, firing techniques, timing and duration of ignition, fuel arrangements and loading, atmospheric stability, than the Rim Country Alternatives.

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 in the vegetation types targeted for restoration treatments in this analysis produce behavior and effects that are mostly low to moderate. Large, uncharacteristically high severity fires usually create more emissions over a longer time that prescribed fires, because of differences in the size and duration of the fires (Hardy *et al.* 2001) 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).

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 limit how much smoke an airshed can absorb at any point in time without violating NAAQS (details on page 10) 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 12) and, as such, during daytime hours, fire activities within the Rim Country 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, dead/down wood), which often 'pools' 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 (page 10) 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" (Appendix A-10, pg. 35 of the Arizona State Implementation Plan)

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

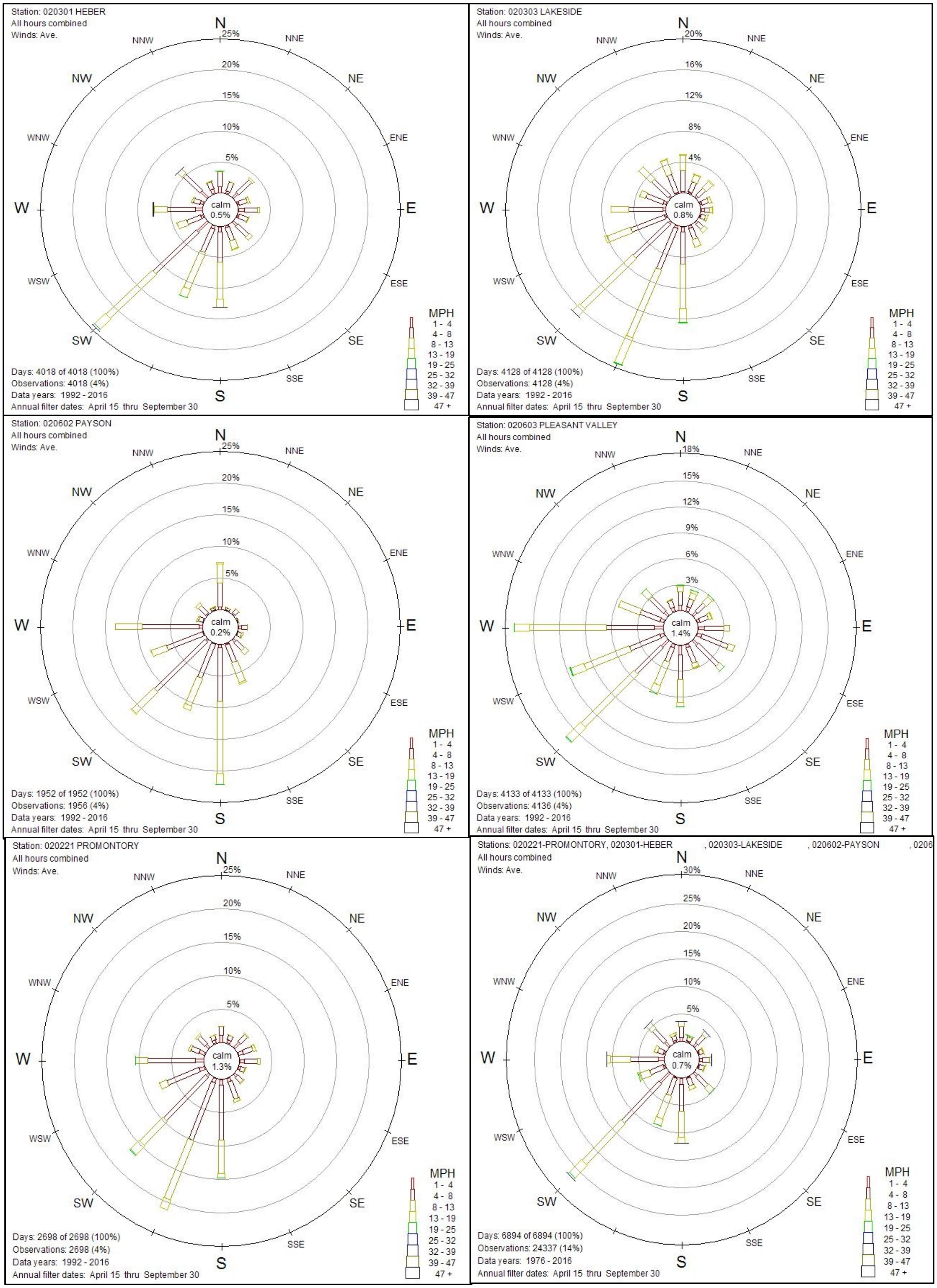

Figure 12: Wind roses from Remote Automated Weather Stations (RAWS) showing average wind speed and direction in the project area. Bottom right: data averaged from all RAWS.

Emissions and Public Health

- There are six pollutants identified by the Environmental Protection Agency (EPA) that are considered to be 'fire-related' pollutants (Hyde *et al.* 2017), these are:
    - **Carbon monoxide** (CO) is a colorless, tasteless, odorless gas produced primarily by motor vehicles. Other sources include wood-burning stoves, fireplaces, wildland fires and industries that process metals or manufacture chemicals. High CO concentrations can occur in large urban areas and mountain valleys. CO is poisonous at high levels and can damage the heart and central nervous system.
    - **Lead** in the air exists primarily as particulates. The major source used to be gasoline, but is currently metals processing. Other sources are waste incinerators, utilities, and lead-acid battery manufacturers. Lead particularly affects young children and infants, and is found at high levels in urban and industrial areas. Lead deposits on soil and water, and can harm other animals.
    - **Nitrogen Dioxide** (NO2) has a reddish-orange-brown color and a pungent odor. Nitrogen oxides form when fuel is burned at high temperatures, as in a combustion process. The primary sources are motor vehicles, electric utilities, and other industrial, commercial, and residential operations that burn fuels. Some nitrogen dioxide is emitted by wildland fires. NO2 is easily converted to nitrates, a major component of acid rain, contributing to impacts on vegetation, visibility, and soil and water quality. Nitrogen dioxide also impairs human health.
    - **Ozone** is an unstable gas, and has a characteristic odor. Ozone forms when hydrocarbons and nitrogen oxides chemically react in sunlight. Motor vehicle exhaust and industrial emissions, gasoline vapors, chemical solvents and natural sources emit compounds that form ozone. Ozone can trigger a variety of health problems including permanent lung damage after long-term exposure. It can also damage plants and ecosystems.
    - **Particulate Matter** (PM) consists of particles of solid or semi-solid materials in the atmosphere. Most human-made particles are 0.1 to 10 micrometers in diameter. Particulates less than or equal to 10 micrometers (PM10) can cause respiratory problems, while larger particulates settle out of the air. Airborne dust, or particle pollution, causes significant problems with human health and the environment, and should be minimized. Particulates less than or equal to 2.5 micrometers (PM2.5) are generally created during combustion and are the major cause of visibility impairment. These fine particles move over long distances by wind and settle on ground or water. High PM concentrations are often associated with large urban areas or mountain valleys where dust, smoke, and emissions are common. Health effects of PM include: respiratory problems, decreased lung function, asthma, chronic bronchitis, irregular heartbeat, nonfatal heart attacks, and premature death in people with heart or lung disease.
    - **Sulfur dioxide** (SO2) is a colorless gas that easily dissolves in water to form acid. It is a major pollutant throughout the world and potentially carcinogenic. The main source is burning fossil fuels.

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. All of these pollutants except lead are monitored and reported by the daily Air Quality Index (AQI), which ranging from Good to Hazardous (Figure 13). This index focuses on adverse health effects from exposure to unhealthy air. Each day, monitors record concentrations of the major pollutants at more than a thousand locations across the country. These raw measurements are converted into a separate AQI value for each pollutant (ground-level ozone, particle pollution, carbon monoxide, and sulfur dioxide) using standard formulas developed by EPA. The highest of these AQI values is reported as the AQI value for that day.

While it is difficult to determine exactly how much emissions from wildfire fires contributes to the overall AQI compared to other polluters such as vehicles, dust and industrial pollutants, trends in AQI can help identify areas with increased need for mitigation of wildfire emissions. The pollutant most directly linked to AQI and wildfires is Particulate Matter (both PM10 and PM2.5)

AQI Value	Actions to Protect Your Health From Particle Pollution
Good (0 - 50)	None
Moderate (51 - 100*)	Unusually sensitive people should consider reducing prolonged or heavy exertion.
Unhealthy for Sensitive Groups (101 - 150)	The following groups should reduce prolonged or heavy outdoor exertion: - People with heart or lung disease - Children and older adults
Unhealthy (151 - 200)	The following groups should avoid prolonged or heavy exertion: - People with heart or lung disease - Children and older adults Everyone else should reduce prolonged or heavy exertion.
Very Unhealthy (201 - 300)	The following groups should avoid all physical activity outdoors: - People with heart or lung disease - Children and older adults Everyone else should avoid prolonged or heavy exertion.

Figure 13: AQI Table with levels of health concerns. Taken from the Environmental Protection Agency's airnow.gov website: https://airnow.gov/index.cfm?action=aqi_brochure.index

Particulate Matter (PM)

Air pollutants called particulate matter (PM) 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. This pollutant is the greatest concern of wildland fire emissions, from wildland fire (Ottmar 2001; Graham 2012-2014), 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. The EPA has used 'PM10' since 1987 to refer to particles of 10 micrometers or less in the ambient air. In 1997, the EPA added 'PM2.5', which includes only those particles with aerodynamic diameter smaller than 2.5 micrometers.

Studies indicate that 90% of smoke particles emitted during wildland fires are PM 10, and about 90% of PM10 is PM2.5 (Ward and Hardy 1991). Human health studies on the effects of particulate matter indicate that it is PM2.5 that is largely responsible for health effects (Dockery *et al.* 1993). Because of its small size PM2.5 has an especially long residence time in the atmosphere, penetrating deeply into lungs (Ottmar 2001).

The Clean Air Act defines the NAAQS for PM 2.5 as an annual mean of 15µg/m3, and a 24 hour average of 35µg/m3. 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. Particulate matter can from sources other than fire. In many cases windblown dust and dust kicked up on unpaved roads by vehicle traffic, such as logging trucks, account for much of this fine particulate matter (Kleindienst 2012).

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, and may soil or damage materials.

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.

Radioactive emissions

Radioactive emissions are out of the legal scope of this analysis. However, during the SCOPING periods for the first 4FRI EIS, concerns were raised about the potential for radioactivity in smoke from prescribed fire treatments proposed in 4FRI to contain radioactive substances, so it has been included in this analysis.

During the Cerro Grand fire of 2000, there was also considerable public concern regarding the potential release of radionuclides from fires burning on lands managed by 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:

http://www.nmenv.state.nm.us/OOTS/PR/2011/NMED_Monitoring_Air_Quality_in_Los_Alamos.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/nmrcb/documents/LasConchasFireAirMonitoring.html).

A study that included Lockett Meadow, within the project 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.* ; Graham 2012-2014).

Communication with the EPA (Gerdes 2012 - 2014; Graham 2012-2014), and studies that addressed these emissions (H. *et al.* 2002; 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 (Graham 2012-2014) and NMED 2002 as cited above) and the greatest health risk is from breathing high concentrations of particulate matter in the smoke.

Mercury

Mercury in emissions is out of the legal scope of this analysis. However, during the SCOPING periods for the first 4FRI EIS, concerns were raised about the potential for there to be mercury in smoke from prescribed fire treatments proposed in 4FRI to contain radioactive substances, so it has been included in this analysis.

Mercury is present at some background level around the world, and is sometimes present in emissions from wildland fires (Friedli *et al.* 2003; Biswas *et al.* 2007; Wiedinmeyer and Friedli 2007; Obrist *et al.* 2008; Selin 2009; De Simone *et al.* 2016; Webster *et al.* 2016). However, there is insufficient science to support conclusions about specific effects from the prescribed fires proposed in the Rim Country EIS. General conclusions may be possible, but no valid effects could be presented so, even if we did have the means of providing an estimate of mercury emissions, we would still not know the effects. We were not able to find any information on levels of mercury in the biomass in or near the project area, or in emissions from wildfires or prescribed fires in, or close to the project area. The amount and impact of mercury that is in emissions from a specific fire depends on how much mercury is present in the biomass that is burning; how intensely the fire burns, moisture content of the fuel, how complete the burn is, and wind for the duration of the time there are emissions in the air. There is little question that there would be more mercury in emissions from high intensity wildfires than from the low intensity fires that would typify the prescribed fires proposed by the Rim Country (Friedli *et al.* 2003; Biswas *et al.* 2007; Obrist *et al.* 2008; Lahm 2014; Webster *et al.* 2016). Mercury is not a Criteria Pollutant, that is, it is not one of the six substances for which there are National Ambient Air Quality Standards, because it is not considered an 'ambient' substance. Mercury is regulated as a "point source", meaning emissions are regulated by the specific sources which discharge pollutants into the air from a specific and clearly discernable discharge point, such as a power plant. Additionally, prescribed fires help reduce the intensity of ensuing wildfires for several years, depending on the pre-burn condition of the burn unit (Brennan and Keeley 2015).

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 8). 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 Rim Country 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 8. Smoke sensitive areas and sensitive receptors

Area	Proximity to implementation area	Concerns
Verde Valley	Less than 10 miles downslope south and southwest of project area	Hospitals, schools, human habitation, young children, senior citizens,
The Navajo Reservation	Northeast and east of the project area	Hospital, schools, human habitation, young children, elders
Fort Apache Reservation	Adjacent to project area to the south and east	Hospital, schools, human habitation, young children, elders
The Hopi Reservation	Northeast and east of the project area	Hospital, schools, human habitation, young children, elders

Area	Proximity to implementation area	Concerns
Snowflake / Taylor	About 15 miles north of the project area	Human habitation, schools, young children, seniors
Tonto Basin /Roosevelt	About 10 miles south southwest of the project area	Human habitation, schools, young children, senior citizens
Show Low	Project area to the east and west of Show Low	Hospital, human habitation, schools, young children, seniors
Heber Overgaard	Project area is adjacent to town in multiple directions	Human habitation, young children, school, seniors
Strawberry / Pine	Project area is on all sides of the both towns	Human habitation, young children, school, seniors
Blue Ridge	Project area is on all sides of the developed areas	Human habitation, young children, seniors
Pinetop/Lakeside	Project area is on all sides of the project area	Human habitation, young children, school, seniors
Payson	Project area is on all sides of the project area	Hospital, schools, human habitation, young children, seniors

A ‘Class I’ 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 Rim Country project area are Petrified Forest National Park, Mazatzal Wilderness, and Sierra Anchas Wilderness (Figure 14).

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.

The night skies over the Northern Arizona offer professional and amateur astronomers exceptional viewing opportunities. There are several astronomical sites in northern Arizona, but the closest one is over 30 miles mostly west and south from the boundary of the project area, so the impacts would be expected to be minimal.

Non-attainment areas are where air quality has violated one or more of the National Ambient Air Quality Standards (page 10). 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.”

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

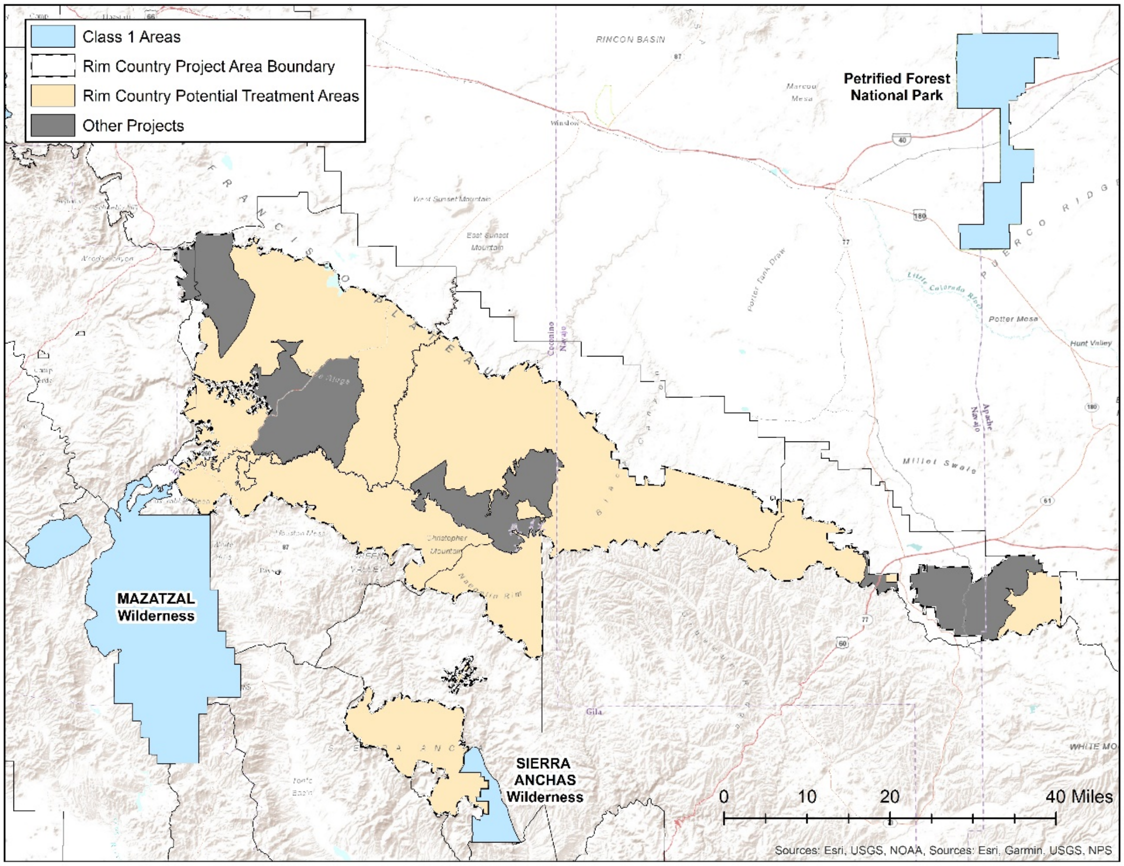

Figure 14: Class 1 areas with greatest potential to be impacted by Rim Country Smoke

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 (Tong and Mauzerall 2008; Koo *et al.* 2010) . 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, 5 and can be expected to experience the majority of the smoke impacts originating from the proposed treatment area.

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 fires and from wildfires that are not being actively suppressed

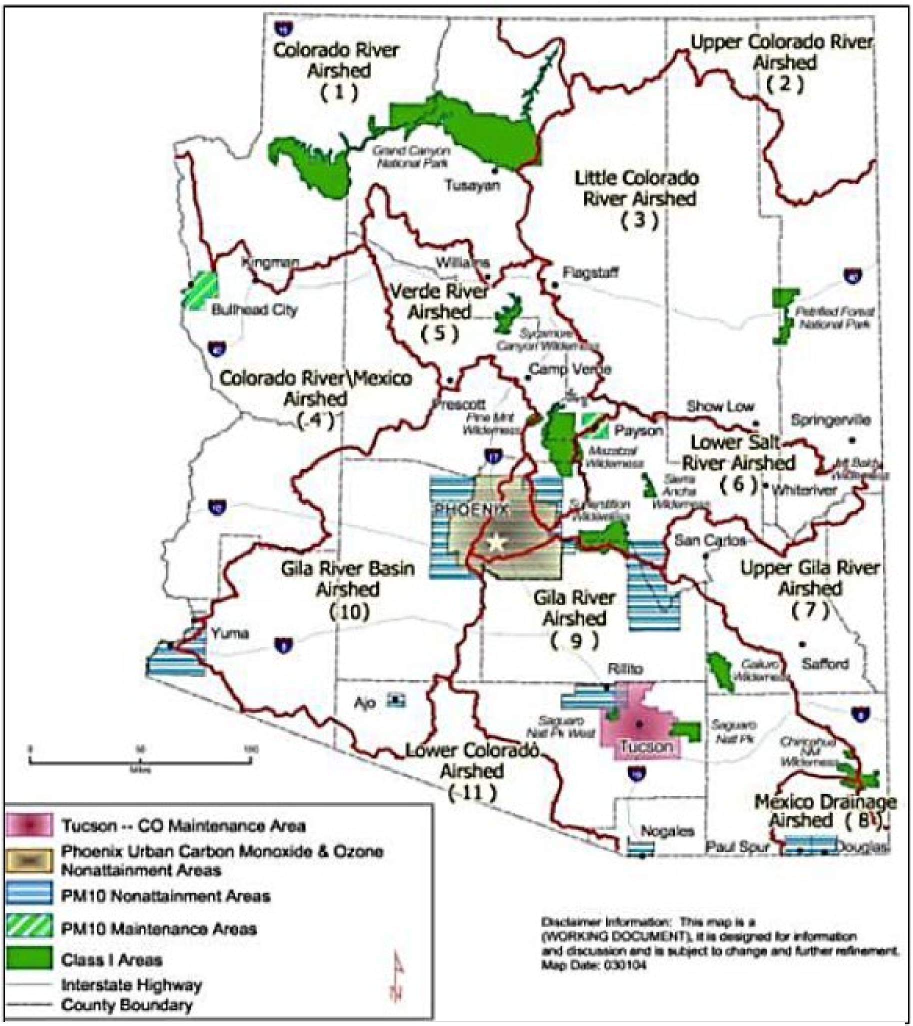

Figure 15: Arizona State Airsheds

in 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 partnership with the State, and housed in the ADEQ offices in Phoenix. The personnel in the group are funded largely by 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 area towards desired conditions in the Forest 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.

The Forest Service will continue to adhere to requirements in the Arizona State Implementation Plan to meet natural condition visibility goals. 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 track emissions concentrations, and other equipment captures images for evaluating visibility. 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 are primarily concerned with the reduced quality of highly valued scenic views.

Visibility is measured in deciviews (dv). A 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/. This includes data for all Class I areas that have monitors.

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. The 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 (Kleindienst 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 fires 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 year 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

Fire has historically played an important role in defining the character of ecosystems in Northern Arizona. The cover types in the Rim Country analysis that are targeted for restoration treatments are adapted to frequent fire, often area-wide fires (Cooper 1960; Covington *et al.* 1997b; Kaib 2001; Fulé *et al.* 2003; Huffman 2017), indicating an even more frequent smoke regime. Research in Northern Arizona has shown that the emergence of many species is enhanced by exposure to smoke from ponderosa pine needle litter (Abella 2006; Abella *et al.* 2007; Lata 2015).

From an ecological perspective, smoke effects are important to the germination of many native plants and, in some cases, appear to be more important than heat (Abella 2006; Abella *et al.* 2007; Schwilk and Zavala 2012; Lata 2015; Keeley and Pausas 2016). 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 may be attributable to the lack of smoke, or changes in the timing of smoke exposure (Abella 2006; Abella *et al.* 2007; Lata 2015). Many species with adaptations to smoke occur in the Rim Country project area, including, but not limited to, *Nama dichotomum, Heliomersis longifolia, Penstemon barbatus, Penstemon virgatum, Artemisia ludoviciana, Erigeron speciosus, Linum lewisii,* and *Symphyotrichum falcatum.* Pine needle smoke may also be a natural control for mistletoe and other tree infections (Parmeter and Uhrenholdt 1974; Alexander and Hawksworth 1976; Zimmerman and Laven 1987).

Desired and Existing Conditions for Metrics and Measures

Fire Type

Desired Conditions

The desired conditions for fire type generally depends on the vegetation cover type and the proximity to other highly valued resources and assets. For the target vegetation cover types in the project area, the desired conditions are to have less than approximately 20 - 25% of the cover type experience crown fire, with no more than 5 – 10% being active crown fire (see Table 11 below). These values should be lower within the wildland urban interface (WUI).

Existing Conditions

Currently, under extreme weather, 73% of the Rim Country project area is expected to burn with crown fire, and 31% of that is expected to be active. This assumes a wind of 20 MPH which regularly occurs during the fire season (Figure 17) but represents extreme fire weather under which suppression tactics are unlikely to be highly successful.

Post wildfire watershed effects increase with the percent of the watershed that burns at moderate to high severity fire (Cannon 2010; Neary 2011). Currently, 46 watersheds have expected active crown fire under extreme weather conditions for over 30% of the watershed, which would result in high severity effects (Figure 16). Eleven watersheds are have over 50% of the watershed expected to burn with active crown fire. Watersheds 7 (Reynolds Creek) and 56 (Durfee Draw-Chevelon Canyon) have the highest proportion of potential for active crown fire (67% for both). If a wildfire were to burn within these watersheds, detrimental post wildfire effects would be expected

Fire Hazard Index

Desired Conditions

The fire hazard index is not specifically identified in forest plans and therefore, there are no desire conditions. Rather it is a composite measure that represents an overall hazard both during a fire event and after an event (see Table 4 above). Areas with higher FHI are expected to burn with undesirable fire behavior that makes suppression difficult and dangerous. In addition to the immediate fire behavior, high FHI values are also expected to produce undesirable post fire effects such as increased chances of debris flows, erosion, invasive weeds and vegetation type conversion. The lower the FHI, the less chances such undesirable fire effects are to occur, and there is less need for treatment resulting in a more fire adapted the landscape.

Existing Conditions

Currently 37% of the Rim Country project area has an FHI of moderate or higher (Figure 18), which presents difficult and dangerous suppression conditions during a wildfire and potential for adverse post fire effects on soils and surface water quality. Four percent of the landscape is in the very high category.

There are 23 watersheds with over 50% of the watershed in the moderate to very-high FHI categories (Figure 19). Watershed 7 (Reynolds Creek, 76%) and 59 (Upper Spring Creek, 77%) have the highest proportion of FHI in the moderate to very high class. Large wildfires in these watersheds have a high potential to be difficult and dangerous to suppress, and have a high potential for dangerous fire management conditions and adverse post fire effects.

Surface fuels

Desired Conditions

Forest plan direction is shown below in Table 9, along with surface fuel loadings that are 'recommended' in regards to fire effects. Recommended surface fuel loadings are estimates, based on the best available science and expert opinion (Ottmar 2015) on the interaction of surface fuel loading with fire behavior and fire effects.

Combining maximum recommended fuel loadings from the forest plans for ponderosa pine types in a healthy ponderosa pine forest, total recommended surface fuel loading is approximately 27 tons/acre.

For dry mixed conifer, little information was available for surface fuel loading other than CWD for dry mixed conifer, so recommendations were taken from Wahlberg et al. 2017 based on Contemporary Model State E dominated by ponderosa pine. Recommended CWD levels for Dry Mixed Conifer include the broadest range of the forest plans, and will be 5 – 15 tons/acre. Recommendations used for all other surface fuel components in dry mixed conifer, as shown in Table 9, are as follows: duff less than 5.5 tons/acre, litter less than 4 tons per acre, FWD less than 6 tons/acre. Total recommended surface fuel loading should be less than 30 tons/acre (Wahlberg *et al.* in draft).

If the total surface fuel loading exceeds the recommended surface fuel loadings indicated in Table 9, there would be potential for undesirable direct and indirect fire effects including tree mortality from needle scorch and/or root/cambium damage, consumption of organic matter in the top layers of soil affecting living roots, seeds, mycorrhizae, and heat damage to the soil. Furthermore, smoke from excessive surface fuel loading burning in wildfires under unfavorable conditions could negatively impact air quality (Hardy *et al.* 1998). While these recommended levels are not 'desired conditions', this analysis will inform a discussion on the potential fire effects from surface fuel loading that directly or indirectly would affect desired conditions. This metric (total surface fuel loadings) is used as a general recommendation, though site specific needs would vary across the treatment area.

Existing Conditions

Desired conditions for total surface fuel loadings are less than 27 tons/ac in Ponderosa Pine vegetation types and less than 30 tons/ac in Dry Mixed Conifer. Currently, 105,528 acres have total surface fuel loadings greater than 27 tons/acre. Surface fuel loadings exceed recommended levels for 69,935 acres of Ponderosa Pine and 18,288 acres of Dry Mixed Conifer vegetation types (Figure 20).

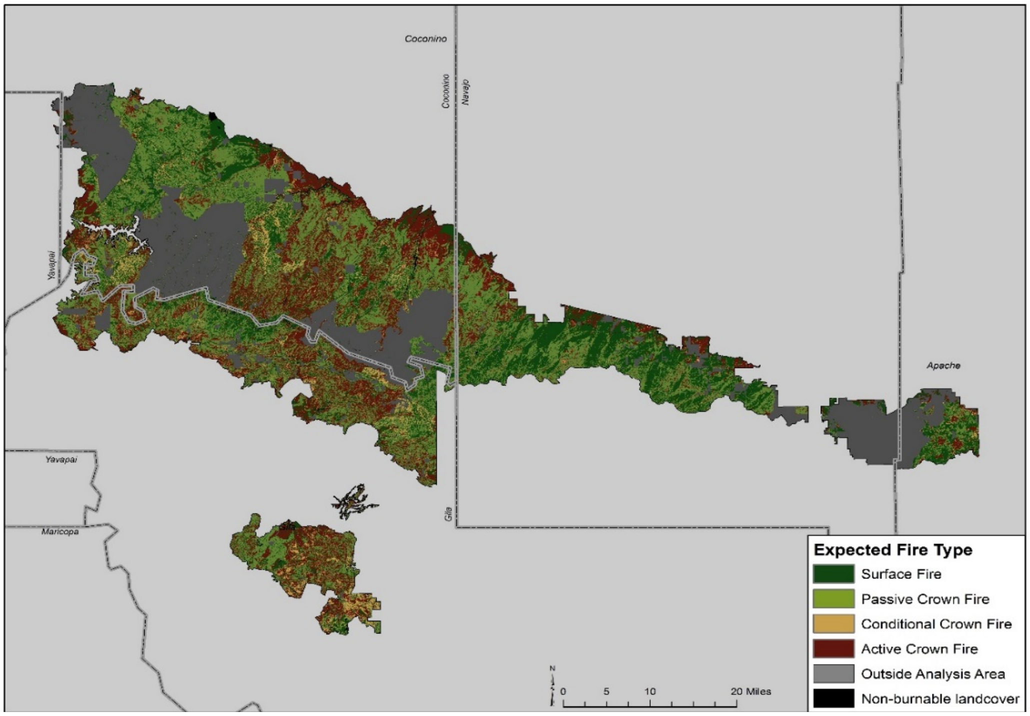

Figure 17: Expected Fire Type for Existing Conditions, under modeled weather conditions.

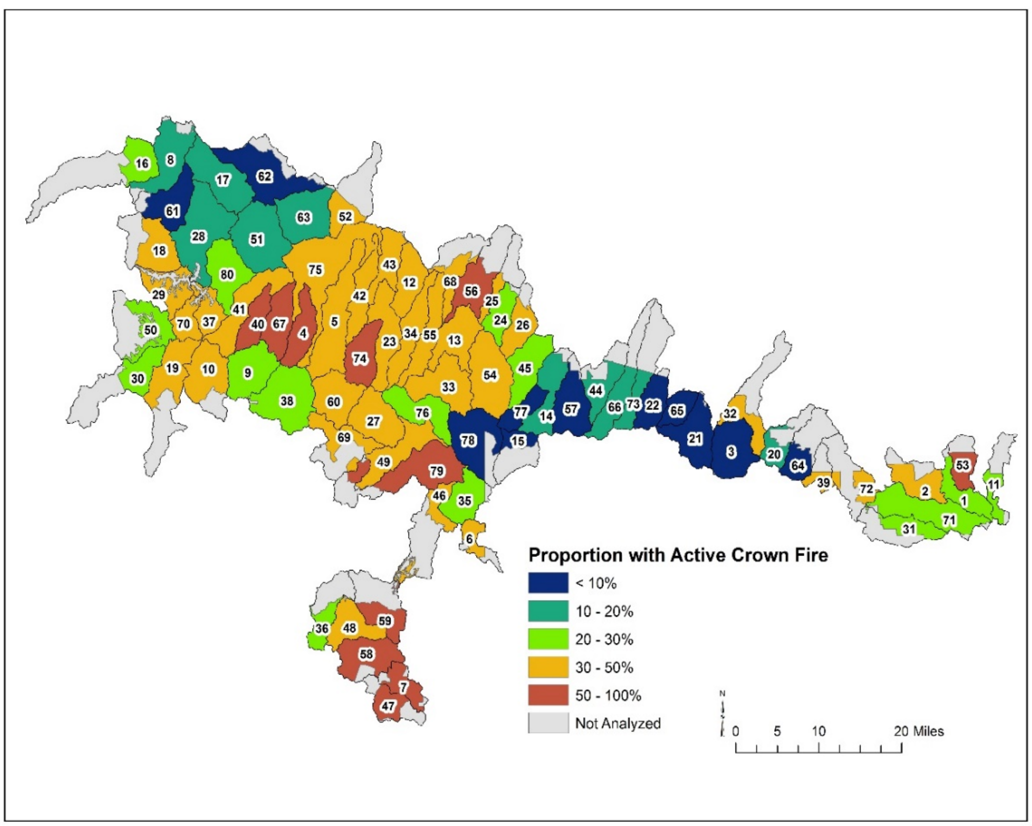

Figure 16: Existing Conditions Proportion of HUC6 watersheds with expected Active Crown Fire, under modeled weather conditions.

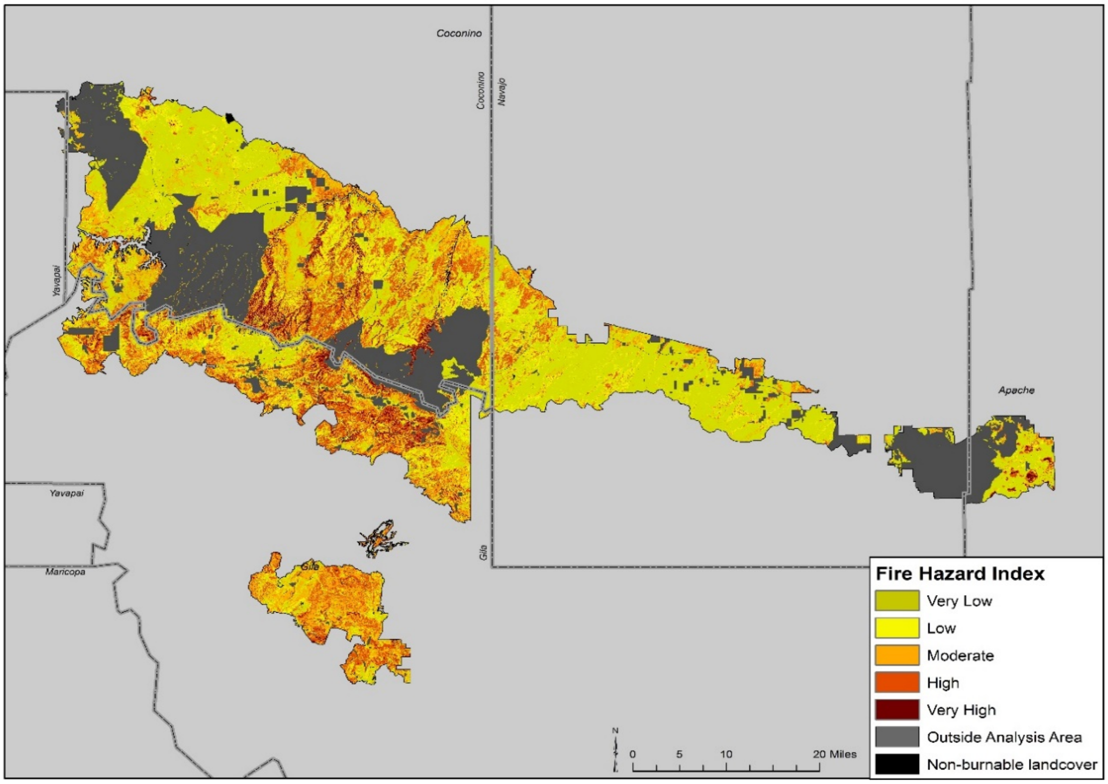

Figure 18: Fire hazard Index for Existing Conditions, under modeled fire weather

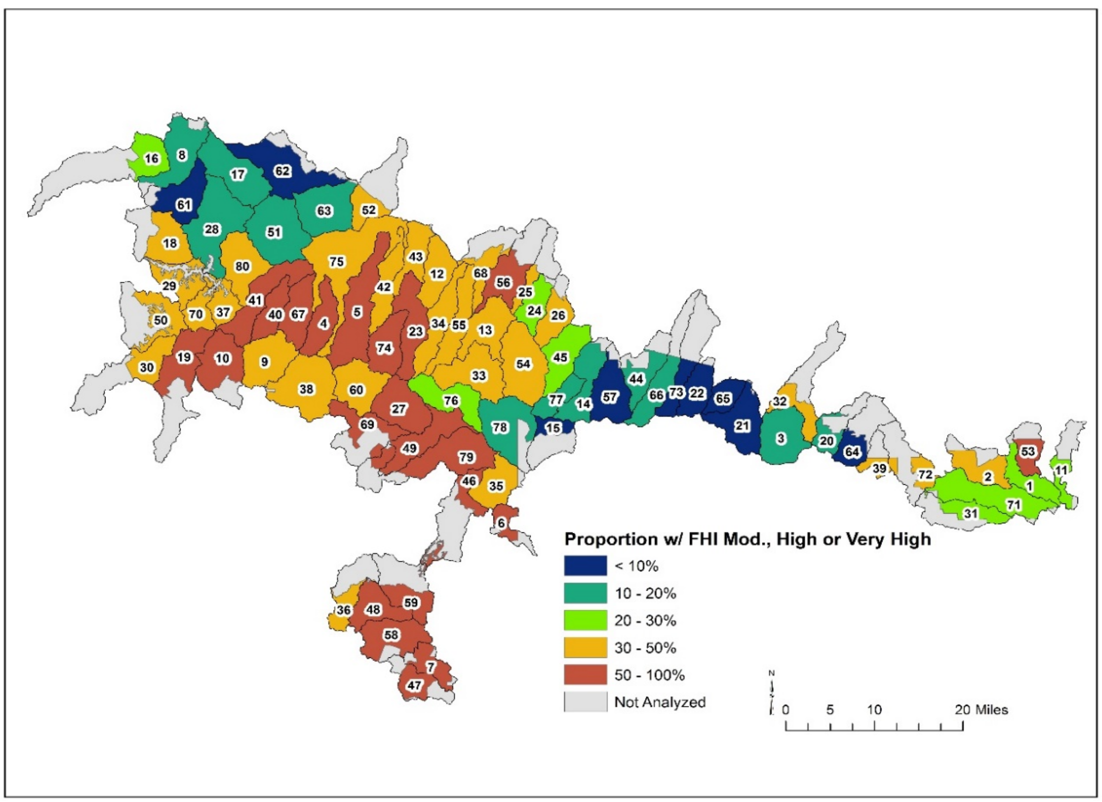

Figure 19: Proportion of each HUC6 watershed with FHI in the moderate, high or very high category for Existing Conditions, under modeled fire weather

Table 9: Forest Plan direction for surface fuel loading that significantly affect fire behavior, fire effects, and/or emissions.

Cover Type	Type of Fuel (tons/acre)	Tonto	Coconino	Apache / Sitgreaves	Recommended for the Rim Country Project area*	Acres exceeding levels
Ponderosa Pine	CWD	5 – 7 (or as directed by the current forest plan)	3-10	3 - 10	Total Levels < 27 tons/acre	Total levels = 35,505
	FWD, litter, duff	"Maintain a minimum of 30% effective ground cover for watershed protection and forage production...Where less than 30% exists…goal is to obtain a minimum of 30% effective ground cover." Multiple references to 'suitable ground cover'.	"Ground cover consists primarily of perennial grasses and forbs capable of carrying surface fire,... A mosaic of dense cover, high amounts of litter, and bare ground provide habitat for a variety of species..."	"...60 percent or greater of soil cover is composed of grasses and forbs as opposed to needles and leaves."		
Dry Mixed Conifer	CWD	10 – 15 (or as directed by the current forest plan)	5 - 15	5 - 15	Total Surface Fuel Loads < 30	TOTAL 16,765
	FWD, litter, duff	"Maintain a minimum of 30% effective ground cover for watershed protection and forage production...Where less than 30% exists, it will be the management goal to obtain a minimum of 30% effective ground cover." Multiple references to 'suitable ground cover'.	"...A mosaic of dense cover, high amounts of litter, and bare ground provide habitat for a variety of species... Graminoids, forbs, shrubs, needle cast (fine fuels), and small trees maintain the natural fire regime..."	"...60 percent or greater of soil cover is composed of grasses and forbs as opposed to needles and leaves."		

*Informed by consult with Roger Ottmar (Ottmar 2015)

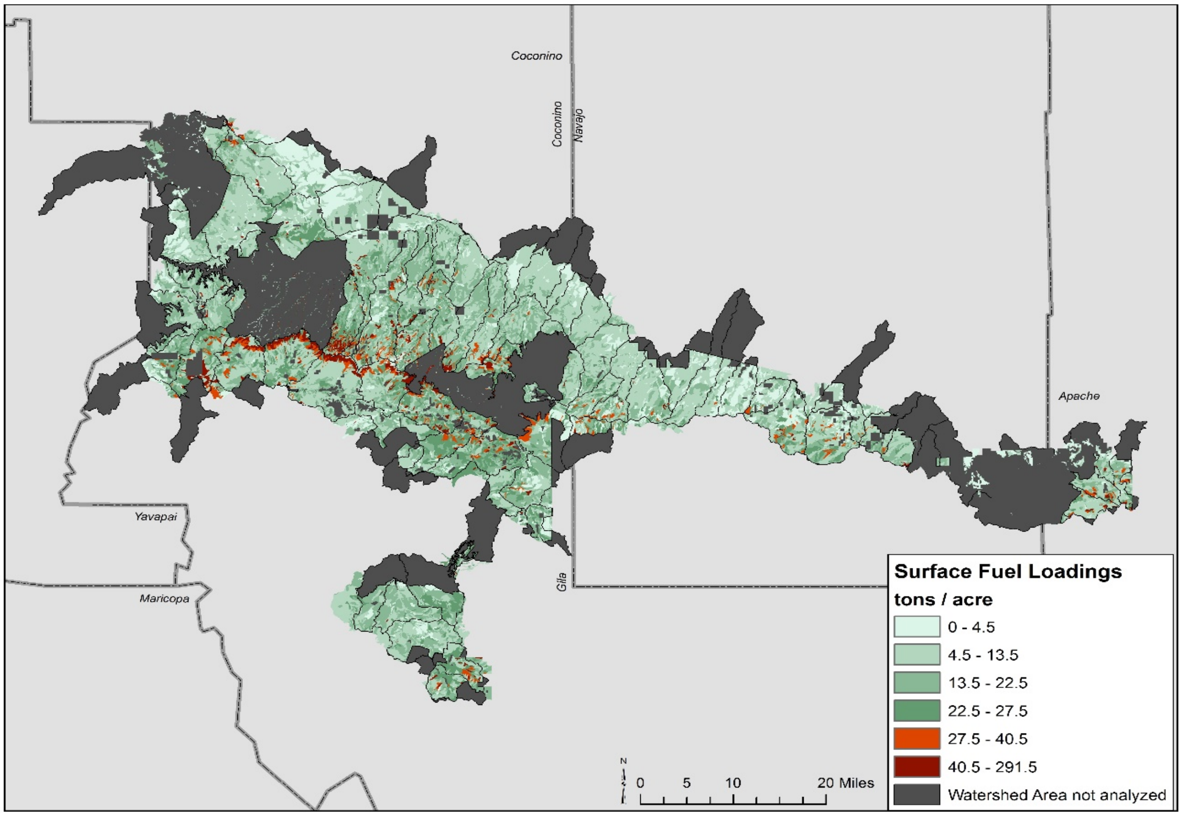

Figure 20: Total Surface Fuel Loadings in tons per acre. Areas in orange and red exceed recommended levels.

Desired and Existing Conditions for Resources, Values and Assets

Wildfire Management

Desired Conditions

It also states that wildland fire . . . "would be used to protect, maintain, and enhance resources and, as nearly as possible, be allowed to function in its natural ecological role as a disturbance factor in the ecosystem." (USDA and USDOI 2009

The Cohesive Strategy takes a holistic approach to the future of wildland fire management, and identifies three primary, national goals:

- Restore and Maintain Landscapes, making them resilient to fire-related disturbances.
- Create Fire-adapted Communities.
- Ensure safe, effective, and efficient Wildfire Response.

• Human life, property, and natural and cultural resource are protected within and adjacent to NFS lands.

• Wildland fires burn within the range of frequency and intensity of natural fire regimes. Uncharacteristic high severity fires rarely occur and do not burn at the landscape scale.

• Wildland fire maintains and enhances resources and functions in its natural ecological role.

1 *Public and firefighter safety is the highest priority in managing fire.*
2 *Wildland fires burn within the historic fire regime of the vegetation communities affected. High-severity fires occur where this is part of the historical fire regime and do not burn at the landscape scale.*
3 *Wildland fires do not result in the loss of life, property, or ecosystem function.*
4 *People understand that wildland fire is a necessary natural disturbance process integral to the sustainability of the ecosystems in which fire is the primary disturbance.*

The priorities for managing wildland fire will be the protection of public and firefighter safety, property, natural and cultural resources to minimize negative impacts

Existing Conditions

Currently there are many conditions which fires burn that do not allow for wildfires to be managed in such as manor that do not result in the loss of life, property or ecosystem function. Wildfires are not always burning within natural fire regimes. Recent economic and ecological high loss wildfires in the area include the Rodeo Chedisky, Whitewater Baldy, and Wallow fires. The Rodeo Chedisky fire destroyed 426 residences.

The recent Tinder Fire, which burned within the project area, consumed 41 homes in 2018.

The dude fire of 1990 claimed 6 lives and 63 homes.

Schultz and Highline fires both resulted in post wildfire debris flows that resulted in deaths.

The Yarnell Hill fire just southwest of the project area in fuel similar to those found on the Tonto National Forest (though not indicative of the Rim Country project area). 19 fire fighters lost their lives in that fire and 127 homes burned.

https://www.nifc.gov/fireInfo/fireInfo_stats_histSigFires.html

Lowering the probability of large scale high severity fires, particularly around areas adjacent to the wildland urban interface, will move the landscape towards the desired conditions of safe, effective wildfire management. Currently XX acres within the project area have potential for active crown fire. There are XX acres in the most extreme FHI and XX acres in the moderate to high classes of FHI, all of which have potential for high intensity, difficult to suppress wildfires with potential to cause adverse post wildfire effects such as debris flows.

Wildland Urban Interface

Desired Conditions

Safe and effective firefighting environment. More open than the rest of forest….

Existing Conditions

Prescribed fire is often focused on areas strategic to Wildland Urban Interface, and many prescribed burns next to WUIs have been implemented in the past 24 years. While this has lowered fire hazard within this area relative to the general landscape, desired conditions are not fully met, where 27% - 41% of the lands surrounding the WUI have potential for active crown fire and 34% - 51% are in the moderate to very high fire hazard index category (Table 10)

Table 10: Existing Conditions Metrics for the Wildland Urban Interface Classes

WUI CLASS	Total Acres	Fire Hazard Index				Fire Type	
		Very Low - Low	Moder-ate	high	very high	Passive & Active Crown Fire	Active Crown Fire
High Value Rec. Sites	375	49%	16%	18%	16%	79%	38%
Communication Sites	2074	66%	15%	17%	2%	75%	27%
NonFS Lands w/ structures	22638	66%	16%	15%	3%	68%	28%
Transmission Lines	4083	64%	18%	15%	3%	66%	32%
FS Buildings	1683	51%	14%	27%	8%	83%	41%

Large and/or old trees

Desired Conditions

Ideally, there 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.

Existing Conditions

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. In the historic period, mortality in large trees was mostly caused by lightning fires, dwarf mistletoe, bark beetles, windthrow, or senescence (Cooper 1960). Since the exact location of Large/old trees is unknown the analysis of this value at risk is qualitative and comparisons will be made as such.

Vegetation Cover Types

The desired and existing conditions for the primary target cover vegetation cover types are discussed below. A detailed discussion of the desire and existing conditions for the other vegetation cover types in Rim Country can be found in Appendix XX. Table 11 shows a summary of the metrics measured for each vegetation cover type.

Table 11: Desired and Existing Conditions for vegetation cover types for each metric.

Vegetation Cover Type (VCT)	Total Acres	Fire Type				Fire Hazard Index			Total Surface Fuel Loading		
		All Crown Fire		Active Crown Fire		Mod-erate	high	very high		Meets	Exceeds
		Desired % of VCT	Exist-ing %	Desi-red %	Existin g %	Existi ng %	Existi ng %	Exist ing %	Desired (tons / ac)	Existing (ac)	Existing (ac)
Ponderosa Pine	556284	< 20%	72%	< 5%	21%	9%	12%	2%	< 27	XX	XX
Ponderosa Pine Evergreen Oak	147989	< 25%	82%	< 10%	29%	31%	24%	4	< 27	XX	XX
Dry Mixed Conifer	49281	< 20%	75	< 7	50	18	27	26	< 30	XX	XX

Wet Mixed Conifer	3130	NA	71%	NA	66%	5%	25%	38	NA	NA	NA
Aspen	1438	NA	6%	NA	4%	1%	3%	2%	NA	NA	NA
Pinyon Juniper	135085	NA	71%	NA	65%	34%	26%	2%	NA	NA	NA
Madrian Pinyon Oak	23318	NA	85%	NA	79%	31%	43%	6%	NA	NA	NA
Grasslands	18851	< 3%	15%	< 1%	3%	2%	0%	0%	NA	NA	NA
Riparian Areas	14567	NA	44%	NA	18%	11%	11%	5%	NA	NA	NA

Ponderosa Pine (Montane)

Desired Conditions

Desired conditions for montane ponderosa pine forests include fire regime that have been restored to a sustainable state and is maintained by a combination of planned and unplanned ignitions which regulate landscape structure, pattern, and composition, aligning forest changes with climate changes.

Under current climate conditions, the desired Fire Return Interval would average about 12 years, but with a fair amount of variability (Weaver 1951; Cooper 1960; Moore *et al.* 1999; Fulé *et al.* 2003; Heinlein *et al.* 2005; Diggins *et al.* 2010). The vast majority of acres would burn with low severity surface fire. There would be potential for crown fire on no more than 20% of the montane ponderosa pine (under conditions modeled), with less than 5% being active crown fire. High severity acres would be spatially distributed and rarely occur in patches as large as 50 acres (Cooper 1960; Swetnam and Baison 1996; Roccaforte *et al.* 2008).

In a very general sense, ponderosa pine is a Fire Regime 1, with a fire return interval <35 years, and <25% high severity. A 20 year maintenance Fire Return Interval (almost doubling the historic Fire Return Interval) should be the average maximum, with some variability produced by differences in soils, precipitation, natural ignition frequencies. Fire in montane ponderosa pine forests should be more frequent close to the edge of the Mogollon Rim, because the slightly higher precipitation allows ponderosa pine seedlings to mature at a faster rate and with a higher survival rate (in the absence of fire). Therefore, the maintenance return interval for those areas should be closer to 10, with a 20 year interval being the maximum in the drier areas. A delay of more than 20 years between fires or treatments is likely to result in undesirable fire behavior and effects.

Existing conditions of ponderosa pine (Montane)

Existing conditions, as modeled under extreme conditions, indicate potential for 72% of this vegetation cover type to burn with crown fire. Of that, 21% would be active crown fire Table 11. About 11,125 acres (2%) of the montane ponderosa pine is in the “very high” category of the Fire Hazard Index, and another 116,820 acres are in the moderate to high category. In those areas, fire effects could produce irreversible detrimental effects when topsoil is burned or eroded, changing site potential for decades.

Ponderosa Pine – Evergreen Oak & Transitional pine (PPEO)

Desired Conditions

Desired conditions for this vegetation type need to be site specific because, in its historic condition, there was potential for high intensity/high severity fire in some capacity. If site-specific information indicates that high severity fire would have been the historic fire potential for a given site, consideration needs to be given to potentially affected values at risk as a treatments are set up for implementation. Restoration treatments in this cover type should include reducing the density of trees that have established due to fire exclusion; reintroduction of frequent surface fire, and reducing shrub abundance to favor herbaceous species in understory communities (Huffman *et al.* 2018). There would be an annual fire return interval of about 7 years, with some variability based on individual site evaluation. Some of the crown fire potential indicated by the modeling could, on the ground, be representing patches/inclusions of naturally occurring chaparral or Madrean types for which higher levels of high severity is normal. Fire regimes would be maintained by a combination of planned and unplanned ignitions.

Existing Conditions

Long-term fire suppression in this type, has created conditions where large areas are highly departed from historic conditions. Typically these changes include in-filling of the canopy gaps, increased density of tree groups; reduced composition, density and vigor of the herbaceous understory plants. Other significant changes resultant from fire exclusion are increased homogeneity of the shrub structural stages on the landscape, facilitating larger patch sizes of high-severity fire effects. Currently, many of these sites are closed-canopy forests, capable of supporting active crown fire (Wahlberg *et al.* 2017 (in draft)) .

The lack of fire has allowed sprouting shrub species to become established underneath ponderosa pine, more so in the Evergreen Shrub Subclass. It is patchy, with areas of mostly chaparral-like vegetation interspersed with areas of ponderosa pine cover. Historically, the patchiness would be maintained by high severity fire in areas where there is less ponderosa pine, and more even-aged stands with low to mixed severity fire where there are ponderosa pine needles to facilitate the more frequent fire. The effects of fire suppression are decreased herbaceous surface cover and diversity, and the associated fire behavior producing increased severity in both the PPEO and the Shrub Subtype. This is conducive to fewer pines and more sprouting shrubs. Most of the Shrub Subclass occurs at the lower elevations of the ponderosa pine, and/or on drier, hotter areas. There are no spatial data available for the inclusions of what could be naturally occurring shrub patches, so these areas were all delineated as PPEO.

Under modeled conditions, there is potential for 69% of the PPEO to support crown fire; 36% of that would be active crown fire (Table 11). Almost 40,000 acres (25%) of the PPEO is classified as being at 'high' or 'greatest' need for treatment. In these areas, type conversion to a shrub system is a high probability because of the vigorous sprouting response of various shrubs to being top-killed, and the difficulty of ponderosa seedlings to thrive with that competition.

Dry Mixed Conifer

Desired Conditions

Fire should be allowed to play its natural role, with a fire return interval averaging about 12-15 years with mostly low severity; less than 20% crown fire, with <7% active crown fire. High severity patches would rarely reach 60 acres.

Existing Conditions

On contemporary landscapes, more shade tolerant conifers, such as Douglas-fir, white fir, and blue spruce (*Picea pungens*), tend to increase in cover in late succession, contrary to conditions under the characteristic fire regime. Historically, these species could have achieved dominance in localized settings where aspect, soils, and other factors limited the spread of surface fire, but this would not have been widespread. Much of this type is currently dominated by closed structure and climax species as a result of a disrupted fire regime (Swetnam and Baison 1996; Huffman *et al.* 2015; Rodman *et al.* 2016; Wahlberg *et al.* 2017 (in draft)).

Modeled conditions show that, currently, there is potential for about 37,400 acres (77%) of DMC to burn with crown fire, of which about 26,156 acres (54%) would be active crown fire (Table 11). About 20,000 acres (43%) of the mixed conifer has a 'high' or 'greatest' need for treatment.

Air Quality

Desired Conditions

Desired conditions for Air Quality for the Rim Country analysis are:

- Air quality meets all State and Federal ambient air quality standards.
- Visibility in Mount Baldy, Superstition, Mazatzal, and Sierra Ancha Wildernesses, which are 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.

Existing Conditions

Coconino County enjoys good air quality most of the time. From 1992 – 2015, 168 days were rated above moderate, and none were rater higher than unhealthy. Approximately 2% of days per year were rated in the Unhealthy for Sensitive Groups or Unhealthy category, and no days were rated Very Unhealthy or Hazardous (US EPA 2010). Navajo County had 40 days and Apache County only had one day in the Unhealthy for Sensitive Groups category. All other days were in the good to moderate category, however there are many days missing (~ 64%) in the Navajo County record. Gila County has had higher AIQ values, with approximately 30% of days in categories higher than moderate for the same time period, and one day in the Very Unhealthy category due to PM10.

Management activities with the largest direct impact on Air Quality are prescribed fires. Road dust has not been demonstrated to be a measureable contributor on a regional level to visibility in the 16 Class I areas located on the Colorado Plateau (ADEQ 2003). In the last ten years, acres of prescribed fire have increased across all three forests, though the actual amount fluctuates from year to year (Figure 21). Table 6 (page 41) displays the average number of acres by alternative that need to burn annually (prescribed fire or wildfire) to produce the desired fire return interval in the target vegetation types.

Total surface fuel loadings also determines the amount of emissions produced per acre during a wildfire (or prescribed fire), since much of the lingering smoke comes from duff, CWD, litter, stumps, and other fuels that can smolder. Watersheds 75 (East Clear Creek / Clear Creek) and 79 (Haigler Creek) have the greatest potential to produce emissions due to high total surface fuel loading (Figure 22). Watersheds 4 (Barbershop Creek) and 27 (Christopher Creek) have the most dense total surface fuel loading, both with an average of 24 tons/acre.

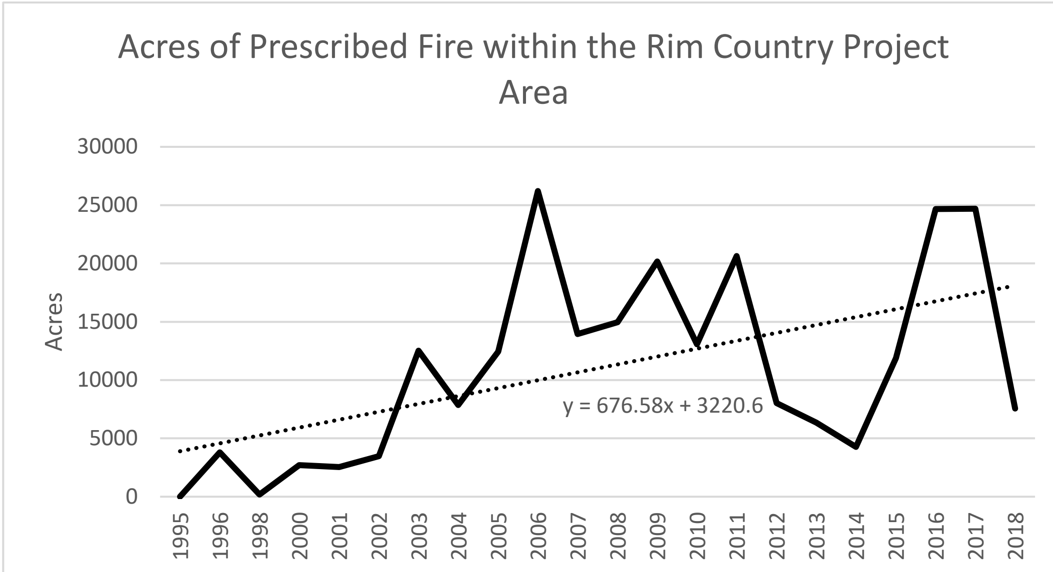

Figure 21: Acres of prescribed fire and trends for Rim County Project Area from 1995 through 2018.

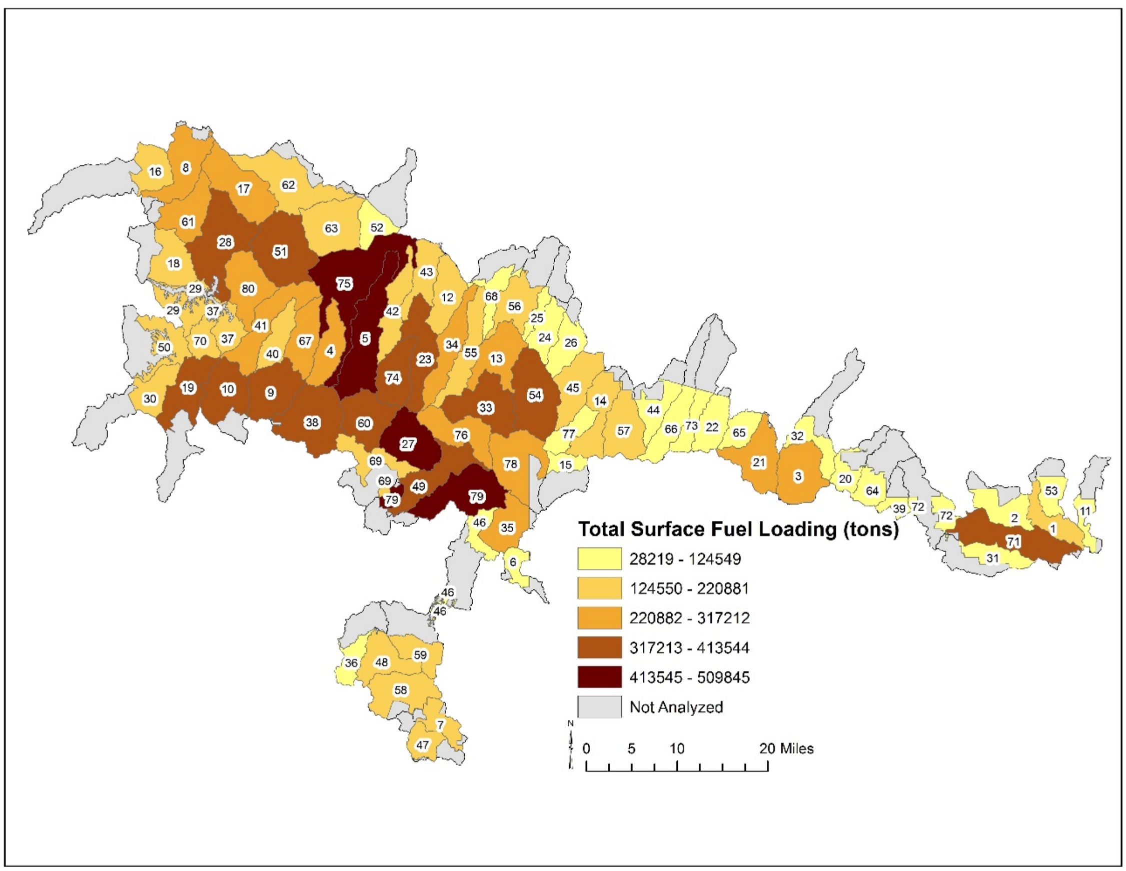

Figure 22: Total Surface Fuel loadings of each HUC-6 watershed for Existing Conditions, as modeled using FVS

Summary of Alternatives

Alternative 1 – No Action

This is the no action alternative as required by 40 CFR 1502.14(c). There would be no changes in current management and the forest plans would continue to be implemented. Approximately 611,851 acres of ongoing, current and reasonably foreseeable (next 5 years) of vegetation treatments and 59,815 acres of prescribed fire projects would continue to be implemented adjacent to the treatment area. Alternative 1 is the point of reference for assessing action alternatives 2 and 3.

Alternative 2 – Revised Proposed Action

Alternative 2 proposes a mixture of mechanical and/or prescribed fire treatments on 953,132 acres (77%) of the 1.24 million acre project area. Approximately 889,344 acres are proposed for mechanical treatment, following be two prescribed fires within 10 years, and the remaining 63,788 acres are proposed for prescribed fire treatment only. Approximately 36,216 acres of grassland restoration is also proposed.

Further activities include road decommissioning and improvements:

- The Tonto National Forest Travel Management EIS has identified approximately 290 miles of road within the Rim Country analysis area for decommissioning. In addition to system road decommissioning, up to 800 miles of unauthorized roads on all 3 forests may be decommissioned under this alternative.
- Improve approximately 150 miles of existing non-system roads and construct approximately 330 miles of temporary roads for haul access; decommission all temporary roads when treatments are completed.
- Relocate and reconstruct existing open roads adversely affecting water quality and natural resources, or of concern to human safety.
- Decommission approximately 200 miles of existing system and unauthorized roads on the Coconino and Apache-Sitgreaves NF.

Information on the details of the locations and type of treatments can be found in the Silviculture report.

Alternative 3 – Focused Alternative

This alternative is designed to focus restoration treatments in areas that are the most highly departed from the natural range of variation (NRV) of ecological conditions, and/or that put communities at risk from undesirable fire behavior and effects. High value assets will be better protected and burn boundaries will be designed to create conditions safe for personnel and to ensure fire can meet objectives. Treatment areas would be chosen to optimize ecological restoration, those areas that are most important to treat and can be moved the furthest toward desired conditions. Focusing on the higher priority ecological restoration will result in fewer acres being treated.

Alternative 3 is a subset of Alternative 2, where treatments will be implemented on 528,060 acres (43%) of the 1.24 million acre project area. Approximately 483,158 acres of mechanical treatment followed by 2 prescribed burns within 10 years are proposed. An additional 45,902 acres of prescribed fire alone are proposed. These treatments surround areas of high value and concern to resource managers. Alternative 3 responds to the Smoke/Air Quality, Economics, Roads, and Dwarf Mistletoe Mitigation issues.

Approximately 36,217 acres of grassland restoration is also proposed.

Further activities include road decommissioning and improvements:

- Decommission approximately 230 miles of existing system and unauthorized roads on the Coconino and Apache-Sitgreaves NFs.
- Decommission approximately 20 miles of unauthorized roads on the Tonto NF.
- Improve approximately 150 miles of existing non-system roads and construct approximately 350 miles of temporary roads for haul access; decommission all temporary roads when treatments are completed.
- Relocate and reconstruct existing open roads adversely affecting water quality and natural resources, or of concern to human safety.

Information on the details of the locations and type of treatments can be found in the Silviculture report.

Environmental Consequences

Throughout this section, changes directly attributable to proposed actions, such as thinning or prescribed fire, are direct effects. These include changes to shading, canopy continuity, canopy base height, consumption of surface fuel, etc. Changes to the potential behavior and effects of future wildfires that result from the direct effects are considered indirect effects. Effects of proposed actions for stream restoration and roads are discussed separately from those of thinning and prescribed fire.

Alternative 1 – No Action

Under Alternative 1, there would be no changes to current management. Alternative 1 would not meet the purpose and need of this project because most of 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 (page 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 1 are indirect because there would be no new management actions. The effects of implementing Alternative 1 are discussed as follows:

1. Rim Country Project Area and Watershed analysis of measures and metrics
2. Values, Resources and Assets analysis of measures and metrics
    a. Wildfire Management
    b. WUI
    c. Vegetation Cover Types
    d. Old Growth Trees
    e. Air Quality

This alternative would not meet the purpose and need of Rim Country. Under Alternative 1, all three forest plans would continue to be implemented, but there would be no decrease in undesirable fire behavior and effects, except that resulting from wildfires or other natural disturbances. The direct and indirect effects of Alternative 1 relate to the effects of the continued degradation of surface and canopy fuel conditions, and the effects of the continued interruption of the natural fire regimes. These include the potential for the direct effects of large, high-severity wildfires occurring within the project area. The indirect effects of such burns could also compromise water resources due to post-fire 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, Snowflake, and Showlow.

Rim Country Project Area Metrics and Measures

The Alternative 1 modeled percent active crown fire, percent in the moderate to extreme Fire Hazard Index and the mean surface fuel loadings for each 6th code HUC in the project area are presented in Table 12.

Table 12: Alternative 1 HUC 6 watershed metrics.

Map Label	Watershed Name	% Active Crown Fire	% Moderate - Extreme FHI	Mean Surface Fuel Loading (tons/ac)
1	Upper Brown Creek	30%	31%	17
2	Upper Rocky Arroyo	37%	36%	13
3	Mortensen Wash	12%	12%	13
4	Barbershop Canyon	56%	73%	28
5	Leonard Canyon	50%	59%	20
6	Gentry Canyon	49%	67%	17
7	Reynolds Creek	68%	81%	25
8	Double Cabin Park-Jacks Canyon	13%	13%	16
9	East Verde River Headwaters	30%	49%	23

10	Webber Creek	39%	60%	21
11	Sepulveda Creek	25%	28%	18
12	Cabin Draw	35%	36%	14
13	Upper Chevelon Canyon-Chevelon Canyon Lake	36%	44%	17
14	Bear Canyon-Black Canyon	19%	21%	14
15	Bull Flat Canyon	6%	10%	17
16	Red Tank Draw	21%	23%	19
17	Upper Willow Valley	11%	11%	16
18	Home Tank Draw	37%	33%	11
19	Pine Creek	40%	58%	23
20	Linden Draw	15%	15%	13
21	West Fork Cottonwood Wash-Cottonwood Wash	6%	6%	13
22	Upper Day Wash	7%	7%	7
23	Upper Willow Creek	47%	54%	23
24	Middle Wildcat Canyon	25%	27%	11
25	Lower Wildcat Canyon	43%	42%	8
26	Upper Potato Wash	40%	39%	12
27	Christopher Creek	45%	61%	26
28	Lower Willow Valley	12%	13%	13
29	Upper West Clear Creek	45%	47%	16
30	Hardscrabble Creek	30%	47%	15
31	Billy Creek	23%	24%	16
32	Dodson Wash	34%	33%	9
33	Long Tom Canyon-Chevelon Canyon	42%	47%	22
34	Upper West Chevelon Canyon	38%	47%	20
35	Parallel Canyon-Cherry Creek	33%	50%	20
36	Rock Creek	21%	51%	17
37	Clover Creek	42%	45%	21
38	Ellison Creek	25%	42%	17
39	Fools Hollow	40%	40%	16
40	Miller Canyon	55%	62%	22
41	East Clear Creek-Blue Ridge Reservoir	51%	56%	18
42	Wilkins Canyon	43%	46%	19
43	Lower Willow Creek	47%	47%	16
44	Upper Pierce Wash	14%	12%	8
45	Upper Brookbank Canyon	28%	29%	14
46	Gruwell Canyon-Cherry Creek	39%	62%	17
47	Workman Creek	50%	68%	23
48	Buzzard Roost Canyon	47%	72%	17
49	Gordon Canyon	46%	65%	25
50	Upper Fossil Creek	32%	39%	17
51	Windmill Draw-Jacks Canyon	19%	19%	15
52	Hart Tank	49%	44%	7
53	Ortega Draw	60%	56%	11
54	Upper Wildcat Canyon	47%	50%	18
55	Alder Canyon	36%	40%	17
56	Durfee Draw-Chevelon Canyon	68%	63%	11
57	Buckskin Wash	6%	6%	12
58	Upper Salome Creek	51%	73%	17
59	Upper Spring Creek	55%	77%	22
60	Horton Creek-Tonto Creek	37%	53%	22
61	Brady Canyon	6%	6%	16
62	Tremaine Lake	7%	7%	7
63	Dogie Tank-Jacks Canyon	13%	15%	8
64	Bagnal Draw-Show Low Creek	6%	6%	14
65	Stinson Wash	10%	11%	9
66	Upper Phoenix Park Wash	14%	13%	10
67	Bear Canyon	55%	66%	23

68	Lower West Chevelon Canyon	44%	39%	9
69	Bull Tank Canyon-Tonto Creek	42%	62%	16
70	Toms Creek	51%	55%	20
71	Porter Creek	26%	27%	17
72	Show Low Lake-Show Low Creek	40%	40%	11
73	Decker Wash	11%	10%	9
74	Gentry Canyon	61%	71%	26
75	East Clear Creek-Clear Creek	39%	43%	15
76	Woods Canyon and Willow Springs Canyon	29%	30%	18
77	West Fork Black Canyon	9%	16%	16
78	Canyon Creek Headwaters	9%	15%	18
79	Haigler Creek	52%	72%	23
80	Long Valley Draw	32%	32%	16

Fire Type

Fires that did occur in the project area would be wildfires; some of which could be beneficial, and some could be catastrophic or detrimental, depending on environmental conditions at the time of the fire, and the condition of the forests at the time they burn. If historic patterns of burn severity were to continue, approximately 73% of the area burned in wildfires larger than 1,000 acres would burn with low severity effects that could be beneficial. However, given extreme weather conditions, there would be an increased potential for crown fire compared to the existing conditions. All crown fire types (active, passive or conditional) can be expected across approximately 80% of the project area under extreme weather conditions (Figure 23), up from 73% in the existing conditions. Approximately 33% of the projected area has the potential to burn with active or conditional crown fire, up from 31% in the existing conditions.

Post wildfire watershed effects increase with the percentage of the watershed that burns at moderate to high severity (Cannon, 201; Neary 2011). Under Alternative 1, 47 watersheds are expected to burn with active crown fire under extreme weather conditions for over 30% of the watershed, resulting in high severity effects (Figure 24). Thirteen watersheds are have over 50% of the watershed expected to burn with active crown fire. Watersheds 56 (Durfee Draw-Chevelon Canyon) and 7 (Reynolds Creek) have the highest proportion of potential for active crown fire (68% for both). If a wildfire were to burn within these watersheds, detrimental post wildfire effects would be expected.

Fire Hazard Index

The short term (< 20 years) effects of Alternative 1 would include an increased risk of undesirable wildfire behavior and effects. Wildfire behavior and effects could threaten lives, resources, and infrastructure. Forty percent of the project area is within the moderate to extreme FHI, which presents difficult and dangerous suppression conditions during a wildfire and potential for adverse post fire effects on soils and surface water quality, up from 37% in the existing conditions (Figure 25).

There are 25 watersheds with over 50% of the watershed in the moderate to very high FHI categories (Figure 26). Watershed 7 (Reynolds Creek, 80%) and 107 (Upper Spring Creek, 77%) have the highest proportion of FHI in the moderate to very high class. Large wildfires in these watersheds have a high potential to be difficult and dangerous to suppress, and have a high potential for adverse post fire effects.

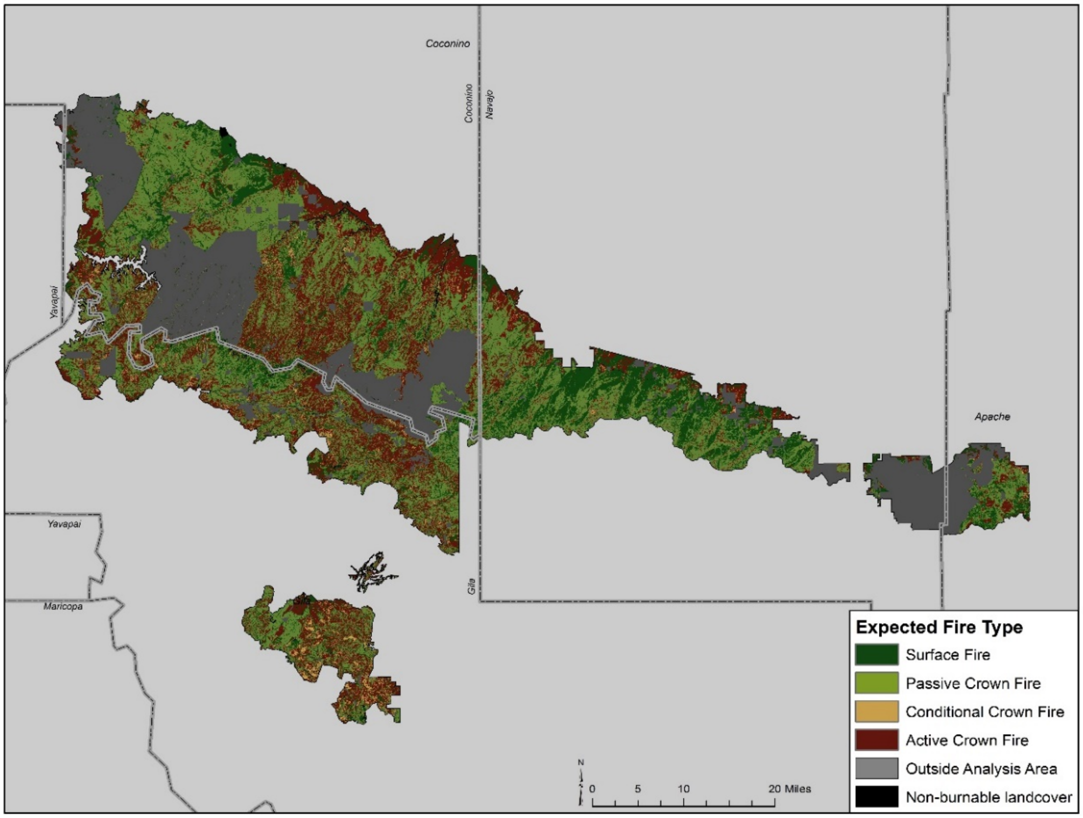

Figure 23: Expected Fire Type for Alternative 1, under modeled weather conditions.

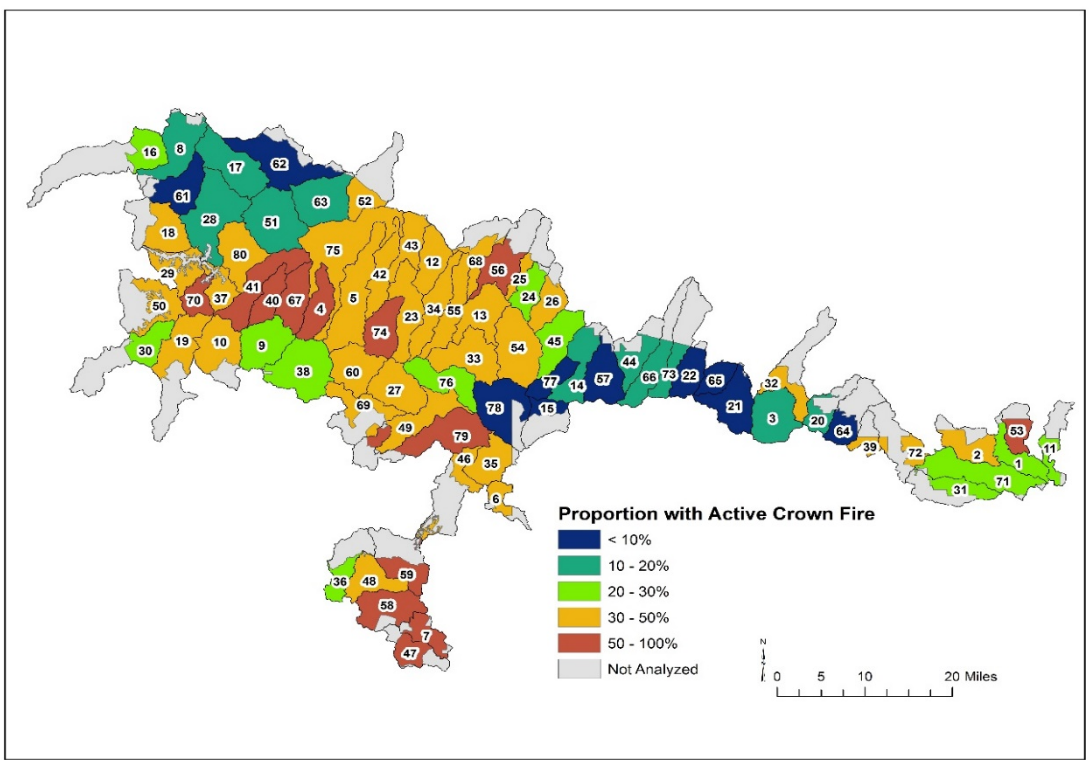

Figure 24: Alternative 1 Proportion of HUC6 watersheds with expected Active Crown Fire, under modeled weather conditions.

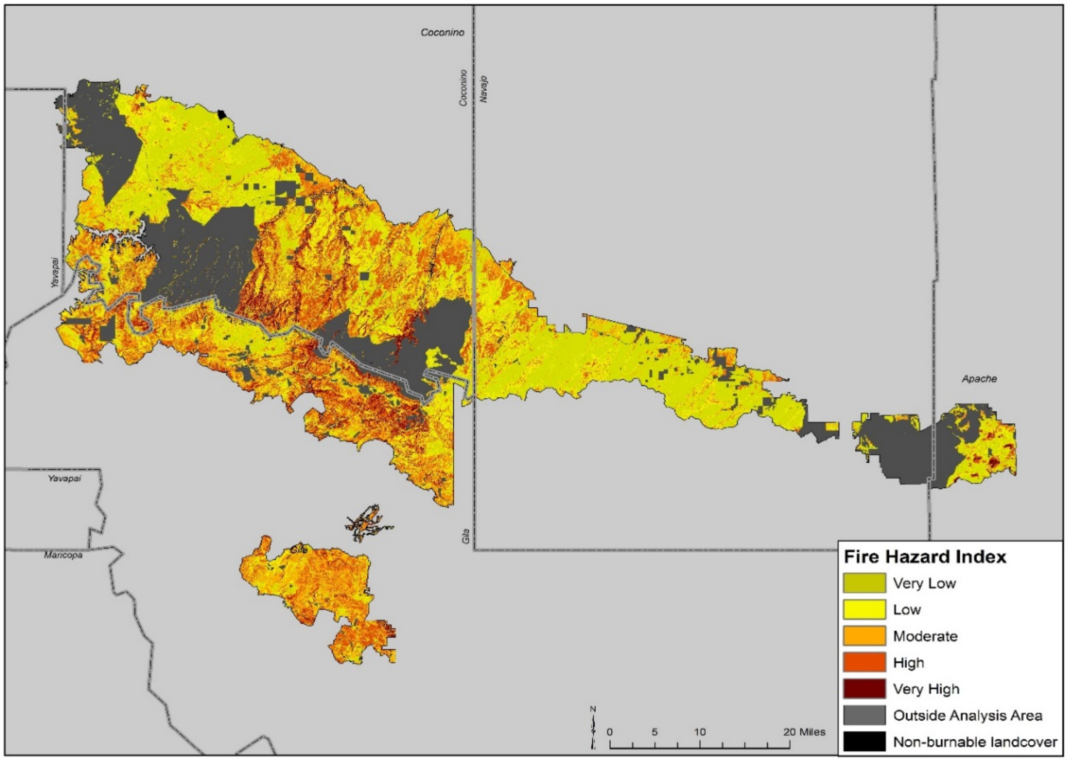

Figure 25: Fire hazard Index for Alternative 1, under modeled fire weather

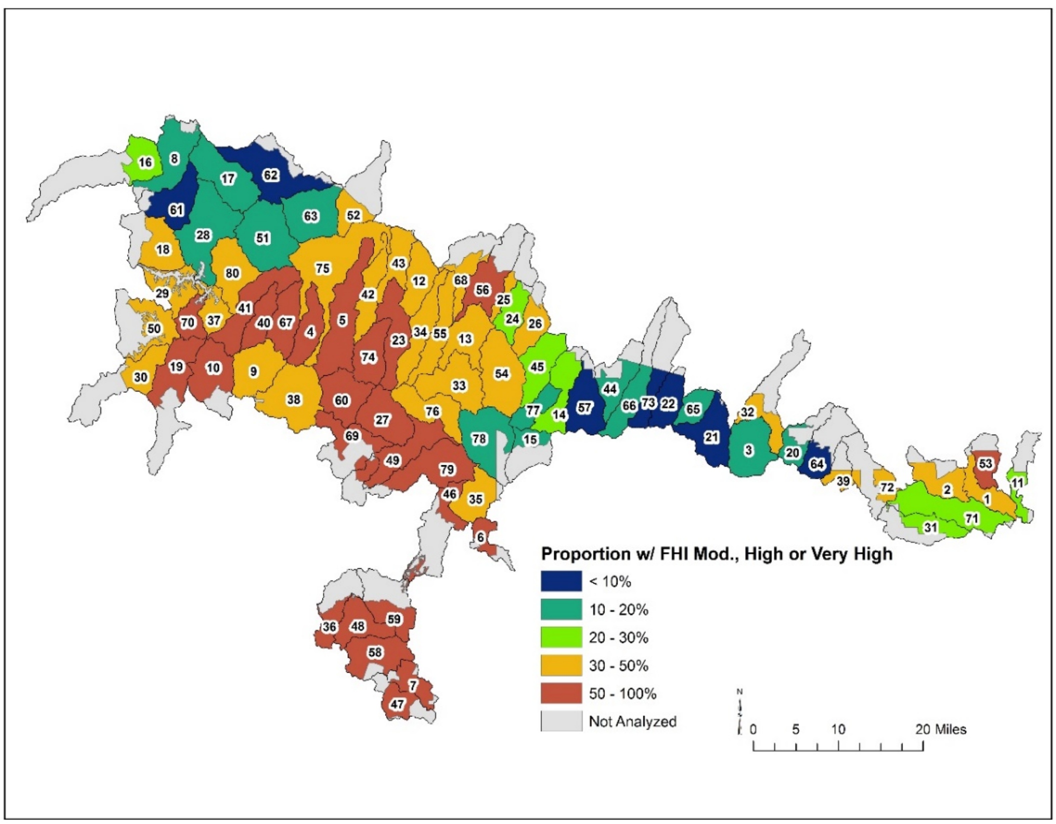

Figure 26: Proportion of each HUC6 watershed with FHI in the moderate, high or very high category for Alternative 1, under modeled fire weather

Surface Fuels loadings

Under the No Action Alternative, surface fuel loading would continue to accumulate. This would lead to high burn severity (fire effects to soil) as residence time increases with increasing surface fuel loading. Coarse Woody Debris (dead/down woody fuels greater than 3" in diameter) could be expected to switch from predominantly sound to predominantly rotten debris after about 15 years with no fire, with the highest CWD loading expected from 6 – 12 years after the last fire (Roccaforte *et al.* 2012). Desired conditions for total surface fuel loadings are less than 27 tons/ac in Ponderosa Pine vegetation types and less than 30 tons/ac in Dry Mixed Conifer. Under Alternative 1, 171,440 acres exceed 27 tons per acre, up from 105,528 acres in existing conditions. 123,077 acres of Ponderosa Pine and 25,967 acres of Dry Mixed Conifer vegetation types exceed recommended fuel loadings (Figure 27).

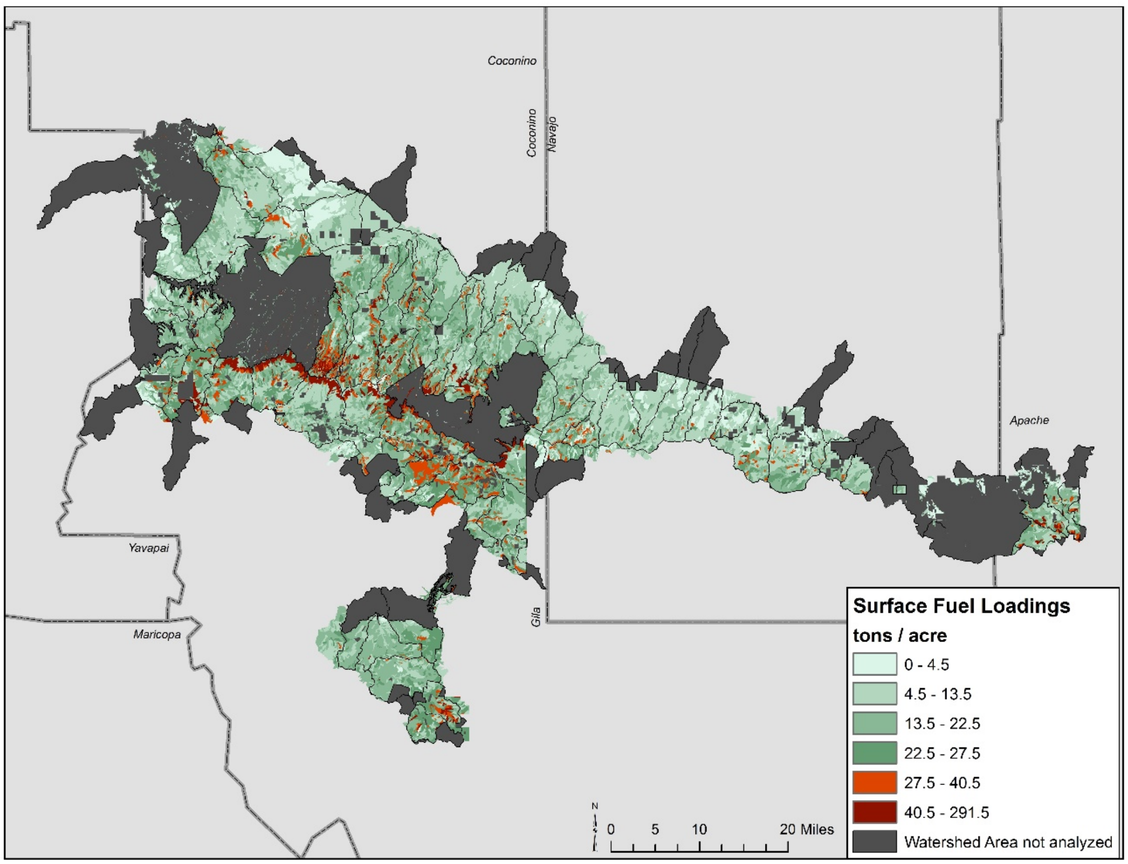

Figure 27: Surface Fuel Loads for Alternative 1, under modeled fire weather

Wildfire Management

Wildfire management environment would become increasingly complex as both CFA and FHI increase. Under extreme fire weather, suppression tactics would continue to be non-effected and dangerous.

WUI

Under the No Action Alternative, WUI areas across the treatment area would be threatened by the increasing extent of high severity of wildfires (Table 13). CFA and FHI both increase. The potential for home and asset loss from crown fires, high intensity surface fires and ember lofting would continue to increase.

Table 13: WUI Measures and Metrics for Alternative 1

WUI CLASS	Total Acres	Fire Hazard Index				Fire Type	
		Very Low - Low	moderate	high	very high	Passive & Active Crown Fire	Active Crown Fire
High Value Rec Sites	375	45%	19%	18%	19%	83%	40%
Communication Sites	2074	63%	16%	18%	3%	79%	28%
NonFS Lands w/ structures	22638	63%	17%	18%	3%	73%	29%
Transmission Lines	4083	61%	17%	18%	4%	74%	33%
FS Buildings	1683	49%	14%	29%	9%	85%	43%

Vegetation Cover Types

In the long term (>20 years), tens of thousands of acres (the actual amount would be a subset of the 334,800 acres in the treatment area that would likely burn with high severity effects) would potentially be 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. Woody species continue to encroach into grasslands and shrublands, and sprouting shrubby species would increasingly occupy understories in Ponderosa Pine Evergreen Oak. Table 14 shows the metrics for each vegetation cover type.

Table 14: Vegetation Cover Type Measures and Metrics for Alternative 1

ERU	Total Acres	Fire Hazard Index				Fire Type	
		Very Low - Low	moderate	high	very high	All Crown Fire	Active Crown Fire
Ponderosa Pine	556284	75%	7%	16%	3%	81%	22%
PIPO Evergreen Oak	147989	36%	33%	26%	5%	85%	30%
Dry Mixed Conifer	49281	26%	17%	28%	29%	77%	54%
Wet Mixed Conifer	3130	29%	4%	26%	41%	74%	70%
Aspen	1438	95%	1%	3%	2%	6%	5%
Pinyon Juniper	135085	36%	33%	28%	3%	71%	67%
Madrian Pinyon Oak	23318	19%	33%	41%	7%	86%	80%
Grasslands	18851	98%	2%	0%	0%	16%	3%
Riparian Areas	14567	70%	11%	13%	6%	48%	19%

Large and old trees

Under the No Action Alternative, large and old trees across the treatment area would be threatened by the increasing extent of high severity of wildfires (Swetnam 1990a; Covington and Moore 1994; Swetnam and Betancourt 1998; Westerling *et al.* 2016). In areas where a wildfire would be a first entry burn and there had been no prescribed fire or thinning, there would be a much greater potential for mortality than in treated areas. In this alternative, many old trees would be killed or damaged by wildfire, as well as those trees that die or decline slowly from the cumulative effects of fire and other stressors (Minard 2002).

Emissions and Air Quality

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

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. Smoke impacts would be from naturally occurring wildfires. Wildfire smoke is less predictable, less frequent, and more concentrated than emissions from prescribed fires.

If the current average annual acres burned by wildfire remained the same (27,426 acres), it is likely that the entire treatment area would burn with wildfire by 2065, along with the associated air quality impacts. Due to increased potential for crown fire and increase total surface fuel loadings, a wildfire burning under Alternative 1 conditions in 2029 would produce more emissions than one burning under current existing conditions (Figure 28). Wildfire would be the only source of emissions from the treatment area under this alternative. On a per acre basis, emissions increase by XX%, due to the increase in surface fuel loadings. This in combination with the expected increase in annual acres burned will lead to an increase in overall emissions from wildfires.

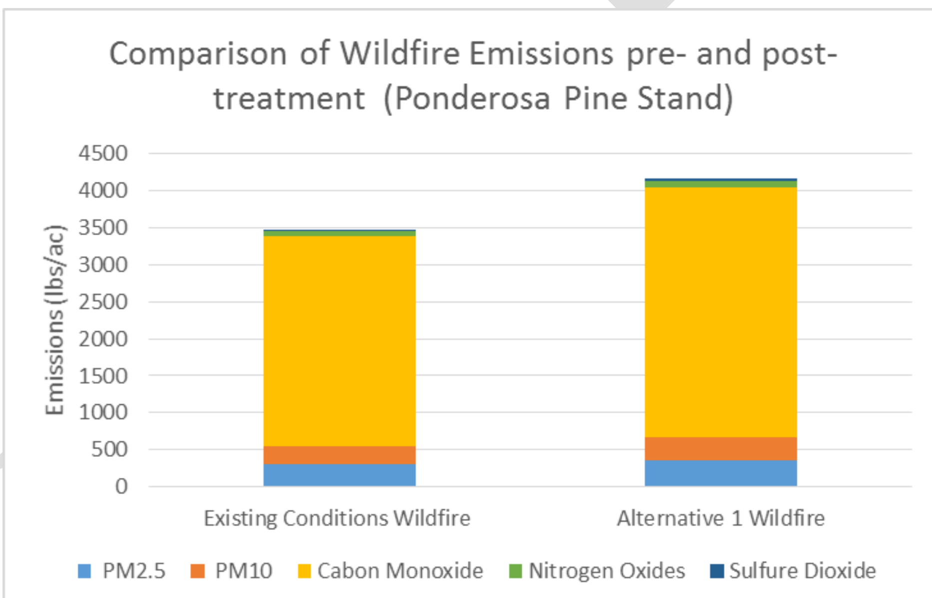

Figure 28: Emissions for Alternative 1

This alternative would not increase potential smoke impacts during the 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 timing and type of smoke effects would change little initially, but as the likelihood of large fires increase so does the potential for air quality levels that exceed National Ambient Air Quality Standards (NAAQS), and nuisance smoke. The likelihood and degree of potential impacts from wildfire smoke would continue to increase as fuel loading increased, since much of the lingering smoke comes from duff, CWD, litter, stumps, and other fuels that can smolder. Watersheds 75 (East Clear Creek-Clear Creek) and 79 (Haigler Creek) have the greatest potential to produce emissions because of surface fuel loading (Figure 29). Under Alternative 1 all watershed increased in total surface fuel loadings, with watershed 58 (Upper Salome Creek) and 37 (Clover Creek) increasing the most (33% increase from existing conditions; Table 25). Watershed 75 (East Clear Creek / Clear Creek) has the highest total surface fuel loadings and therefore has the potential to produce the most emissions should it burn (Figure 29). Watersheds 4 (Barbershop Creek) and 27 (Christopher Creek) have the most dense total surface fuel loading, both with an average of 24 tons/acre.

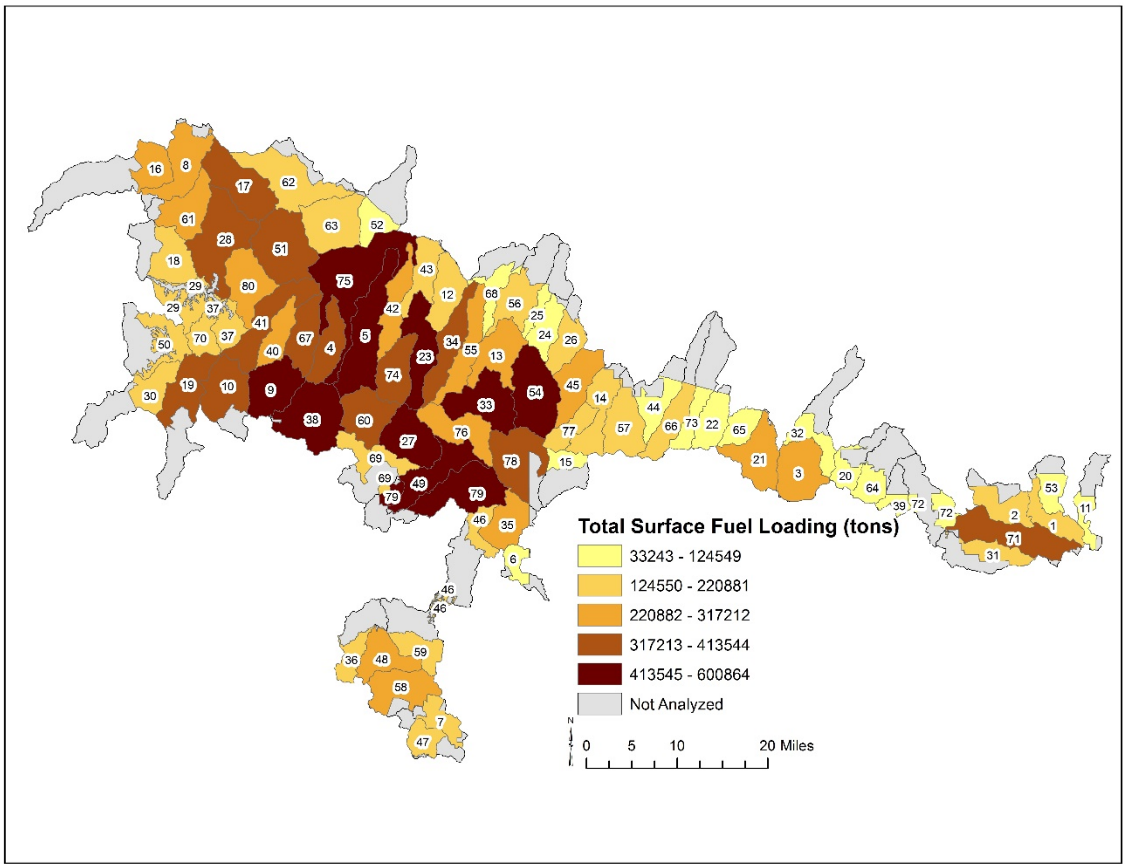

Figure 29: Total Surface Fuel Loads in each HUC6 watershed Alternative 1, as modeled using FVS

Unavoidable Adverse Effects, Irreversible and Irretrievable Commitment of Resources

As described above, with no treatment, high severity fire effects would become more widespread, and extreme fire behavior would become more common. In recent years, fires on the Mogollon Rim have taken human lives, destroyed homes/property/infrastructure, and produced high severity effects across large areas not adapted to high severity fire including Rodeo/Chediski 2002 (469,000 acres), Wallow 2011 (538,000 acres), and Whitewater 2012 (~297,000 acres). 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 ~27% or more of the burned area (assuming ~27% 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 natural resources, and degradation of water resources for wildlife, livestock, and humans. Some of these effects would last just a few days or weeks, some would take much longer. 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 to centuries to recover.

Effects Common to All Action Alternatives

Activities that will effect fire and fuels include mechanical treatments and/or prescribed fire. While the number of acres of prescribed fire and mechanical treatments varies by Alternative, their effects, were implemented, will be the same.

Mechanical treatment alone has the potential to alter fire behavior primarily through a reduction of CBD, but can also increase surface fuel loadings through the placement of slash on the ground (Carey and Schuman, 2003). Carey and Schumann (2003) further note that the use of mechanical thinning alone has a varied effect on modifying fire behavior, primarily because of the created slash. All of the thinning treatments proposed within this analysis are paired with prescribed burning, therefore, the effects will be a combination of thinning and burning. Various researchers have concluded that the combination of thinning and burning as the most effective way to alter fire behavior (Strom 2005; Graham et al. 2004; Peterson et al. 2005; Cram et al. 2006).

The effectiveness of using prescribed fire as a tool, alone or combined with mechanical treatment, to restore ponderosa pine to a healthier, more sustainable and resilient condition is well documented (Fulé et al. 2001b, Roccaforte et al. 2008, Strom and Fulé 2007, Fulé et al. 2012). Prescribed fire is used as a proxy for wildfires which allows for more control over where and when fire burns and often leads to lower overall severity and emissions.

Most of the effects of the natural role of fire could not be effectively replicated by means other than fire. These effects include nutrient recycling; seed scarification (by both heat and smoke); promotion of a mosaic of seedlings, shrubs, forbs, and grasses; regulating surface fuel loads, changes in soil moisture, changes to albedo, etc.. (Laughlin *et al.* 2008; Pyke *et al.* 2010; Laughlin *et al.* 2011). Over time, prudent use of prescribed burning, particularly when combined with mechanical thinning, would reduce the potential for damage from wildfires, as well as the costs associated with fire suppression (Jaworski 2014). Fire increases structural heterogeneity and diversity and promotes natural regeneration of ponderosa pine, providing favorable seedbeds and enhancing the growing environment for survival (Harrington and Sackett 1992).

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, so that an appropriate number of seedlings survive to maintain healthy forest conditions.

The longevity of the effects of a prescribed fire depends on the specific effect being evaluated; the condition of the burned area before a burn; the conditions under which it burned, and post-treatment conditions (such as precipitation). For example, a denser forest will accumulate litter faster than a more open forest; soil conditions and moisture affect the rate of decay; the germination and survival of seedlings depends on cone production and environmental conditions for the first 2-3 years.

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.

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 would be maintenance burns (see below). 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 warranted to reduce smoke in sensitive receptors as mitigation for prescribed fires.

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) (Keyes and O’Hara 2002). 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 (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, there are much broader conditions under which the area could burn and meet objectives than with maintenance burns, when seasonality is more important to maintain the diversity of understory species (Westlind and Kerns 2017). 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 of second entry burns 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. Dead needles from the lower branches have fallen to the ground and are now part of the surface fuel load.

Maintenance burns in ponderosa pine generally begin with the 2^{nd} or 3^{rd} 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 (Robinson 2004), 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 (Fulé et al. 2007).

Direct and Indirect Effects

In the short term (<20 years), ***where treatments are implemented***, 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 (direct effects). It would be expected that the growth of light, flashy fuels 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 adjacent to, or near areas (such as MSO habitat or Wet Mixed Conifer) that were not 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 surface and canopy fuels, would remain lower than existing condition for about 37% of the Rim Country area proposed for treatment. Potential for undesirable fire effects, as assessed by changes to canopy and surface fuels, would remain lower than existing condition for about 31% of the ponderosa pine in the treatment area. Impacts to air quality as a result of fire related pollutants emitted as a result of prescribed fire could decrease some as the majority of the treatment area would be in maintenance burn mode, producing fewer emissions per acre. However, since there would be more acres burned, the number of days of air quality impacts could increase.

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 Rim Country (and other projects) are implemented.

Fire Type

Decreasing the horizontal and vertical continuity of canopy fuels is a direct effect of the proposed treatments that 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, could 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). After the first prescribed fire, surface fuels would be lower so, even with the changes described above, the potential fire behavior and effects would be improved following the treatments under Alternatives 2 & 3.

Fire Hazard Index

Some components of the Fire Hazard Index are fixed and not susceptible to changes due to proposed treatments. These components include slope and soil erodibility. While these components are necessary for determining potential fire behavior and/or post fire effects, treatments will not result in changes to these parts. The rest of the components, which relate more directly to fire behavior, will be influenced by proposed treatments in manors consistent with those discussed above in the Fire Type section and below in the Surface Fuels section.

Surface fuels

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 that are not removed from the treatment area remain a potential source of heat and emissions. Effects may be spottier but, where fuels have been pushed into piles or furrows (intentionally or otherwise), they may smolder for days or weeks. Mechanical thinning often increases surface fuel loading by small amounts (Fulé *et al.* 2012).

Litter, Duff, and Coarse Woody Debris greater than 3” diameter 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)

(Lata 2006, Neary et al. 2005, Valette et al. 1994), as well as 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 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.

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, Haase and Sackett 2008, Roccaforte et al. 2012), 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 Alternatives 2 and 3 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.

CWD could be expected to switch from predominantly sound to predominantly rotten debris after about 15 years with no fire, with the highest CWD loading expected from 6 – 12 years after the last fire (Roccaforte *et al.* 2012).

Large/old trees

Ponderosa pine (*Pinus ponderosa* Dougl. ex P. & C. Laws) stands with late-seral features are found infrequently, owing to past management activities throughout western North America. Thus, management objectives often focus on maintaining existing late-seral stands. Observations over a 65 year period of stands with no past history of harvest showed substantial ingrowth in the smaller diameter classes and elevated rates of mortality among the largest mature trees in the stand. Adjacent stands, with combinations of thinning and prescribed fire, had far fewer high-risk mature trees and generally lower rates of mortality aftr treatment. Forecasts using individual-tree diameter growth and mortality models suggest that observed declines in these stands with remaining old trees and a dense understory will contiu=nue in the absence of any treatment. Increased vigor in thinned stands appeared to be offset by an increase in mortality of large trees when thinning was followed by prescribed fire. (Richie *et al.* 2008)

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, whether by high or low intensity fire. 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 40,000 to 60,000 acres of prescribed fire units each year. Data collected from restoration treatments in the White Mountains indicates that mortality of pre-settlement trees increased with thin/burn, or burn only treatments over controls, although those that survived grew significantly faster than those in untreated stands (Fule et al. 2007; Roccaforte et al. 2015). Managers will have to consider tradeoffs between treatment options, and the increasing likelihood of the trees burning in wildfires under conditions that would be more extreme than conditions under which a prescribed fire would be conducted.

Mechanical treatments and prescribed fire would 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 both alternatives 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.

Mitigation measures (page XX) are unpredictable, and site specific (Kolb et al. 2007, Hood 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 (Progar *et al.* 2017). Low intensity fire that causes little crown scorch can stimulate resin production in old trees that 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.

Air Quality and Smoke

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 30 shows differences in emissions from wildfire or prescribed fires that burn at different stages in burn only and mechanical plus burn treatment cycles.

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 the action alternatives, and hence, Air Quality is not expected to be a primary driver in selecting one alternative over another.

Some comparison between alternatives can be made by looking at the indirect effects of management activities that reduce the likelihood of active crown fire and heavy surface fuel loading. Active crown fire and heavy surface fuel loading produce large quantities of emissions that may be 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.

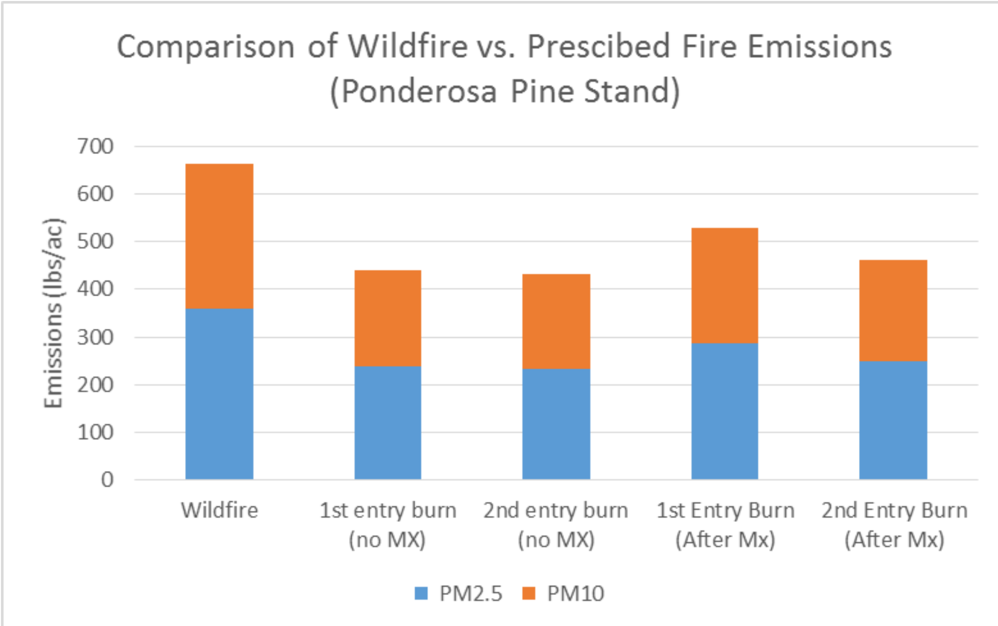

Figure 30: PM 2.5 and PM10 emissions from wildfires vs. prescribed fire at different stages of treatments.

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 would 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 be target to reduce smoke in sensitive receptors as mitigation for prescribed fires.

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 Rim Country 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 (Fulé 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 too steep or remote to access with mechanical methods.

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). 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.

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 would be impacts.

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.

Under Alternative 2, 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 difference in emissions between the treatments stays roughly the same, with no statistical difference and can generally be attributed the initial difference in fuel loading. The first prescribed fire following a mechanical treatment produced a little over 500 pounds/acre of emissions. The first prescribed fire without thinning produced a little over 400 pounds/acre of emissions. Since stands receiving mechanical treatment prior to prescribed fire start out with more surface fuel than those that are not mechanically treated prior to burning, additional emissions are produced.

Effects Unique to Each Alternative

Alternative 2 – Modified Proposed Action

Alternative 2 proposes to conduct about 889,344 acres of mechanical and prescribed fire treatments and an additional 63,788 acres of prescribed fire only treatments over about 10 years or until objectives are met. On average, 88,934 acres of vegetation would be mechanically treated annually. On average, 95,313 acres of prescribed fire would be implemented annually across the

Forests (within the treatment area). Up to two prescribed fires[1] would be conducted on all acres proposed for burning over the 10-year period.

When analyzed at the scale of the treatment area, Alternative 2 would meet the purpose and need by moving the project area towards the desired condition of having potential for less than 10% active crown fire under extreme weather conditions, lessening post fire detrimental effects and creating a safer and more effective firefighting environment.

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 Rim Country 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. Rim Country 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 would 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

From a fire ecology perspective, direct and indirect effects of Alternative 2 relate primarily to treatments that include mechanical thinning, prescribed fire, or both to meet the purpose and need of the project.

Changes to potential fire behavior are the indirect effects of changes to fuel loading and structure. A direct effect of implementing Alternative 2, would be changes to the horizontal and vertical continuity of canopy fuels. As that continuity is broken up, an indirect effect would be decreased potential for crown fire.

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. Trees 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 Rim Country (and other projects) are implemented.

[1] A single prescribed fire may include burning piles and a follow-up broadcast burn. Prescribed fire would be implemented as indicated by monitoring data to augment wildfire acres, with the expectation that desired conditions would require a fire return interval of about 10 years.

Rim Country Project Area Metrics and Measures

Tables showing the modeled fire hazard index, fire type and surface fuel loadings for each 6th code HUC in the project area as modeled for Alternative 2 are presented in Table 15.

Table 15: Alternative 2 HUC6 watershed metrics

Map Label	Watershed Name	% Active Crown Fire	% Moderate - Extreme FHI	Mean SFL (tons/ac)
1	Upper Brown Creek	16%	17%	12
2	Upper Rocky Arroyo	33%	33%	13
3	Mortensen Wash	1%	1%	6
4	Barbershop Canyon	5%	17%	18
5	Leonard Canyon	7%	14%	13
6	Gentry Canyon	9%	14%	11
7	Reynolds Creek	19%	28%	17
8	Double Cabin Park-Jacks Canyon	8%	8%	15
9	East Verde River Headwaters	5%	9%	15
10	Webber Creek	9%	16%	15
11	Sepulveda Creek	3%	3%	11
12	Cabin Draw	5%	6%	9
13	Upper Chevelon Canyon-Chevelon Canyon Lake	10%	15%	12
14	Bear Canyon-Black Canyon	1%	2%	6
15	Bull Flat Canyon	0%	2%	8
16	Red Tank Draw	13%	14%	18
17	Upper Willow Valley	1%	1%	10
18	Home Tank Draw	4%	4%	7
19	Pine Creek	9%	17%	14
20	Linden Draw	10%	9%	7
21	West Fork Cottonwood Wash-Cottonwood Wash	0%	0%	6
22	Upper Day Wash	2%	2%	4
23	Upper Willow Creek	15%	21%	16
24	Middle Wildcat Canyon	6%	8%	8
25	Lower Wildcat Canyon	11%	10%	7
26	Upper Potato Wash	11%	11%	8
27	Christopher Creek	9%	16%	18
28	Lower Willow Valley	4%	4%	9
29	Upper West Clear Creek	4%	5%	11
30	Hardscrabble Creek	6%	10%	9
31	Billy Creek	22%	23%	16
32	Dodson Wash	21%	20%	7
33	Long Tom Canyon-Chevelon Canyon	27%	35%	19
34	Upper West Chevelon Canyon	4%	8%	12
35	Parallel Canyon-Cherry Creek	1%	4%	12
36	Rock Creek	10%	6%	11
37	Clover Creek	23%	26%	18
38	Ellison Creek	10%	13%	13
39	Fools Hollow	37%	37%	16
40	Miller Canyon	54%	61%	22
41	East Clear Creek-Blue Ridge Reservoir	50%	55%	18
42	Wilkins Canyon	3%	6%	11
43	Lower Willow Creek	15%	18%	12
44	Upper Pierce Wash	5%	5%	4
45	Upper Brookbank Canyon	2%	2%	8
46	Gruwell Canyon-Cherry Creek	5%	9%	10
47	Workman Creek	11%	18%	14
48	Buzzard Roost Canyon	14%	17%	12
49	Gordon Canyon	11%	18%	16

50	Upper Fossil Creek	2%	3%	11
51	Windmill Draw-Jacks Canyon	6%	6%	11
52	Hart Tank	23%	21%	6
53	Ortega Draw	51%	49%	11
54	Upper Wildcat Canyon	33%	36%	15
55	Alder Canyon	3%	4%	11
56	Durfee Draw-Chevelon Canyon	31%	30%	10
57	Buckskin Wash	0%	0%	4
58	Upper Salome Creek	17%	20%	10
59	Upper Spring Creek	11%	13%	13
60	Horton Creek-Tonto Creek	8%	14%	15
61	Brady Canyon	4%	4%	16
62	Tremaine Lake	1%	1%	5
63	Dogie Tank-Jacks Canyon	5%	6%	6
64	Bagnal Draw-Show Low Creek	1%	1%	7
65	Stinson Wash	3%	3%	5
66	Upper Phoenix Park Wash	3%	2%	5
67	Bear Canyon	55%	65%	23
68	Lower West Chevelon Canyon	17%	15%	8
69	Bull Tank Canyon-Tonto Creek	17%	22%	10
70	Toms Creek	4%	8%	13
71	Porter Creek	21%	22%	15
72	Show Low Lake-Show Low Creek	32%	33%	10
73	Decker Wash	3%	2%	5
74	Gentry Canyon	15%	24%	20
75	East Clear Creek-Clear Creek	13%	17%	11
76	Woods Canyon and Willow Springs Canyon	28%	29%	18
77	West Fork Black Canyon	0%	2%	7
78	Canyon Creek Headwaters	3%	5%	12
79	Haigler Creek	13%	25%	15
80	Long Valley Draw	30%	30%	15

Fire Type

Once fully implemented, Alternative 2 is expected to reduce the potential for active and conditional crown fire to within desired conditions for all vegetation cover types (see Table 17 below). Over the rim country project area, 12% of the area burned under extreme weather conditions would be expected to be active or conditional crown fire, down from 31% given existing conditions (Figure 31). Passive crown fire increases slightly (57% up from 47% EC) under extreme conditions, due to the desired clumpy canopy characteristics of the mechanical treatments. Under less extreme wind conditions (5 MPH instead of 20 MPH), the majority of the landscape (95%) is expected to burn as a surface fire, and only 43,396 acres are expected to burn with passive crown fire, and 270 acres with active or conditional crown fire.

Post wildfire watershed effects increase with the percent of the watershed burns with moderate to high severity fire (Cannon 2010; Neary 2011). Under Alternative 2, 9 watersheds are expected to burn with active crown fire under extreme weather conditions for over 30% of the watershed, which would result in moderate to high severity effects (Figure 32). Three watersheds are have over 50% of the watershed expected to burn with active crown fire. Watersheds 67 (Bear Canyon) and 40 (Miller Canyon) have the highest proportion of potential for active crown fire (55% for both). If a wildfire were to burn within these watersheds, detrimental post wildfire effects, such as debris flows, would be expected.

Fire Hazard Index

Alternative 2 would decrease the risk of undesirable wildfire behavior and effects that could threaten lives, resources, and infrastructure. After implementation, the Fire Hazard Index decreases resulting in 15% of the project area is within the moderate to extreme FHI, down from 37% in the existing conditions (Figure 34). The areas of moderate to extreme presents difficult and dangerous suppression conditions during a wildfire and potential for adverse post fire effects on soils and surface water quality,

There are 3 watersheds with over 50% of the watershed in the moderate to extreme FHI categories (Figure 33). Watershed 40 (Miller Canyon, 61%) and 67 (Bear Canyon, 65%) have the highest proportion of FHI in the moderate to very high class. Large wildfires in these watersheds would still have a high potential to be difficult and dangerous to suppress, and have a high potential for adverse post fire effects.

Surface Fuels loadings

Under the Alternative 2, surface fuel loading would initially increase with mechanical treatment. As first and second entry prescribed burns are implemented, these fuel loadings would decrease in most areas except those proposed for MSO treatments, which are designed to maintain a higher level of fuel loading, especially Coarse Woody Debris (dead/down woody fuels greater than 3" in diameter).

Desired conditions for total surface fuel loadings are less than 27 tons/ac in Ponderosa Pine vegetation types and less than 30 tons/ac in Dry Mixed Conifer. Under Alternative 2, 40,380 acres of Ponderosa Pine (down from 105,528 ac in the Existing Conditions) and 15,550 acres of Dry Mixed Conifer vegetation types (down from 18,288 in the Existing Conditions) exceed recommended fuel loadings (Figure 35).

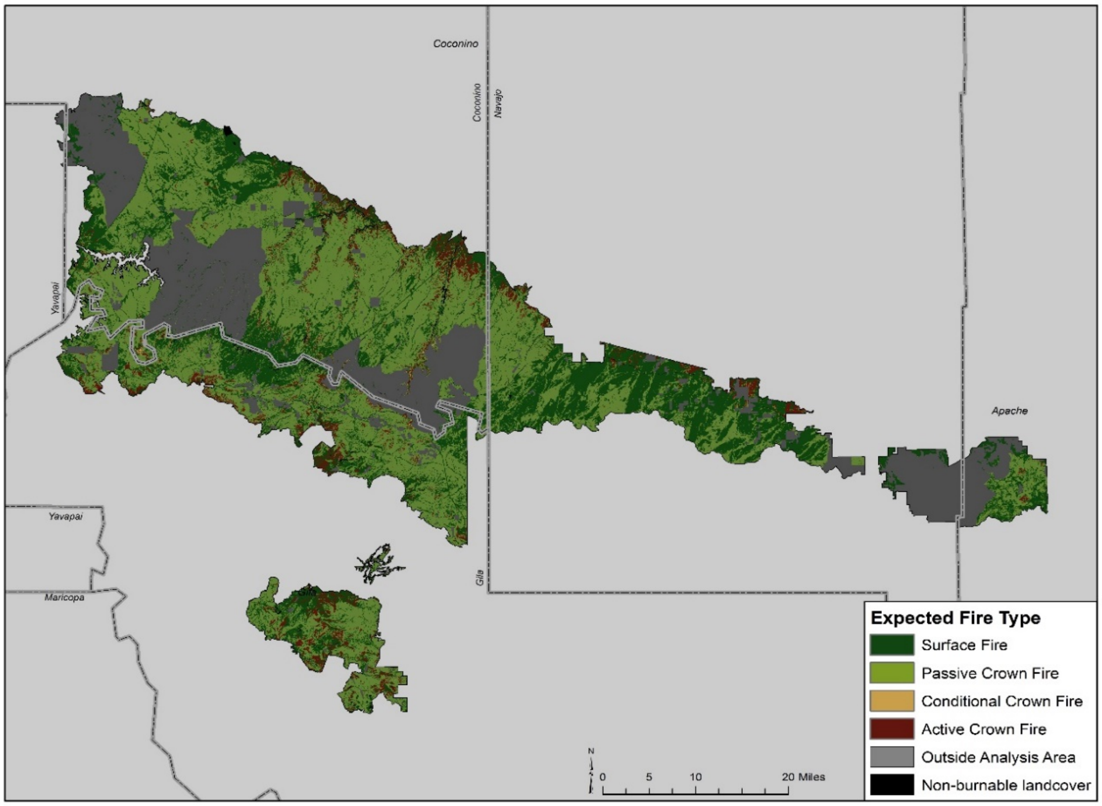

Figure 31: Expected Fire Type for Alternative 2, under modeled weather conditions.

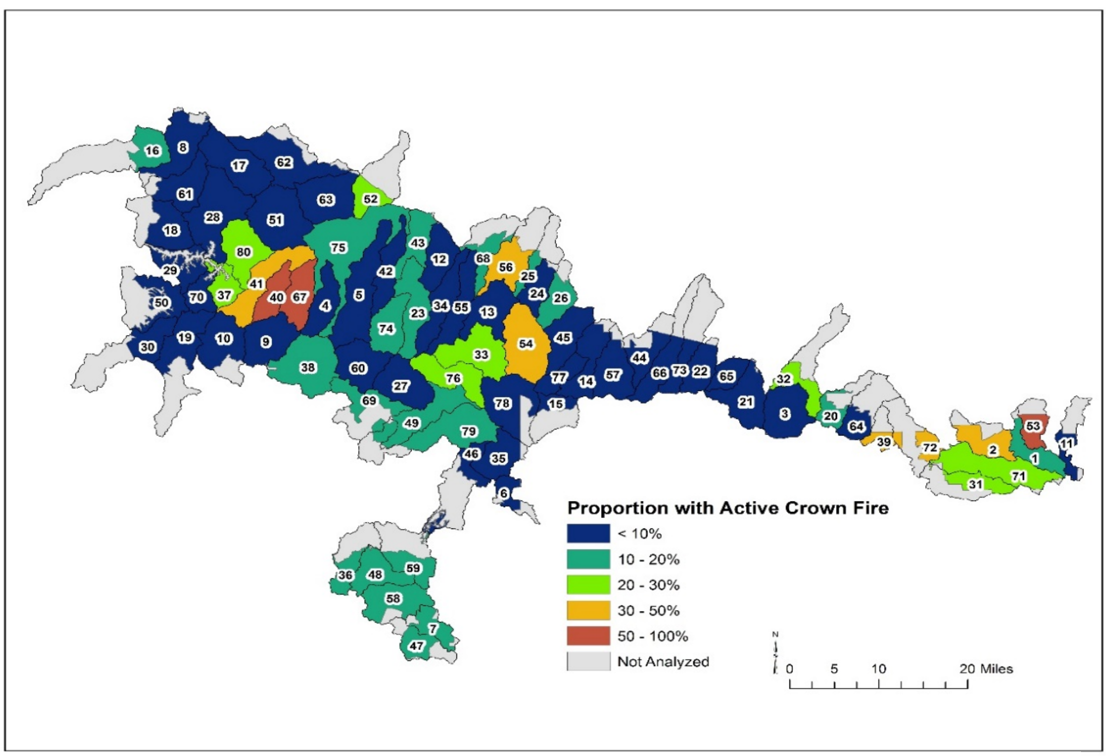

Figure 32: Proportion of each HUC6 watershed with Active Crown Fire for Alternative 2, under modeled weather conditions.

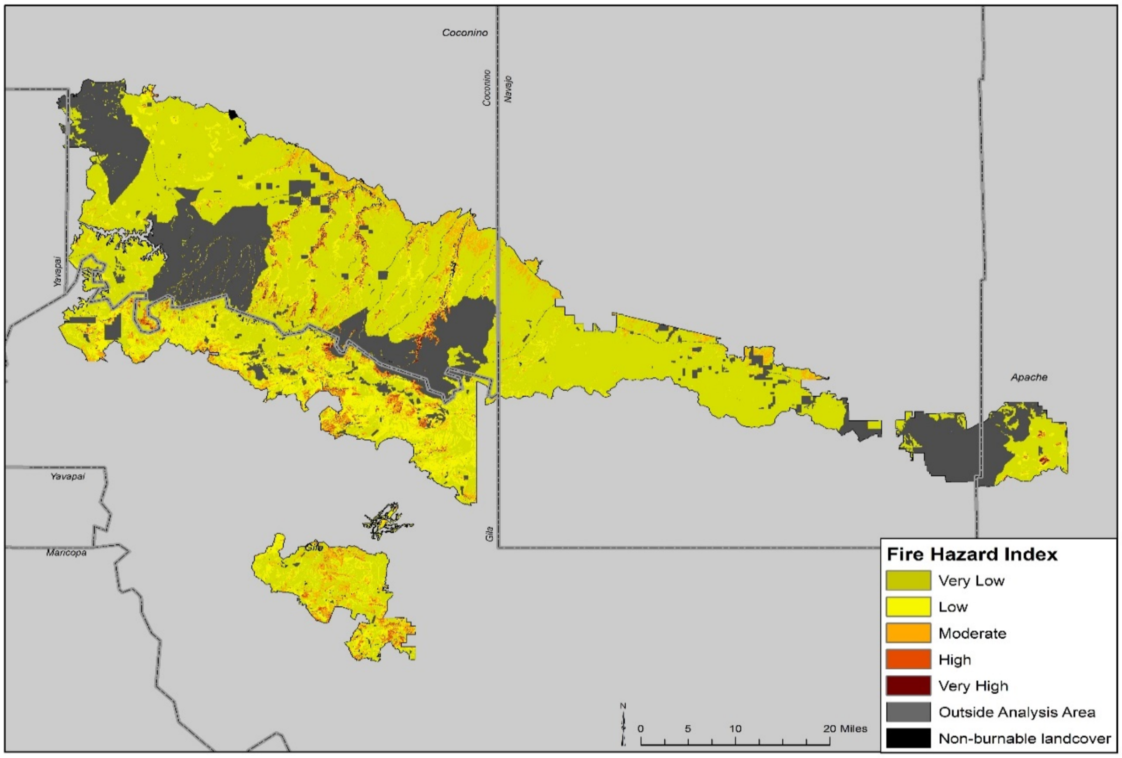

Figure 34: Fire Hazard Index for Alternative 2, under modeled weather conditions.

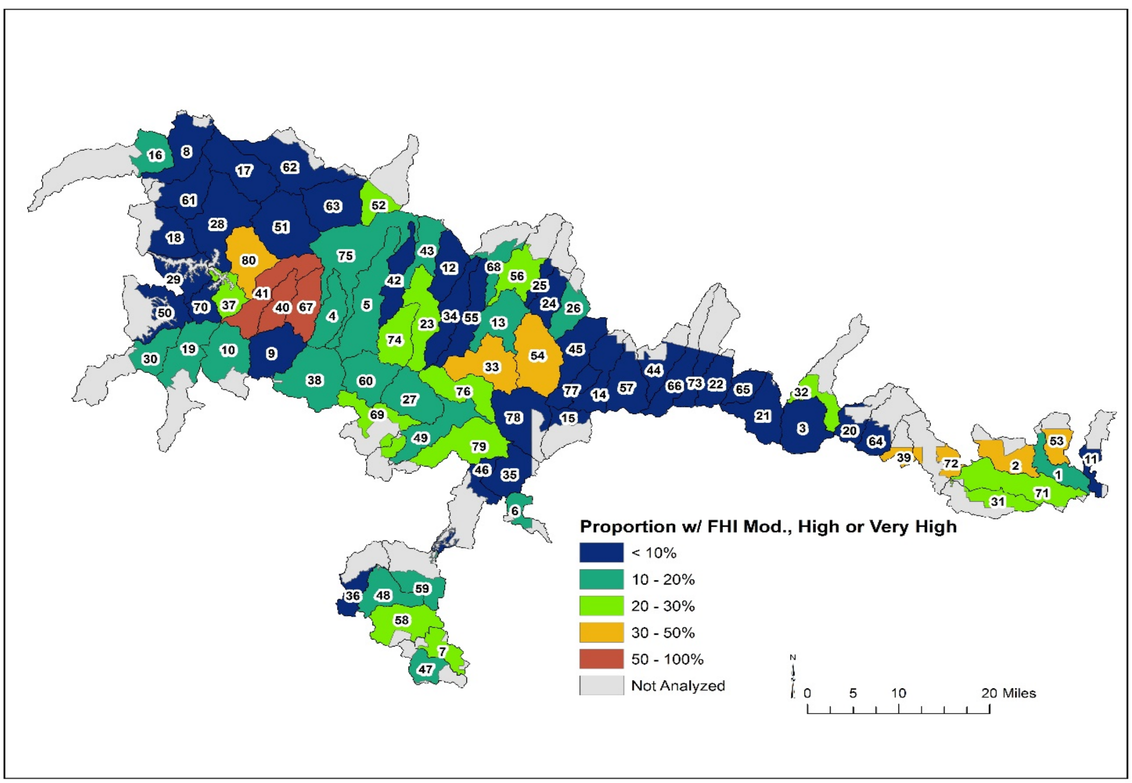

Figure 33: Proportion of each HUC6 watershed with Moderate, High or Very High Fire Hazard Index for Alternative 2, under modeled weather conditions.

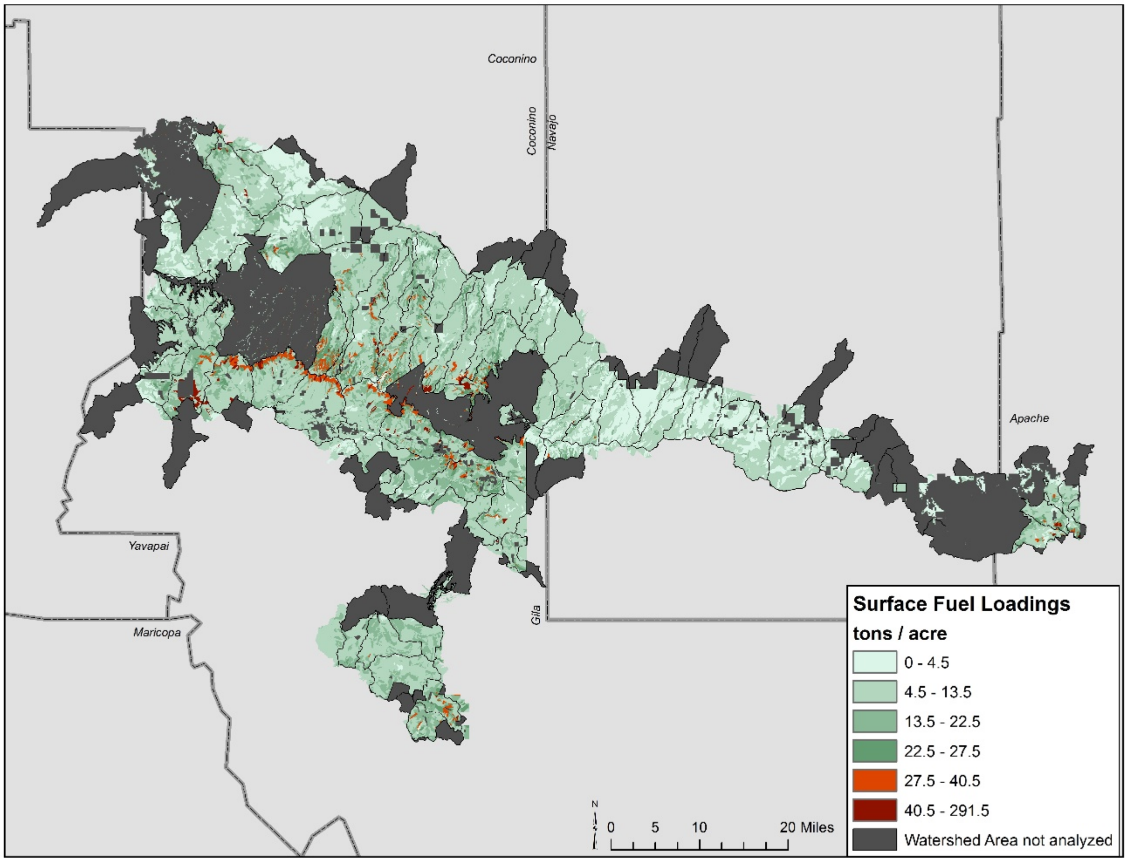

Figure 35: Surface Fuel Loads for Alternative 2, under modeled fire weather

Effects on Values, Resources and Assets

Wildfire Management

Wildfire management environment would become safer and more effected as both CFA and FHI decrease. Even under extreme fire weather, suppression tactics would be more effective than current conditions. Decision space for managing unplanned ignitions would expand as Rim Country is implemented.

WUI

Under the Alternative 2, WUI areas on Forest Service lands across the treatment area would be more fire adapted, however increasing smoke from prescribed fires would be present next to homes. CFA and FHI both decrease on Forest Service lands (Table 16). The potential for home and asset loss from crown fires, high intensity surface fires and ember lofting from fires on Forest Service land would decrease. The need for private and non-forest service land owners to manage fuels on their lands in order to compliment Rim Country initiatives will be imperative to fully mitigate risk and impacts from wildfires.

Table 16: Alternative 2 metrics for the Wildland Urban Interface

WUI CLASS	Total Acres	Fire Hazard Index				Fire Type	
		Very Low - Low	moderate	high	very high	Passive & Active Crown Fire	Active Crown Fire
High Value Rec Sites	375	36%	6%	6%	5%	64%	10%

Comm Sites	2074	35%	6%	2%	0%	65%	6%
NonFS Lands	22638	43%	6%	1%	0%	57%	6%
Transmission Lines	4083	39%	6%	1%	0%	61%	6%
FS Buildings	1683	33%	6%	4%	1%	67%	5%

Vegetation Cover Type

At the project scale, active crown fire and Fire Hazard Index are reduced for all target vegetation cover types (Table 17). At the project area scale, ponderosa pine would meet desired conditions for active crown fire (<10%), under Alternative 2 even under the extreme conditions modeled.

Table 17: Alternative 2 Metrics for Vegetation Cover Type

ERU	Total Acres	Fire Hazard Index				Fire Type	
		Very Low - Low	moderate	high	very high	All Crown Fire	Active Crown Fire
Ponderosa Pine	556284	97%	2%	1%	0%	81%	**1%**
PIPO Evergreen Oak	147989	95%	4%	1%	0%	85%	**0%**
Dry Mixed Conifer	49281	74%	10%	9%	7%	77%	11%
Wet Mixed Conifer	3130	83%	4%	7%	6%	74%	13%
Aspen	1438	98%	1%	1%	0%	6%	2%
Pinyon Juniper	135085	74%	22%	4%	0%	71%	25%
Madrian Pinyon Oak	23318	55%	25%	19%	1%	86%	41%
Grasslands	18851	100%	0%	0%	0%	16%	**0%**
Riparian Areas	14567	92%	5%	2%	1%	48%	2%

Large and old trees

Under Alternative 2, 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.

Stream/spring restoration

Restoration of 777 miles of streams and numerous 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 allows prescribed fire for fuels management riparian areas.

Roads

Under this alternative, there would approximately 490 miles of system roads decommissioned, and up to 800 miles of unauthorized roads decommissioned. From 1992 through 2015, over 1,582,239 acres of human ignited wildfires burned within the ecoregions contained by the Rim Country project area, 35% of all acres burned in wildfires (4,456,949 acres). 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 would eventually grow back, allowing fire to burn across the area. During the implementation of the mechanical treatments, roads improved, constructed or reconstructed for access (480 miles) would be available for access to burn units, and/or to be used as firelines for burns.

Emissions and Air Quality

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 Apache-Sitgreaves, Coconino and Tonto 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.

The number of days (duration) of smoke impacts, as well as the intensity (concentration) of the

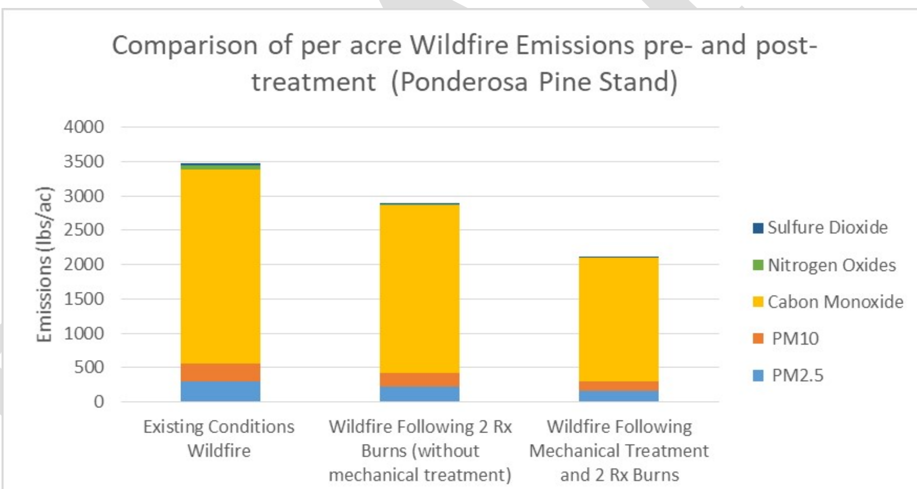

Figure 36: Alternative 2 comparison of per acre wildfire emissions pre- and post-treatments.

impacts are of concern to the public. While the variability from year to year would be large, under this alternative, prescribed fire would need to be implemented on up to 95,313 acres annually to produce an average fire return interval of 10 years across 953,132 acres proposed for prescribed fire. Potential air quality impacts during implementation of Alternative 2, 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. First entry burns produce much more emissions per acre than subsequent burns (see discussion in the section *Effects Common to All Action Alternatives* on first entry burns and Figure 30). 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. Any wildfire that burned subsequent to implementing Alternative 2 would result in lower emissions than if the area burned in a wildfire given current conditions because there would be less biomass to burn (Figure 36).

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 this alternative, for the following reasons. The Apache-Sitgraves, Coconino and Tonto National Forests already burn on the high end of what would be their maximum acres and allowed emissions.

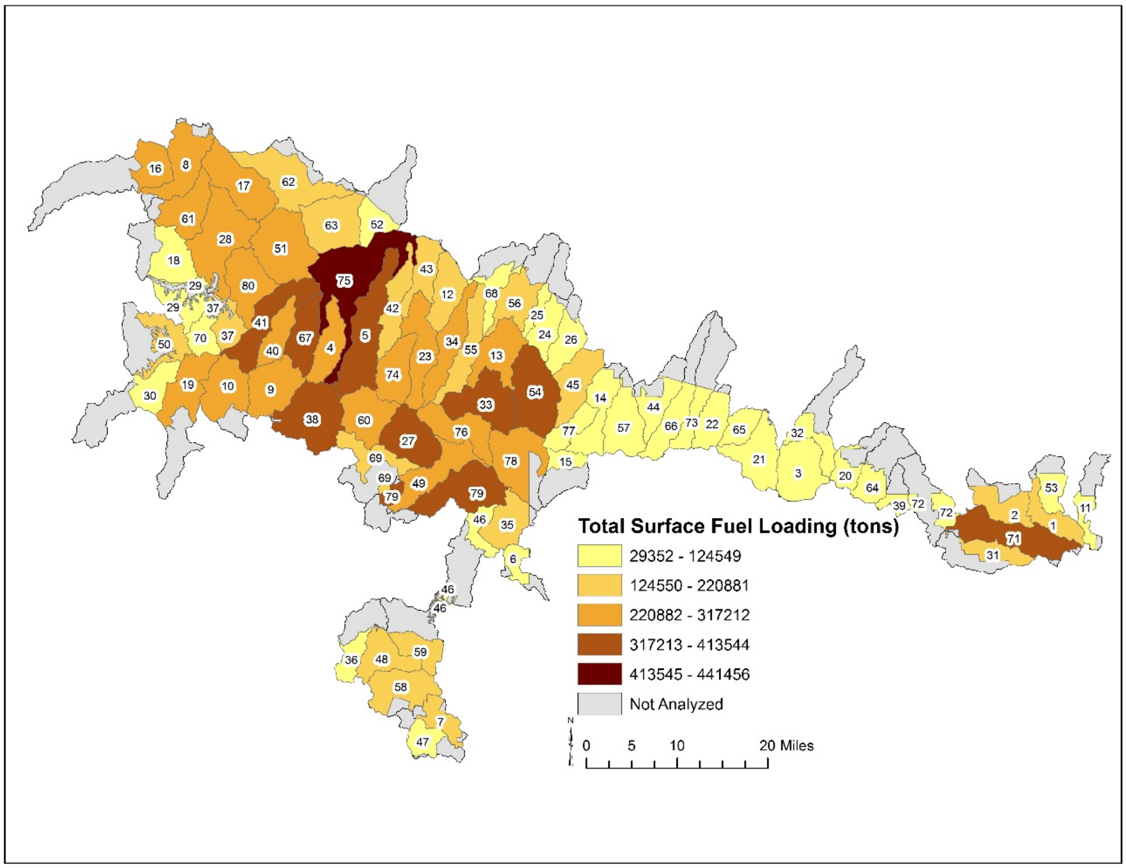

Figure 37: Total Surface Fuel loadings of each HUC-6 watershed for Alternative 2, as modeled using FVS

Under Alternatives 2, the number of acres available for prescribed fire would increase by 953,132 acres, which could average an additional 58,333 acres a year with prescribed fire and wildfire. 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.

Overall, surface fuel loading would decrease (Table 25), with a corresponding decrease in the volume of potential emissions from wildfires and future prescribed fires. However, there is no projected change in CWD fuel loading for Very Low (PAC Burn Only) treatments. In these areas, smoldering fuels would produce high levels of smoke, as well as a high likelihood of high severity fire effects.

The likelihood and degree of potential impacts from wildfire smoke would decrease as fuel loading decrease after prescribed burns. After implementation, Watersheds 75 (East Clear Creek-Clear Creek) and 33 (Long Tom canyon-Chevelon Canyon) have the greatest potential to produce emissions because of surface fuel loading (Figure 37). Under Alternative 2 all but 22 watersheds decrease in total surface fuel loadings. One remains effectively the same (56, Durfee Draw – Chevelon Canyon), and 20 increase in fuel loadings (see Table 25 below). Watershed 2 (Upper Rocky Arroyo) and 41 (East Clear Creek) increase the most (29 and 23% respective).

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 in duration to the degree that the public would tolerate it in those areas discussed the Air Quality section of Alternative 2 in this report.

Under Alternative 2, there is expected to be some old growth tree mortality, however through mitigation measures, this loss is expected to be lower than what a wildfire occurring under existing conditions would produce.

Alternative 3 – Focused

From a fire ecology perspective, direct and indirect effects of Alternative 3 relate primarily to treatments that include mechanical thinning, prescribed fire, or both to meet the purpose and need of the Rim Country. This alternative proposes to conduct about 528,060 acres of restoration activities over about 10 years or until objectives are met. On average, 48,316 acres of vegetation would be mechanically treated annually. On average, 52,806 acres of prescribed fire would be implemented annually across the Forests (within the treatment area). Up to two prescribed fires[2] would be conducted on all acres proposed for burning over the 10-year period.

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,

[2] A single prescribed fire may include burning piles and a follow-up broadcast burn. Prescribed fire would be implemented as indicated by monitoring data to augment wildfire acres, with the expectation that desired conditions would require a fire return interval of about 10 years.

overriding priority. The proposed actions of the Rim Country 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. Rim Country 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 would 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

From a fire ecology perspective, direct and indirect effects of Alternative 3 relate primarily to treatments that include mechanical thinning, prescribed fire as described in the section Effects Common to All Action Alternatives, page 88. Areas without treatments will have the indirect effects associated with Alternative 1 (see section Alternative 1 – No Action, page 78).

Rim Country Project Area Metrics and Measures

Tables showing the modeled fire hazard index, fire type and surface fuel loadings for each 6th code HUC in the project area as modeled for Alternative 3 are presented in Table 18.

Table 18: Alternative 3 HUC6 watershed metrics

Map Label	Watershed Name	% Active Crown Fire	% Moderate - Extreme FHI	Mean SFL (tons/ac)
1	Upper Brown Creek	22%	24%	15
2	Upper Rocky Arroyo	33%	33%	13
3	Mortensen Wash	7%	7%	12
4	Barbershop Canyon	5%	17%	18
5	Leonard Canyon	7%	14%	13
6	Gentry Canyon	9%	14%	11
7	Reynolds Creek	52%	61%	23
8	Double Cabin Park-Jacks Canyon	8%	8%	15
9	East Verde River Headwaters	5%	10%	15
10	Webber Creek	9%	16%	15
11	Sepulveda Creek	11%	14%	14
12	Cabin Draw	29%	29%	11
13	Upper Chevelon Canyon-Chevelon Canyon Lake	17%	24%	14
14	Bear Canyon-Black Canyon	10%	12%	13
15	Bull Flat Canyon	6%	10%	17
16	Red Tank Draw	13%	14%	18
17	Upper Willow Valley	6%	6%	14
18	Home Tank Draw	14%	14%	10
19	Pine Creek	10%	19%	15
20	Linden Draw	13%	13%	11
21	West Fork Cottonwood Wash-Cottonwood Wash	5%	6%	13
22	Upper Day Wash	6%	6%	7
23	Upper Willow Creek	15%	21%	16
24	Middle Wildcat Canyon	23%	24%	10
25	Lower Wildcat Canyon	43%	42%	8

26	Upper Potato Wash	29%	28%	10
27	Christopher Creek	9%	16%	18
28	Lower Willow Valley	7%	7%	11
29	Upper West Clear Creek	20%	21%	12
30	Hardscrabble Creek	11%	19%	10
31	Billy Creek	23%	24%	16
32	Dodson Wash	34%	32%	9
33	Long Tom Canyon-Chevelon Canyon	27%	35%	19
34	Upper West Chevelon Canyon	7%	11%	12
35	Parallel Canyon-Cherry Creek	1%	4%	12
36	Rock Creek	15%	36%	15
37	Clover Creek	23%	26%	18
38	Ellison Creek	12%	18%	14
39	Fools Hollow	38%	38%	16
40	Miller Canyon	54%	61%	22
41	East Clear Creek-Blue Ridge Reservoir	50%	55%	18
42	Wilkins Canyon	7%	10%	12
43	Lower Willow Creek	25%	26%	12
44	Upper Pierce Wash	14%	12%	8
45	Upper Brookbank Canyon	8%	9%	10
46	Gruwell Canyon-Cherry Creek	14%	24%	12
47	Workman Creek	20%	32%	17
48	Buzzard Roost Canyon	26%	45%	15
49	Gordon Canyon	12%	20%	16
50	Upper Fossil Creek	29%	36%	16
51	Windmill Draw-Jacks Canyon	10%	11%	14
52	Hart Tank	23%	21%	6
53	Ortega Draw	52%	49%	11
54	Upper Wildcat Canyon	33%	36%	15
55	Alder Canyon	7%	9%	11
56	Durfee Draw-Chevelon Canyon	67%	62%	11
57	Buckskin Wash	3%	3%	10
58	Upper Salome Creek	31%	43%	13
59	Upper Spring Creek	55%	77%	22
60	Horton Creek-Tonto Creek	10%	19%	17
61	Brady Canyon	4%	4%	16
62	Tremaine Lake	6%	6%	6
63	Dogie Tank-Jacks Canyon	12%	14%	8
64	Bagnal Draw-Show Low Creek	4%	4%	12
65	Stinson Wash	8%	8%	7
66	Upper Phoenix Park Wash	14%	13%	10
67	Bear Canyon	55%	65%	23
68	Lower West Chevelon Canyon	44%	39%	9
69	Bull Tank Canyon-Tonto Creek	21%	30%	12
70	Toms Creek	4%	8%	13
71	Porter Creek	25%	26%	16
72	Show Low Lake-Show Low Creek	32%	33%	10
73	Decker Wash	11%	10%	9
74	Gentry Canyon	15%	24%	20
75	East Clear Creek-Clear Creek	16%	19%	12
76	Woods Canyon and Willow Springs Canyon	28%	30%	18
77	West Fork Black Canyon	9%	16%	16
78	Canyon Creek Headwaters	5%	7%	13
79	Haigler Creek	15%	27%	16
80	Long Valley Draw	32%	32%	16

Fire Type

Alternative 3 is expected to reduce the potential for active and conditional crown fire closer to desired conditions for all vegetation cover types (see Table 20 below), however desired conditions will not be fully attained. Over the rim country project area, 18% of the area burned under extreme weather conditions would be expected to be active or conditional crown fire, down from 31% given existing conditions (Figure 38). Passive crown fire increases slightly (56% up from 47% EC) under extreme conditions, due to the desired clumpy canopy characteristics of the mechanical treatments.

Post wildfire watershed effects increase with the amount of a watershed that burns at high severity fire (Cannon 2010; Neary 2011). Under Alternative 3, 16 watersheds have expected active crown fire under extreme weather conditions for over 30% of the watershed, which would result in high severity effects (Figure 39). Six watersheds are have over 50% of the watershed expected to burn with active crown fire. Watersheds 67 (Bear Canyon) and 56 (Durfee Draw-Chevelon Canyon) have the highest proportion of potential for active crown fire (55% and 67% respective). If a wildfire were to burn within these watersheds, detrimental post wildfire effects would be expected.

Fire Hazard Index

Alternative 3 would decrease the risk of undesirable wildfire behavior and effects that could threaten lives, resources, and infrastructure. After implementation, the Fire Hazard Index decreases resulting in 22% of the project area is within the moderate to very high FHI (Figure 40), down from 37% in the existing conditions. The areas of moderate to extreme presents difficult and dangerous suppression conditions during a wildfire and potential for adverse post fire effects on soils and surface water quality, up from 37% in the existing conditions.

There are 6 watersheds with over 50% of the watershed in the moderate to very high FHI categories (Figure 41). Watershed 67 (Bear Canyon, 65%) and 59 (Upper Spring Creek, 77%) have the highest proportion of FHI in the moderate to very high class. Large wildfires in these watersheds have a high potential to be difficult and dangerous to suppress, and have a high potential for adverse post fire effects.

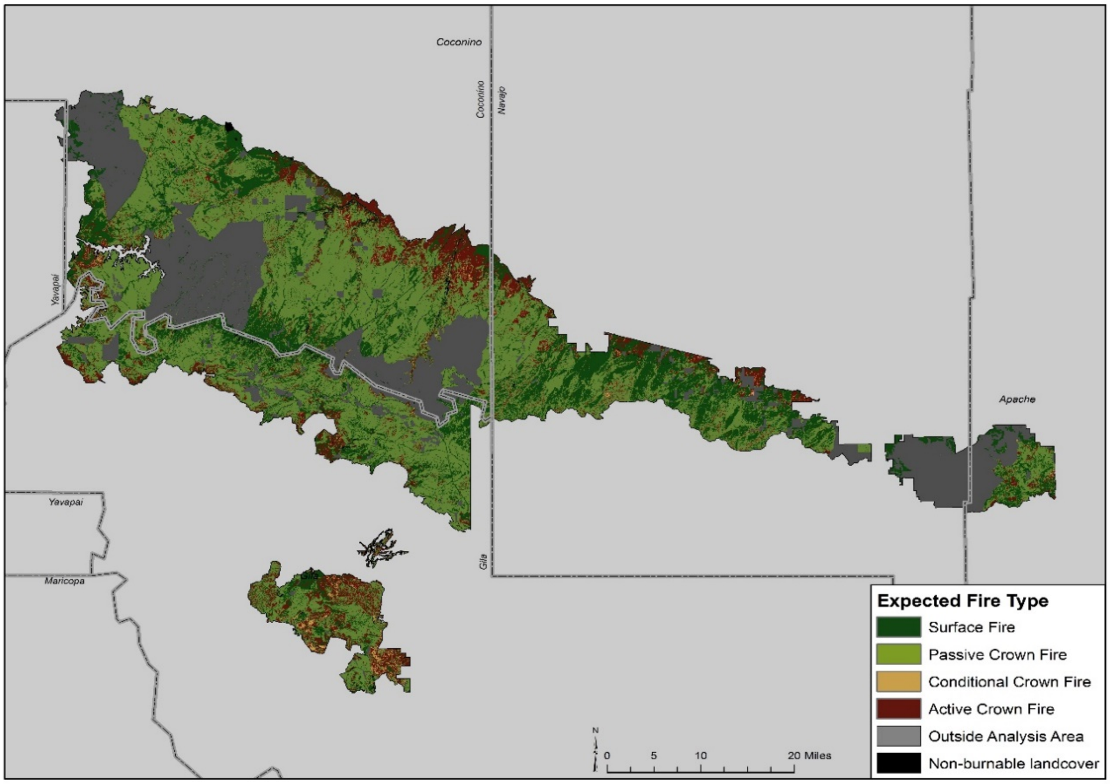

Figure 38: Expected Fire Type for Alternative 3, under modeled weather conditions.

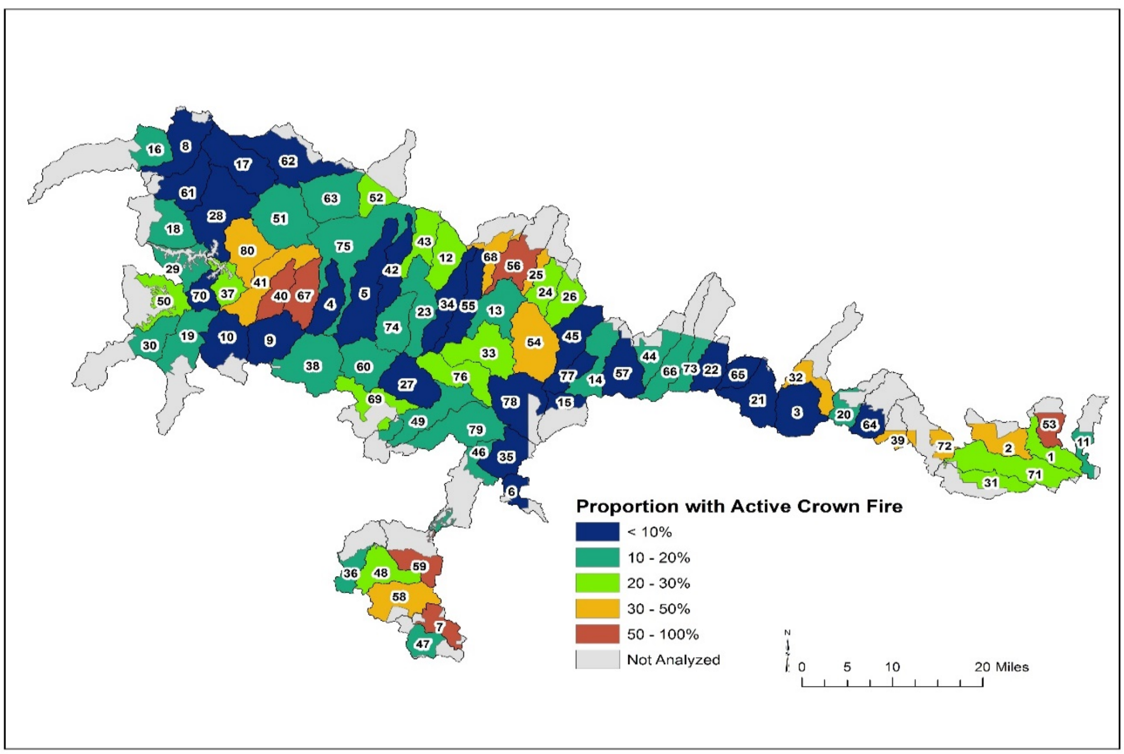

Figure 39: Proportion of each HUC6 watershed with Active Crown Fire for Alternative 3, under modeled weather conditions.

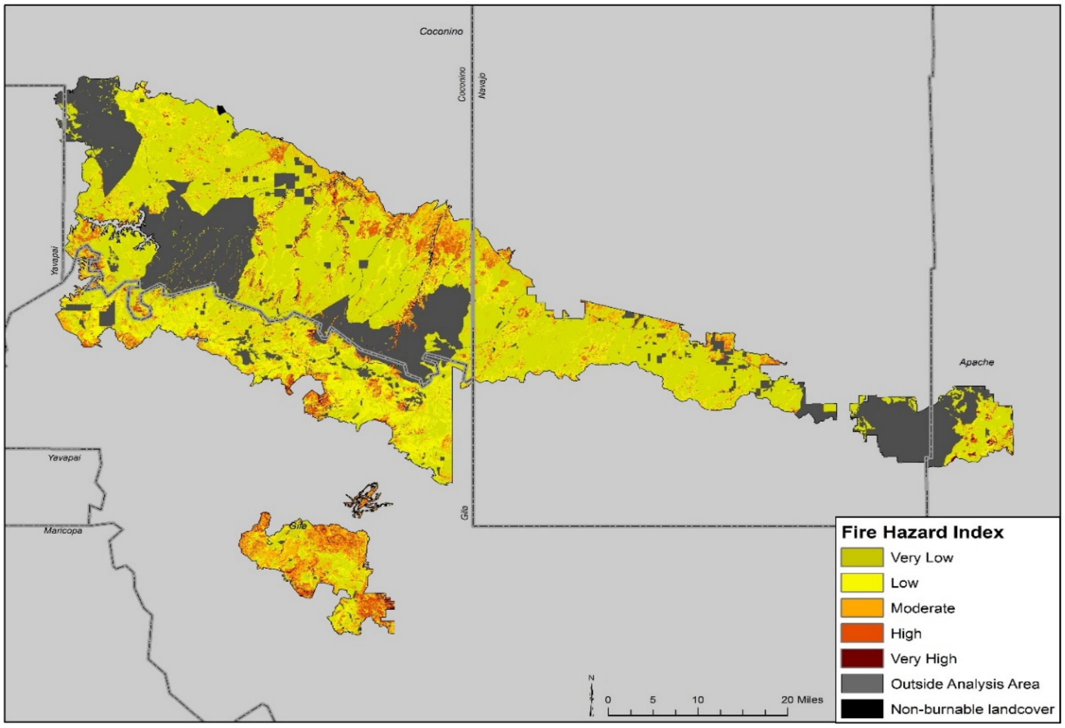

Figure 40: Fire Hazard Index for Alternative 3, under modeled weather conditions.

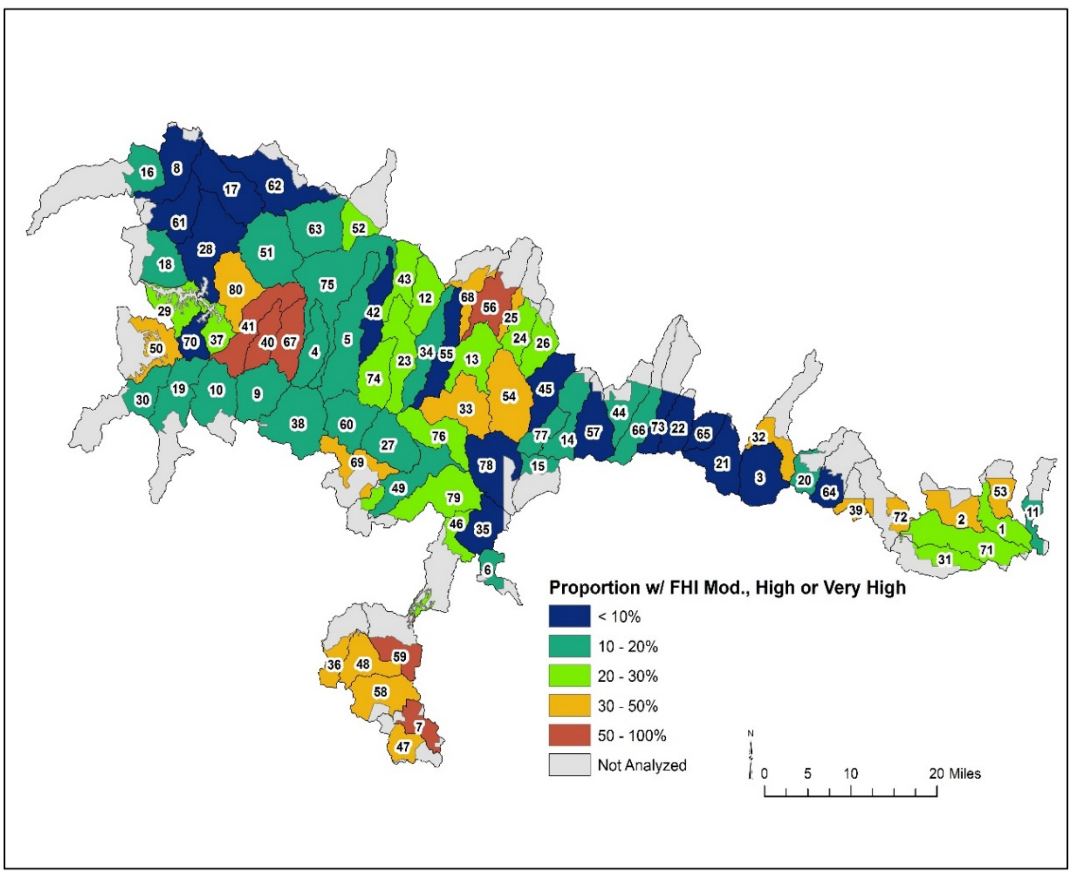

Figure 41: Proportion of each HUC6 watershed with Moderate, High or Very High Fire Hazard Index for Alternative 2, under modeled weather conditions

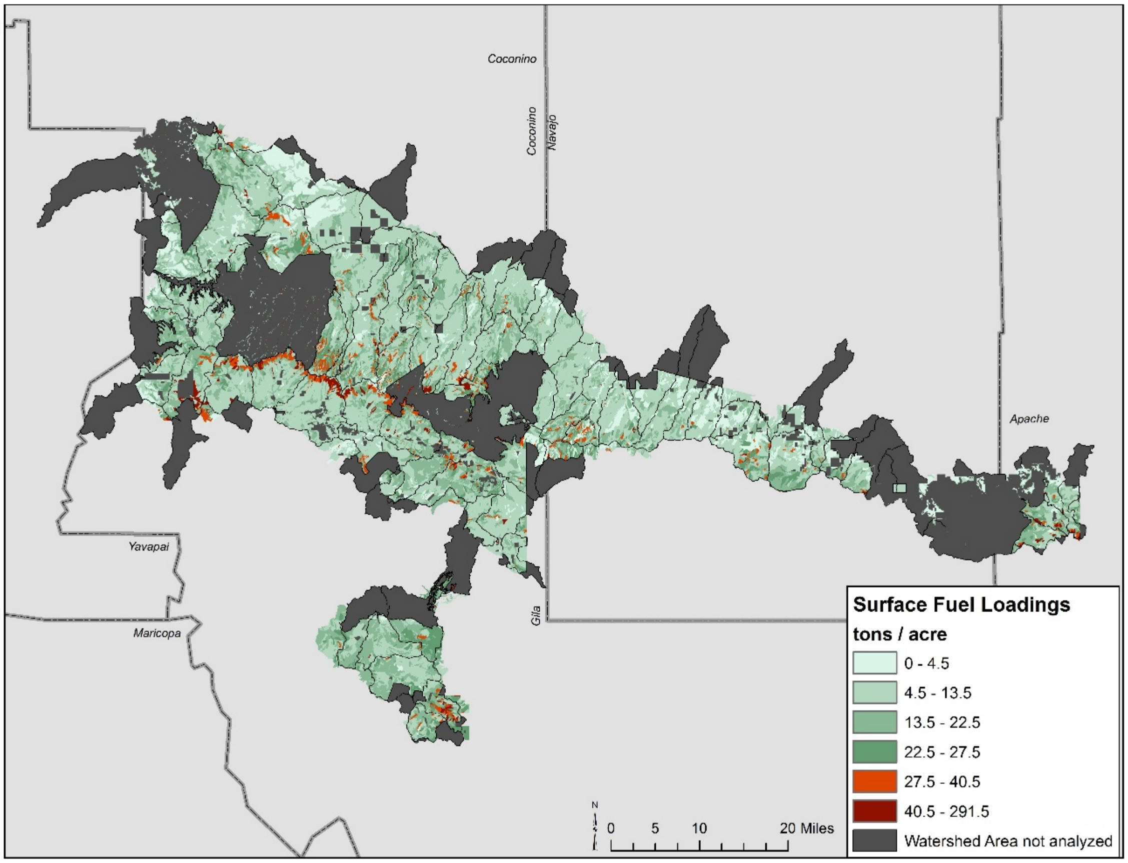

Figure 42: Total Surface Fuel Loadings for Alternative 3, under modeled weather conditions.

Surface Fuel Loadings

Under the Alternative 3, surface fuel loading would initially increase with mechanical treatment, and would also increase where no treatments occur. As first and second entry prescribed burns are implemented, these fuel loadings would decrease in most areas except those proposed for MSO treatments, which are designed to maintain a higher level of fuel loading, especially Coarse Woody Debris (dead/down woody fuels greater than 3" in diameter).

Desired conditions for total surface fuel loadings are less than 27 tons/ac in Ponderosa Pine vegetation types and less than 30 tons/ac in Dry Mixed Conifer. Under Alternative 3, 64,326 acres of Ponderosa Pine and 16,504 acres of Dry Mixed Conifer vegetation types exceed recommended fuel loadings (Figure 42).

Wildfire Management

Wildfire management environment would become safer and more effected as both CFA and FHI decrease. However in areas where no treatments are planned, CFA and FHI both increase. Even under extreme fire weather, suppression tactics would be more effective than current conditions. Decision space for managing unplanned ignitions would expand as Rim Country (and other projects) are implemented.

WUI

Under the Alternative 3, WUI areas on Forest Service lands across the treatment area would be more fire adapted, however increasing smoke from prescribed fires would be present next to homes. CFA and FHI both decrease on Forest Service lands (Table 19). The potential for home and asset loss from crown fires, high intensity surface fires and ember lofting from fires on Forest Service land would decrease. The need for private and non-forest service land owners to manage fuels on their lands in order to compliment Rim Country initiatives will be imperative to fully mitigate risk and impacts from wildfires.

Table 19: Alternative 3 metrics for the Wildland Urban Interface

WUI CLASS	Total Acres	Fire Hazard Index				Fire Type	
		Very Low - Low	moderate	high	very high	Passive & Active Crown Fire	Active Crown Fire
High Value Rec Sites	375	81%	8%	6%	5%	65%	11%
Comm Sites	2074	86%	8%	6%	1%	68%	11%
NonFS Lands	22638	87%	8%	4%	0%	63%	10%
Transmission Lines	4083	84%	10%	6%	1%	65%	15%
FS Buildings	1683	80%	8%	10%	3%	71%	14%

Vegetation Cover Type

At the project scale, active crown fire and Fire Hazard Index are reduced for all target vegetation cover types (Table 20). At the project area scale, ponderosa pine would not meet desired conditions for active crown fire (<10%), under Alternative 3 under the extreme conditions modeled, however it would move the cover type closer to desired conditions.

Table 20: Alternative 3 metrics by Vegetation Cover class

Vegetation Cover Type	Total Acres	Fire Hazard Index				Fire Type	
		Very Low - Low	moderate	high	very high	All Crown Fire	Active Crown Fire
Ponderosa Pine	556284	75%	7%	16%	3%	75%	22%
PIPO Evergreen Oak	147989	36%	33%	26%	5%	62%	30%
Dry Mixed Conifer	49281	26%	17%	28%	29%	29%	54%
Wet Mixed Conifer	3130	29%	4%	26%	41%	30%	70%
Aspen	1438	95%	1%	3%	2%	4%	5%
Pinyon Juniper	135085	36%	33%	28%	3%	53%	67%
Madrian Pinyon Oak	23318	19%	33%	41%	7%	55%	80%
Grasslands	18851	98%	2%	0%	0%	3%	3%
Riparian Areas	14567	70%	11%	13%	6%	35%	19%

Large and old trees

Under Alternative 3, the potential for fire-related mortality of large and/or old trees would be reduced across the landscape where treatments are implemented in the same manner as Alternative 2. In areas where no treatments are applied, old trees would respond as in Alternative 1.

Stream/spring restoration

Restoration of ephemeral streams, and 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 allows prescribed fire for fuels management riparian areas.

Roads

From 1992 through 2015, over 1.6 million acres of human ignited wildfires burned on Williams, Tusayan, Flagstaff, and Mogollon Rim Ranger Districts, 35% of all acres burned in wildfires (FOA Dataset - Short, 2015). 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 would eventually grow back, allowing fire to burn across the area. During the implementation of the mechanical treatments, roads constructed or reconstructed for access would be available for access to burn units, and/or to be used as firelines for burns.

Emissions and Air Quality

This alternative would meet the purpose and need, and desired conditions for Air Quality. Effects to Air Quality from smoke emissions will be a mix of Alternative 1 and Alternative 2. 528,060 acres would be treated resulting in lower emissions from a post-treatment wildfire. The remaining project area acres would increase in potential wildfire emissions due to increases in surface fuel loadings and crown fire potential.

The number of days (duration) of smoke impacts, as well as the intensity (concentration) of the impacts are of concern to the public. While the variability from year to year would be large, under Alternative 3, prescribed fire would need to be implemented on up to 52,806 acres annually to produce an average fire return interval of 10 years across 528,060 acres proposed for prescribed fire. Implementing prescribed fire as proposed in Alternative 3 would result in lower emissions than if the area burned in a wildfire because there would be less biomass to burn (Figure 36).

Under Alternatives 3, the number of acres available for prescribed fire would be 52,806 acres. 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.

Surface fuel loading would decrease where treatments are implemented, 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. In these areas, smoldering fuels would produce high levels of smoke, as well as a high likelihood of high severity fire effects.

The likelihood and degree of potential impacts from wildfire smoke would decrease as fuel

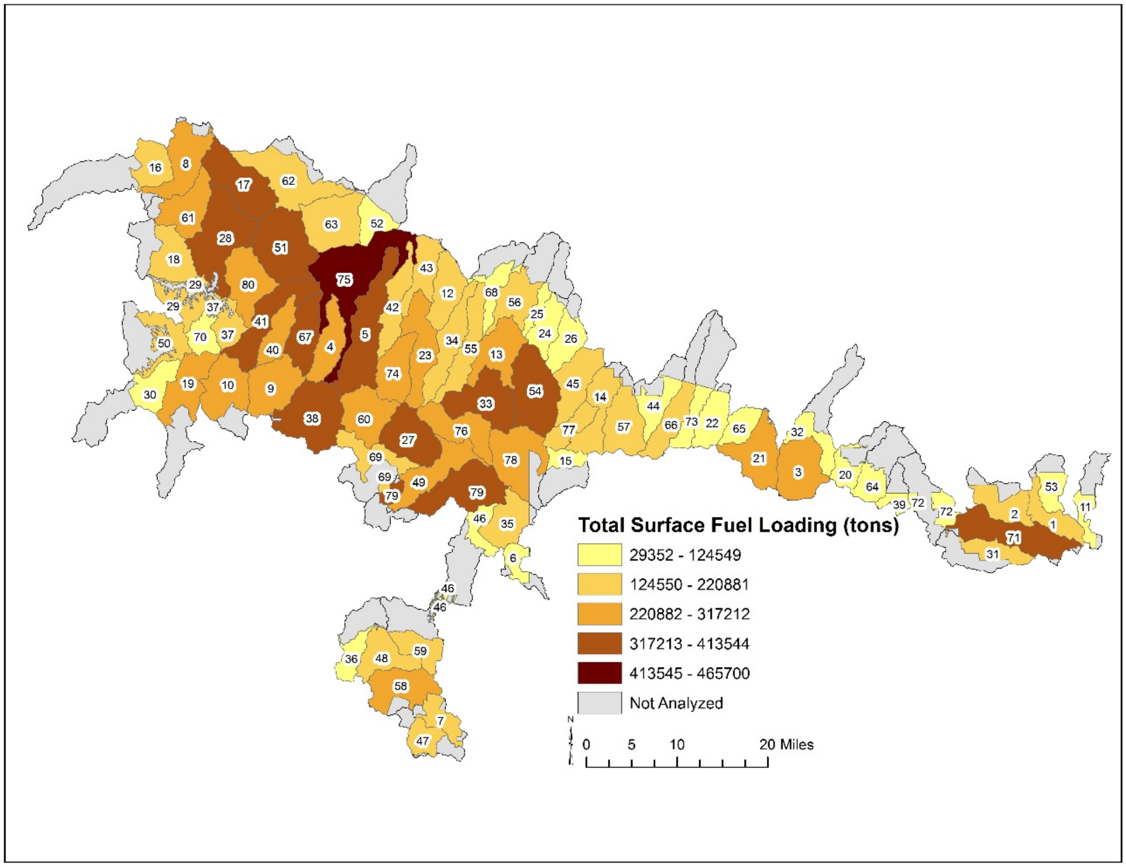

Figure 43: Total Surface Fuel loadings of each HUC-6 watershed for Alternative 3, as modeled using FVS

loading decrease after prescribed burns. After implementation, Watersheds 75 (East Clear Creek – Clear Creek) and 79 (Haigler Creek) have the greatest potential to produce emissions because of surface fuel loading (Figure 43). Under Alternative 3 all but 46 watersheds decrease in total surface fuel loadings. Five remains effectively the same (< 3% change), and 41 increase in fuel loadings (see Table 25 below). Watershed 1 (Upper Rocky Arroyo) and 133 (Decker Wash) increase the most (29% and 28% respective).

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 in duration to the degree that the public would tolerate it in those areas discussed the Air Quality section of Alternative 3 in this report.

Under Alternative 3, there is expected to be some old growth tree mortality. Through mitigation measures, this loss is expected to be lower where treatments occur and higher where treatments do no occur.

Comparison of Alternatives

This report analyzed the effectiveness of 3 alternatives for modifying composition, pattern, and structure as a means of restoring healthy ecological function to ponderosa pine, specifically in regards to fire ecology and air quality. All action alternatives are expected to reset the current trajectory of areas proposed for treatment towards greater sustainability and resilience. Aspen, grasslands, oak communities, and some pinyon/juniper communities associated with ponderosa pine are included. Restoring historic fire regimes plays both direct and indirect roles in achieving or maintaining desired conditions for these vegetation communities. All action alternatives move the Rim Country proposed treatment area toward desired conditions. Differences between them are discussed below, and summarized at the end of this section.

Fire Type

The change from existing conditions to post-treatment conditions in the action alternatives results primarily from: 1) mechanical treatments breaking up the vertical and horizontal continuity of canopy fuels; 2) mechanical treatments and prescribed fire raising canopy base heights; and 3) prescribed fire consuming surface fuels and some canopy fuels, and decreasing the potential intensity of subsequent fires.

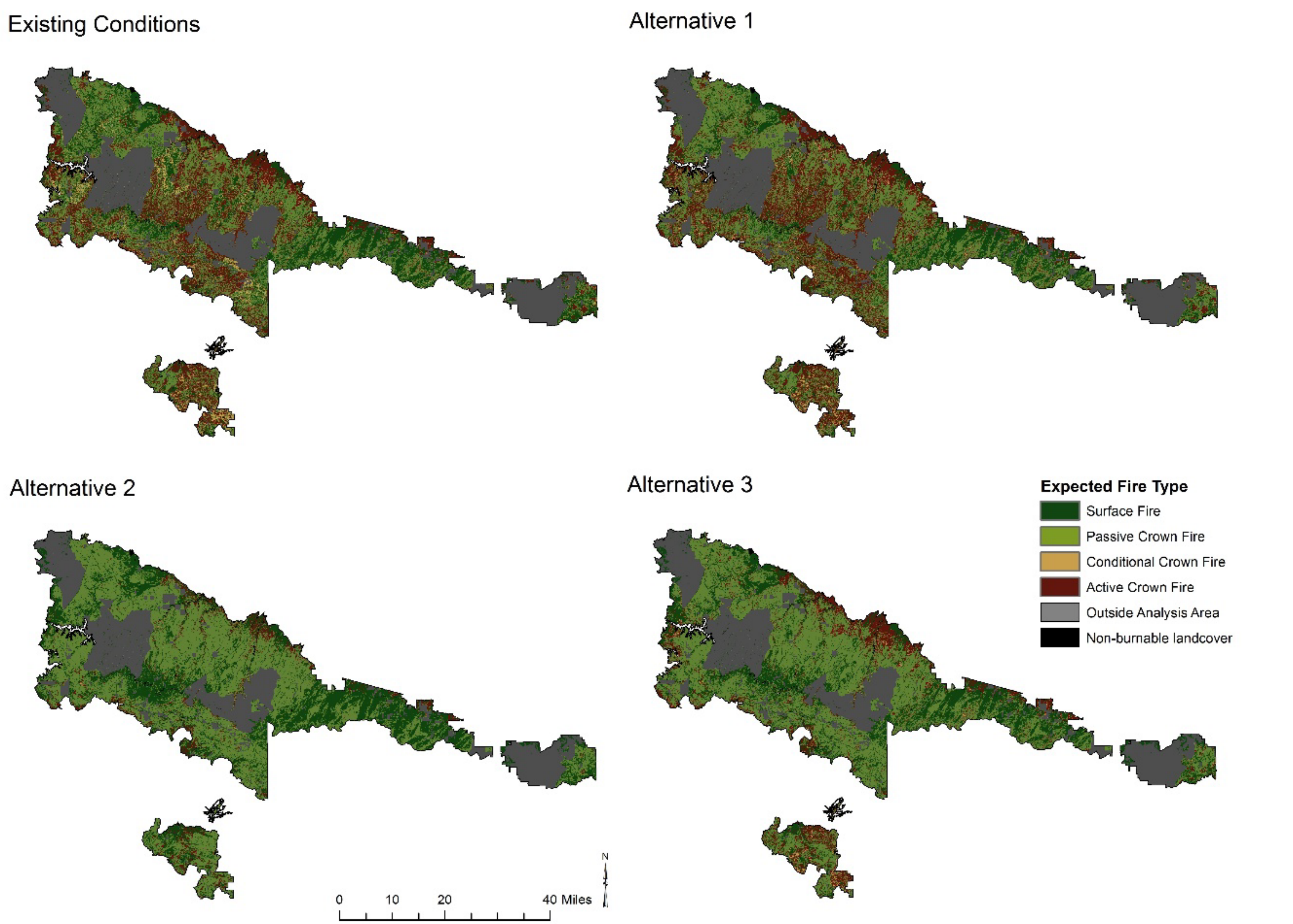

Figure 44: Comparison of Fire Type for each Alternative

Table 21: Comparison of Alternatives Fire Type within the Wildland Urban Interface. Red Numbers are increases from existing conditions (EC), blue number are decreases.

WUI CLASS	Total Acres	Fire Type							
		All Crown Fire*				Active Crown Fire*			
		EC	ALT1	ALT2	ALT3	EC	ALT1	ALT2	ALT3
High Value Rec Sites	375	79%	83%	64%	65%	38%	40%	10%	11%
Communication Sites	2074	75%	79%	65%	68%	27%	28%	6%	11%
NonFS Lands w/ Struc	22638	68%	73%	57%	63%	28%	29%	6%	10%
Transmission Lines	4083	66%	74%	61%	65%	32%	33%	6%	15%
FS Buildings	1683	83%	85%	67%	71%	41%	43%	5%	14%

*Desired condition for ponderosa pine is to have potential for less than 20% crown fire.

Table 22: Comparison of Alternatives for Fire Type by vegetation cover class for extreme fire weather

Vegetation Cover Type	Total Acres	Fire Type							
		All Crown Fire				Active Crown Fire			
		EC	ALT1	ALT2	ALT3	EC	ALT1	ALT2	ALT3
Ponderosa Pine	556284	72%	81%	75%	79%	21%	22%	1%	5%
Ponderosa Pine Evergreen Oak	147989	82%	85%	62%	72%	29%	30%	0%	9%
Dry Mixed Conifer	49281	75%	77%	29%	33%	50%	54%	11%	14%
Wet Mixed Conifer	3130	71%	74%	30%	30%	66%	70%	13%	14%
Aspen	1438	6%	6%	4%	4%	4%	5%	2%	2%
Pinyon Juniper	135085	71%	71%	53%	62%	65%	67%	25%	49%
Madrian Pinyon Oak	23318	85%	86%	55%	71%	79%	80%	41%	59%
Grasslands	18851	15%	16%	3%	5%	3%	3%	0%	5%
Riparian Areas	14567	44%	48%	35%	35%	18%	19%	2%	2%

Fire Hazard Index

An overall comparison of fire hazard index across alternatives is presented in Figure 45. Alternative 1 results in the largest percentage of the project area in the moderate, high and extreme FHI classes. Alternative 2 provides for the largest overall reduction in FHI for the project area as a whole, while Alternative 3 shows significant reductions in FHI ratings across much of the project area, though less so than Alternative 2.

To further understand the impacts of each proposed alternative based on Fire Hazard Index, it is useful to examine the relative change in FHI rating classes within select areas of interest, especially within Wildland Urban Interface (WUI) classes. As shown in Table 23, Alternative 1 results in a relative increase in the amount of acreage in the high and very high FHI classes across nearly all WUI Classes. Both Alternative 2 and Alternative 3 show a relative decline in the area of high and very high FHI classes, with a corresponding increase in the area rated as very low-low FHI. This illustrates the effectiveness of both alternatives in reducing the overall Fire Hazard

Index rating across all WUI classes. The differences between Alternative 2 and Alternative 3 are limited, reflecting the emphasis of treatment in and adjacent to the WUI areas in both action alternatives. Table 24 provides a further examination of the relative changes in FHI for each vegetation cover type across all alternatives.

Surface Fuel Loading

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 (see discussion on page 33). Historic levels were estimated to be 5 - 20 tons/acre for CWD alone.

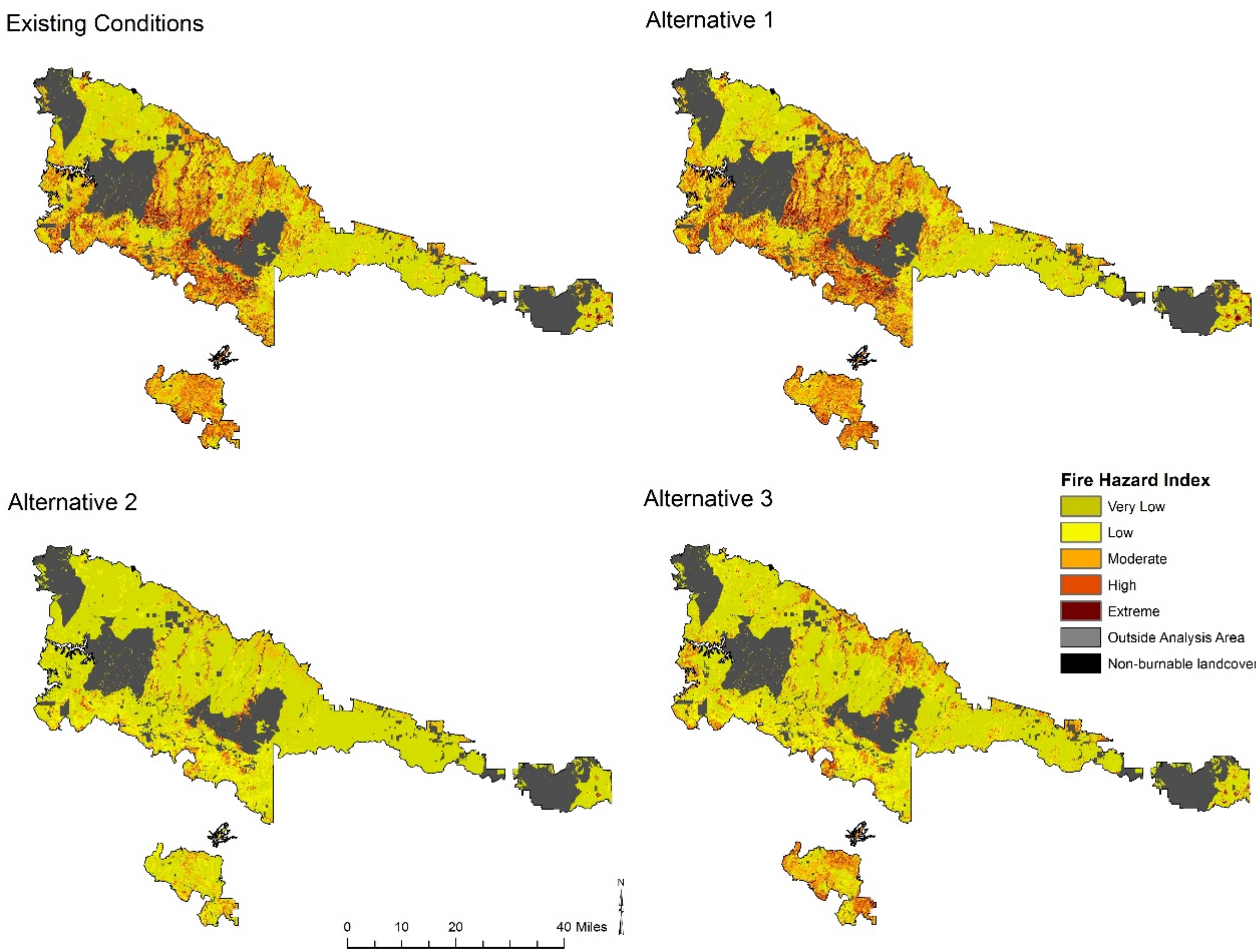

Figure 45: Comparison of Fire Hazard Index between Alternatives

Table 23: Comparison of Alternatives by Fire Hazard Index for the Wildland Urban Interface Classes

WUI CLASS	Total Acres	Fire Hazard Index															
		Very Low - Low				moderate				high				very high			
		EC	ALT1	ALT2	ALT3	EC	ALT1	ALT2	ALT3	EC	ALT1	ALT2	ALT3	EC	ALT1	ALT2	ALT3
High Value Rec Sites	375	49%	45%	83%	81%	16%	19%	6%	8%	18%	18%	6%	6%	16%	19%	5%	5%
Comm Sites	2074	66%	63%	92%	86%	15%	16%	6%	8%	17%	18%	2%	6%	2%	3%	0%	1%
NonFS Lands	22638	66%	63%	93%	87%	16%	17%	6%	8%	15%	18%	1%	4%	3%	3%	0%	0%
Transmission Lines	4083	64%	61%	93%	84%	18%	17%	6%	10%	15%	18%	1%	6%	3%	4%	0%	1%
FS Buildings	1683	51%	49%	89%	80%	14%	14%	6%	8%	27%	29%	4%	10%	8%	9%	1%	3%

Table 24: Comparison of Alternatives by Fire Hazard Index for each Vegetation Cover Type

Vegetation Cover Type	Total Acres	Fire Hazard Index															
		Very Low - Low				moderate				high				very high			
		EC	ALT1	ALT2	ALT3	EC	ALT1	ALT2	ALT3	EC	ALT1	ALT2	ALT3	EC	ALT1	ALT2	ALT3
Ponderosa Pine	556284	77%	75%	97%	93%	9%	7%	2%	3%	12%	16%	1%	3%	2%	3%	0%	0%
Ponderosa Pine Evergreen Oak	147989	41%	36%	95%	75%	31%	33%	4%	16%	24%	26%	1%	8%	4%	5%	0%	1%
Dry Mixed Conifer	49281	29%	26%	74%	70%	18%	17%	10%	12%	27%	28%	9%	11%	26%	29%	7%	8%
Wet Mixed Conifer	3130	32%	29%	83%	82%	5%	4%	4%	4%	25%	26%	7%	7%	38%	41%	6%	6%
Aspen	1438	95%	95%	98%	97%	1%	1%	1%	1%	3%	3%	1%	1%	2%	2%	0%	0%
Pinyon Juniper	135085	37%	36%	74%	53%	34%	33%	22%	27%	26%	28%	4%	19%	2%	3%	0%	1%
Madrian Pinyon Oak	23318	20%	19%	55%	37%	31%	33%	25%	30%	43%	41%	19%	29%	6%	7%	1%	4%
Grasslands	18851	98%	98%	100%	100%	2%	2%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Riparian Areas	14567	74%	70%	92%	92%	11%	11%	5%	5%	11%	13%	2%	2%	5%	6%	1%	1%

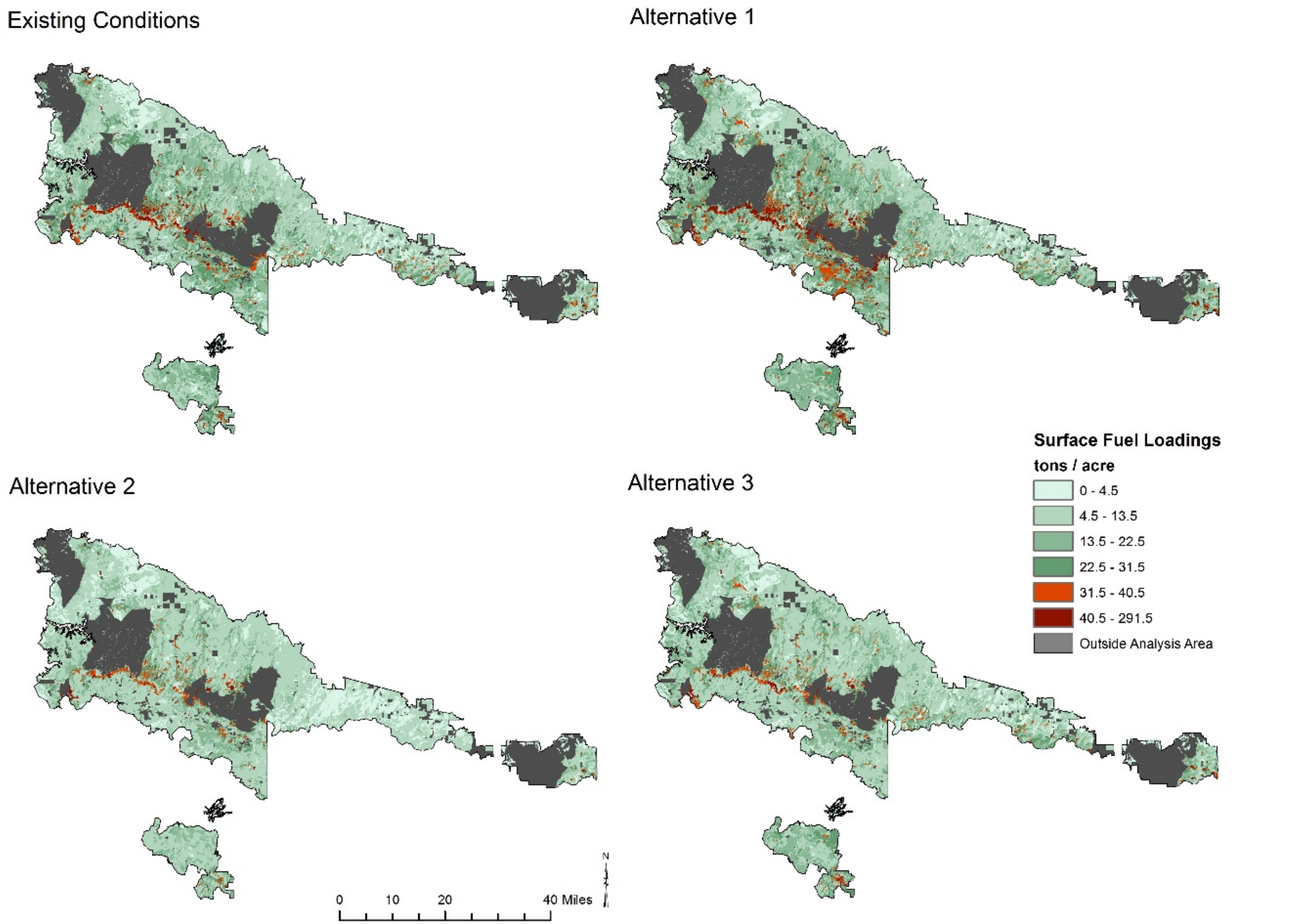

Figure 46: Comparison of Total Surface Fuel Loadings between Alternatives

Emissions and Air Quality

Table 25: Comparison of Percent Changes in Total Surface Fuel Loadings from existing conditions***

Map Label	Watershed Name	Existing Total SFL	ALT 1 % Change	ALT 2 % Change	ALT 3 % Change
1	Upper Brown Creek	143,874	26%	-10%	10%
2	Upper Rocky Arroyo	117,828	30%	29%	29%
3	Mortensen Wash	238,345	9%	-55%	-7%
4	Barbershop Canyon	316,351	19%	-22%	-22%
5	Leonard Canyon	490,214	19%	-22%	-22%
6	Gentry Canyon	77,488	16%	-25%	-25%
7	Reynolds Creek	176,637	20%	-19%	7%
8	Double Cabin Park-Jacks Canyon	264,058	17%	7%	10%
9	East Verde River Headwaters	389,775	12%	-27%	-26%
10	Webber Creek	327,236	16%	-16%	-16%
11	Sepulveda Creek	72,897	23%	-23%	-1%
12	Cabin Draw	159,183	24%	-21%	0%
13	Upper Chevelon Canyon-Chevelon Canyon Lake	234,868	25%	-10%	2%
14	Bear Canyon-Black Canyon	185,764	16%	-46%	8%
15	Bull Flat Canyon	79,640	6%	-47%	5%
16	Red Tank Draw	194,843	14%	5%	5%
17	Upper Willow Valley	290,666	23%	-20%	10%
18	Home Tank Draw	140,654	15%	-22%	7%
19	Pine Creek	349,252	12%	-31%	-27%
20	Linden Draw	75,116	7%	-45%	-8%
21	West Fork Cottonwood Wash-Cottonwood Wash	229,322	9%	-53%	2%
22	Upper Day Wash	64,663	28%	-22%	19%
23	Upper Willow Creek	355,012	19%	-14%	-14%
24	Middle Wildcat Canyon	93,047	15%	-21%	9%
25	Lower Wildcat Canyon	28,219	18%	4%	18%
26	Upper Potato Wash	106,747	19%	-22%	-3%
27	Christopher Creek	444,690	11%	-26%	-26%
28	Lower Willow Valley	337,796	19%	-22%	2%
29	Upper West Clear Creek	148,312	19%	-22%	-12%
30	Hardscrabble Creek	148,864	13%	-30%	-25%
31	Billy Creek	118,406	22%	19%	22%
32	Dodson Wash	71,678	15%	-11%	11%
33	Long Tom Canyon-Chevelon Canyon	394,280	21%	2%	2%
34	Upper West Chevelon Canyon	271,066	20%	-24%	-24%
35	Parallel Canyon-Cherry Creek	237,399	16%	-33%	-33%
36	Rock Creek	105,061	21%	-21%	8%
37	Clover Creek	140,657	33%	15%	15%
38	Ellison Creek	397,878	17%	-15%	-4%
39	Fools Hollow	49,749	19%	15%	16%
40	Miller Canyon	195,395	21%	19%	19%
41	East Clear Creek-Blue Ridge Reservoir	289,492	25%	23%	23%
42	Wilkins Canyon	210,859	24%	-27%	-23%
43	Lower Willow Creek	158,542	20%	-6%	-5%
44	Upper Pierce Wash	78,338	5%	-47%	5%
45	Upper Brookbank Canyon	182,964	23%	-26%	-12%
46	Gruwell Canyon-Cherry Creek	121,988	19%	-30%	-13%
47	Workman Creek	138,566	27%	-22%	-7%
48	Buzzard Roost Canyon	187,727	28%	-10%	10%
49	Gordon Canyon	381,345	14%	-26%	-25%
50	Upper Fossil Creek	173,917	20%	-23%	16%
51	Windmill Draw-Jacks Canyon	353,747	17%	-18%	5%

52	Hart Tank	45,265	23%	18%	18%
53	Ortega Draw	63,924	25%	18%	21%
54	Upper Wildcat Canyon	370,140	25%	5%	6%
55	Alder Canyon	214,676	23%	-23%	-19%
56	Durfee Draw-Chevelon Canyon	134,595	18%	0%	16%
57	Buckskin Wash	191,122	6%	-60%	-7%
58	Upper Salome Creek	214,917	33%	-17%	6%
59	Upper Spring Creek	179,642	22%	-27%	21%
60	Horton Creek-Tonto Creek	341,225	14%	-25%	-15%
61	Brady Canyon	222,194	17%	13%	15%
62	Tremaine Lake	129,905	28%	4%	26%
63	Dogie Tank-Jacks Canyon	142,974	20%	-6%	17%
64	Bagnal Draw-Show Low Creek	93,232	10%	-46%	-3%
65	Stinson Wash	64,844	14%	-32%	-8%
66	Upper Phoenix Park Wash	110,842	15%	-40%	15%
67	Bear Canyon	285,961	18%	17%	17%
68	Lower West Chevelon Canyon	65,172	20%	5%	19%
69	Bull Tank Canyon-Tonto Creek	164,608	22%	-24%	-12%
70	Toms Creek	125,511	29%	-17%	-17%
71	Porter Creek	319,069	27%	11%	24%
72	Show Low Lake-Show Low Creek	56,145	19%	12%	12%
73	Decker Wash	52,388	28%	-24%	28%
74	Gentry Canyon	327,002	19%	-10%	-10%
75	East Clear Creek-Clear Creek	499,780	20%	-12%	-7%
76	Woods Canyon and Willow Springs Canyon	241,500	22%	21%	21%
77	West Fork Black Canyon	122,169	16%	-49%	15%
78	Canyon Creek Headwaters	315,160	18%	-19%	-15%
79	Haigler Creek	509,875	17%	-22%	-20%
80	Long Valley Draw	252,547	18%	10%	17%

****Includes acres of in watersheds that have treatments planned in other projects, these numbers may in reality be lower due to the effects of those treatments which were not analyzed in this report.

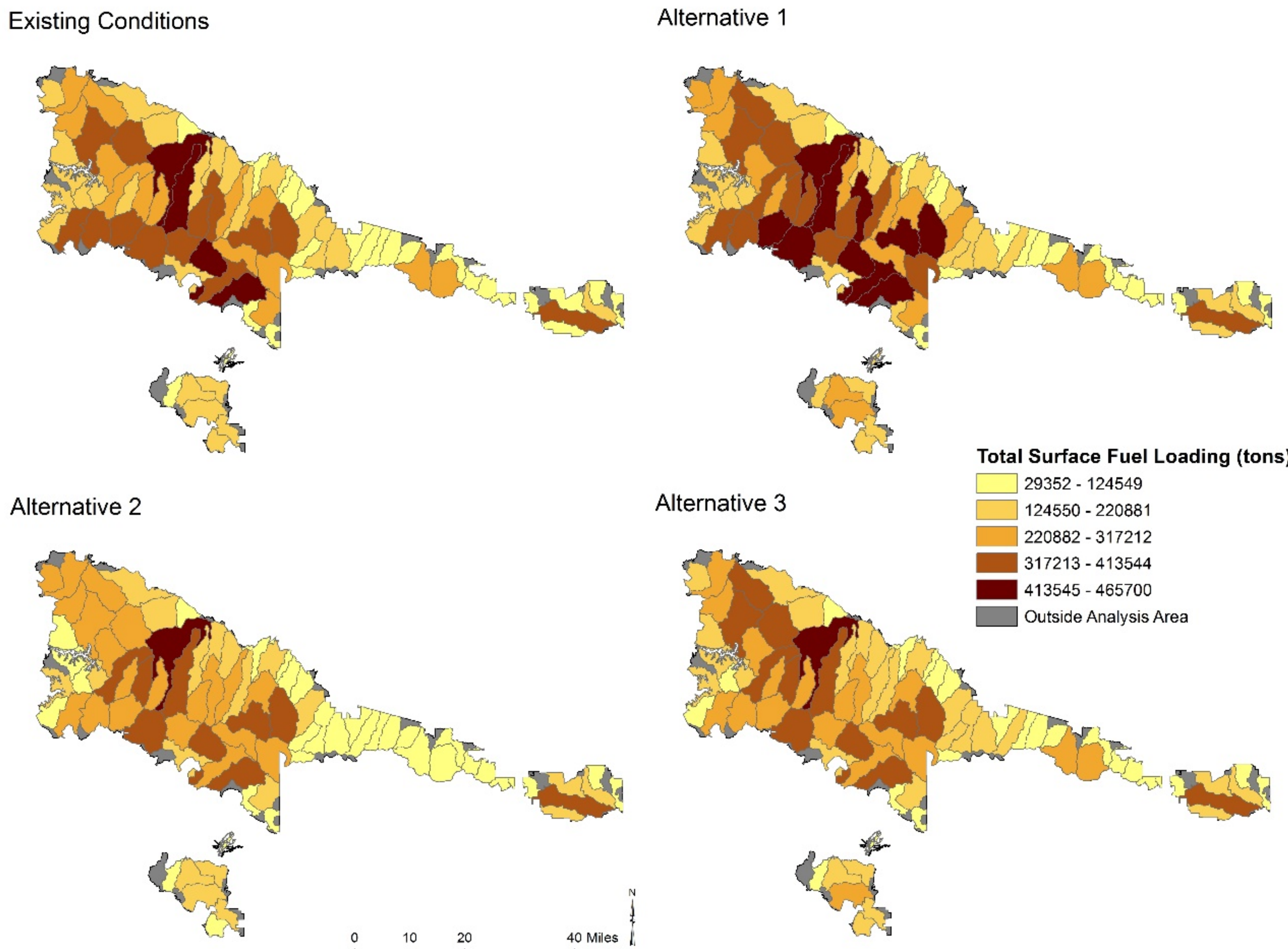

Figure 47: Comparison of Total Surface Fuel Loadings between Alternatives

The amount of biomass consumed during a prescribed fire (and therefore the emissions produced) is more easily controlled than for wildfires burning on dry, hot, windy days. When comparing alternatives, all of the action alternatives propose prescribed fire at some level which could impact air quality in the surrounding communities but in a controllable manner. The post-treatment conditions from implementing these alternatives would reduce the amount of biomass available to burn during wildfire which would moderate fire behavior, fire effects, and reduce the emissions potential of wildfire occurring in those areas. Alternative A does not propose any prescribed burning, and would produce increasing amounts of biomass available to burn in the

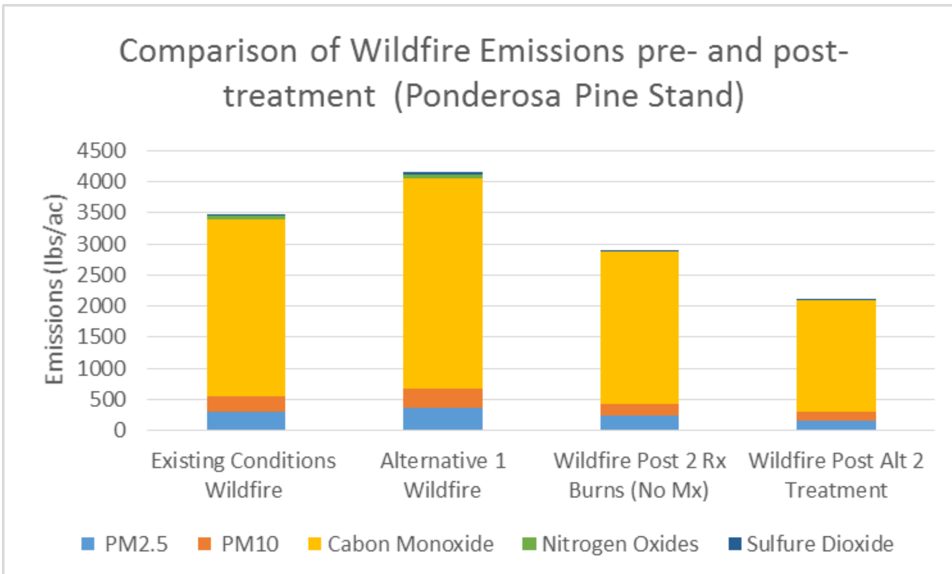

Figure 48: Comparison of emissions between alternatives

event of a wildfire. This would have direct and most likely uncontrollable impacts on recreation and surrounding communities from emissions, as well as longer lasting fire effects.

Examining the 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. 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/m^3 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 all three forests, the Verde River Airshed, the Lower Salt River Airshed, and the Little Colorado River Airshed (Figure 14). The season for broadcast burning is about April through October, pile burning is most often done in the winter months, and wildfires generally occur from April through October. More acres are proposed to be burned in the implementation than are currently being burned annually on all forests, so there would be prescribed burning on more days each year. However, after the first entry burn, fuel loads would be significantly decreased, so potential tons/acre of emissions would be significantly lower. Additionally, because of the decrease in fuels, fire behavior potential would also be significantly lower, so there would be more potential to burn on days with better smoke dispersal (higher winds and more lift).

The action alternatives propose prescribed burning at different levels. There are too many variables affecting the concentration of smoke at specific locations for a given prescribed fire for a spatially explicit evaluation on the scale of this project a year (or more) in advance of implementing a burn. Burn Plans are tiered to the NEPA document for which they direct prescribed fire implementation, and include spatial modeling that identifies what effects are expected where, and helps determine conditions that would 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.

Cumulative Effects Analysis

Cumulative effects related to fire ecology and air quality are incremental impacts of an alternative when added to the effects of other past, present, and reasonably foreseeable future actions. These include the effects of wildfire and vegetation management activities (mechanical treatments, & prescribed fire) on fire behavior and associated fire effects, including air quality.

Geographic Scope - Cumulative effects of wildfires and other projects are considered for the approximately 1.24 million acre Rim Country project area.

Temporal Scope - This analysis primarily considered the past 10 years (2009-2018) of associated activities. This time period is based on recovery times and fuel accumulation rates associated with the ecological systems present in the Rim Country area. This analysis considered a 10 year time frame to reflect future and reasonably foreseeable activities at which time the majority of the actions proposed will have been completed.

For the Rim portion of the DEIS, the effects of wildfires and other project are considered for 1,238,658 acres project area. Prevailing winds during fire season generally have a western, southwestern, or southerly component to them, so fires burning adjacent to the western or southern border of the project area have a greater potential to burn into the project area that fires further away or in other directions. The USFS and the National Interagency Fire Center define 'large fires' as at least 300 acres in grass or shrub fuels, or at least 100 acres in timber (USDA 2014a). All fires included occurred from 2009 through 2018 and are at least 100 acres.

For the Environmental Consequences and Affected Environment analyses fire type, fire hazard index and surface fuel loading were evaluated for assessing movement towards desired conditions because they are indicators of potential fire behavior and effects, including air quality. Specific data are not available for many other projects. For projects included in this cumulative effects analysis, the treatments and the project objectives were considered as they relate to fire behavior and effects and air quality.

Past Actions: Wildfire

Nearly all area of the cumulative effects analysis area has been influenced or altered by past modifications to natural fire regimes as a result of fire suppression and livestock grazing. The culmination of these impacts over more than a century has resulted in the contemporary conditions found throughout the Rim Country project area. While the primary focus of this cumulative effects analysis focusses on the previous 10 years of wildfires and activities, it is important to note the role that past management has had on influencing this landscape and creating undesirable and unnatural conditions.

From 2009 – 2018, a total of 81 large wildfires3 burned within the project acre, representing a total of 217,780 acres burned (Figure 49). Many of the wildfires that burned within the project area in the last 10 years were managed primarily for beneficial resource objectives (as opposed to being managed primarily for suppression objectives). These accounted for 38 wildfires totaling 126,310 acres burned within the project area. Other fires may have had some resource benefit management objectives as well, however the information needed to assess this is not readily available. The fire severity of the 38 wildfires managed primarily for resource benefit was mostly low and moderate. However, high severity fire has continued to occur within the Rim Country area. In the past 10 years, approximately 12,193 acres burned at high severity within the project area. The Tinder fire (managed for suppression) burned with 27% (4,328 acres) high severity, and 33 homes were destroyed. The Highline fire (also managed for suppression) burned with 18% high severity. Post

[3] The USFS and the National Interagency Fire Center define 'large fires' as fires of at least 300 acres in size for grass or shrub fuels, or at least 100 acres in size in timber fuels (USDA 2014a). This analysis includes all fires that occurred from 2009 through 2018 and were at least 100 acres in size.

fire debris flows initiated in part from the Highline Fire claimed the lives of 10 people and caused significant damage to the watershed. These fires demonstrate some of the negative

Past Actions: Vegetation Management Activities

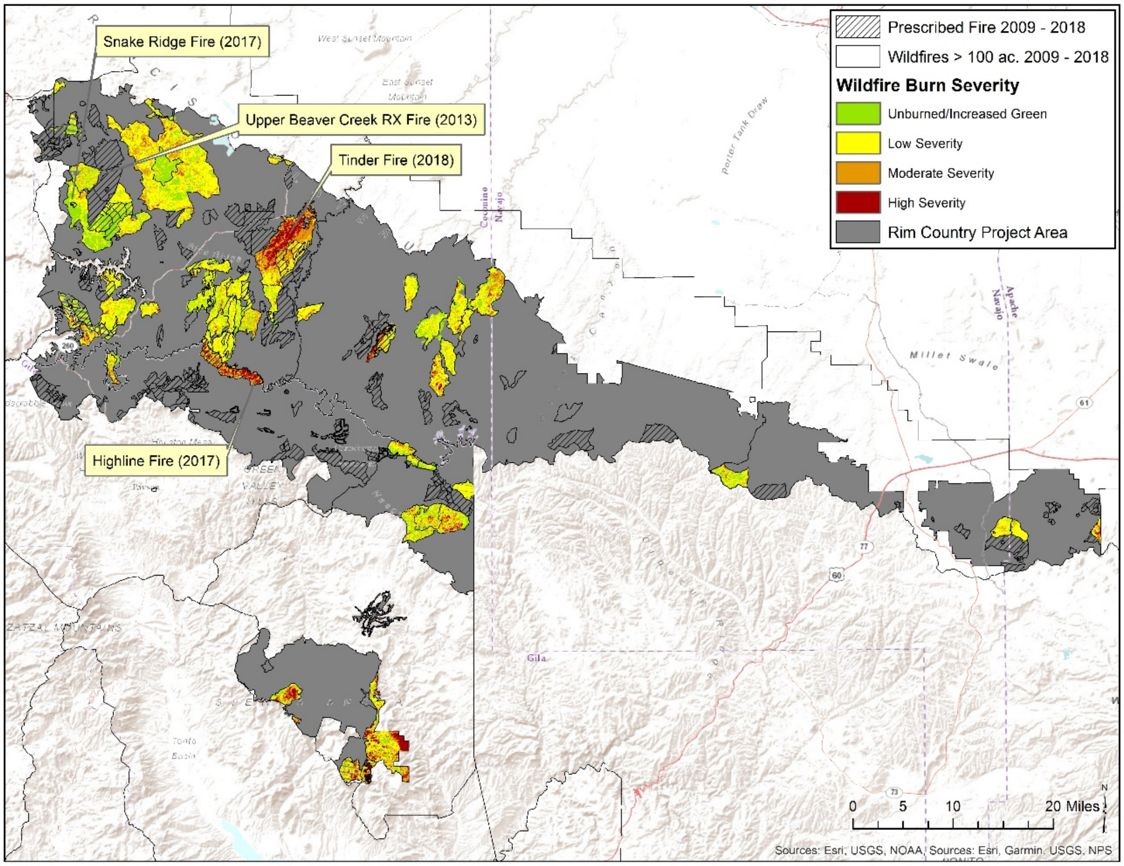

Figure 49: Recent Wildfire and Prescribed Fire (2009 – 2018) and the associated wildfire burn severity

Within the cumulative effects analysis area, there were approximately 164,232 acres of mechanical thinning and approximately 259,661 acres of prescribed fire acres within the past 10 years (Table 18).

Treatment Type	Past Projects (approximate acres)	Current Projects (approximate acres)	Reasonably Foreseeable Projects (approximate acres)	Combined Past, Present and Reasonably Foreseeable Projects (approximate acres)
Mechanical Vegetation Management	164,232	417,551	124,434	*706,217*

Prescribed Fire	259,661	383,541	64,710	*707,912*
Other Activities*	51,072	40,379	93,147	*184,598*
Totals	**474,965**	**841,471**	**282,291**	***1,598,727***

Table 26: Acres of past, present and reasonably foreseeable projects with cumulative effects for fire, fuels and air quality.

***Other activities include but not limited to fuels chipping, range forage improvement or manipulation, range vegetation control, wildlife habitat improvement, tree encroachment control, tree release, fuels compaction, special products removal, insect control and prevention planting, fuel break creation, cultural site protection, scarification and seeding, pruning, and salvage.**

These past activities have, and will continue to moderate potential wildfire effects for the cumulative effects analysis area. This was demonstrated by the Upper Beaver Creek prescribed fires completed in 2013. These treatments allowed for the 2017 Snake Ridge wildfire to be managed for beneficial resource objectives, and influenced the final fire perimeter. 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.

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. Within the project area, near, adjacent to, or within the treatment area, 23 projects were completed within the last 10 years that included mechanical thinning and/or prescribed burning acres (Table 26) and these have, or may, affect potential fire behavior and effects within the treatment area.

In general, the past management actions have decreased the potential for active crown fire, crown fire initiation and high severity fire effects on the acres treated and/or burned by wildfire. Across the cumulative effects analysis area other projects have affected vegetation in similar ways to those described under this project's alternatives, though there are some variations in treatments, particularly for the older fuels treatments. Past mechanical and prescribed fire treatments have 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 intensity of subsequent fires in those locations.

Table 27: Past Vegetation Management Activities

Project Name	Year	Mechanical	Prescribed Fire	Other Activities*	Forest
Bruno Thining and Slash	2009	0	70	0	Apache-Sitgreaves
whitcom wui	2009	925	0	0	Apache-Sitgreaves
hilltop II Fuels reduction	2011	0	799	616	Apache-Sitgreaves

Rodeo-Chediski Site Prep for Reforestation (#48660)	2016	0	0	0	Apache-Sitgreaves
Show Low South (#29987)	2011	3372	0	0	Apache-Sitgreaves
Rodeo-Chediski Fire RX Burn	2012	0	9506	14832	Apache-Sitgreaves
Timber Mesa/Vernon WUI	2012	18781	39760	20441	Apache-Sitgreaves
Rim Lakes Forest Restoration	2016	12483	1335	6447	Apache-Sitgreaves
Section 31 Fuels Restoration	2017	44	0	0	Apache-Sitgreaves
Larson Forest Restoration	2015	1867	0	2516	Apache-Sitgreaves
Upper Rocky Arroyo Restoration	2016	696	5411	3960	Apache-Sitgreaves
Post Tornado Resource Protection and Recovery	2011	765	0	0	Coconino
Lake Mary Road ROW Clearing (ADOT)	2016	788	0	0	Coconino
Upper Beaver Creek Watershed Fuel Reduction	2010	20608	64000	0	Coconino
Blue Ridge Community Fire Risk Reduction	2012	0	45000	0	Coconino
Clints Well Forest Resotration	2013	11	6639	0	Coconino
Hutch Mountain communication site	2017	1	0	0	Coconino
Parallel Prescribed Burn	2014	0	4759	0	Tonto
Cherry Prescribed Burn	2012	0	6582	0	Tonto
Myrtle WUI	2012	103891	75800	1835	Tonto
Pierce Reforestation	2009	0	0	406	Apache-Sitgreaves
Rodeo-Chediski Riparian Planting	2010	0	0	1	Apache-Sitgreaves
long Valley work center meadow resotration	2018	0	0	18	Coconino

*Other activities include but not limited to fuels chipping, range forage improvement or manipulation, range vegetation control, wildlife habitat improvement, tree encroachment control, tree release, fuels compaction, special products removal, insect control and prevention planting, fuel break creation, cultural site protection, scarification and seeding, pruning,

Air Quality

Past treatments and wildfires have decreased the potential emissions by removing canopy fuels, mostly from thinning, but some from wildfire and prescribed fire. Low to Moderate severity fire would have consumed surface fuels, further decreasing potential for emissions on about 205,587 acres. Where wildfires burned with high severity (~12,193 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.

Cumulative Effects – Present and Reasonably Foreseeable Actions

Acres of current, ongoing, and foreseeable projects within the Rim Country project area are shown in Table 62. They include 448,251 acres of prescribed fire and 541,985 acres of mechanical vegetation management. Some of these projects are in the early stages of proposal development or are on hold, so their implementation is reasonably foreseeable but not assured. The acreages shown under mechanical vegetation management and fuels treatments are not all mutually exclusive. There are many acres on which proposed fuels treatments (mechanical and prescribed fire) overlap with proposed mechanical vegetation management treatments.

Table 62. Approximate Acres of Current, Ongoing, and Reasonably Foreseeable Vegetation Management Activities within the Project Area.

Treatment	**Treatment Type**	**Current Projects** Approximate Acres	**Reasonably Foreseeable Projects** Approximate Acres
	Thinning -Habitat Improvement	89,579	10,975
Mechanical Vegetation Management	Thinning – Fuels Reduction Emphasis	114,570	41,046
	Thinning – Restoration Emphasis	53,578	285
	Savanna/Grassland Restoration	0	39,000
	Salvage	5,678	0
	Range Cover Manipulation	34,701	54,147
	Powerline Hazard Tree Removal and Right of Way	4,580	22,963
Total Mechanical:		**302,686**	**168,416**
Fuels Treatments (With Mechanical)	Mechanical Fuels Treatment	155,244	49,165
	Pile and Burn	133,168	5,070
	Broadcast Burn	250,373	59,640
Total Fuels Treatments		**538,175**	**113,875**

Alternative 1

Effects of the Alternative

Alternative 1 would continue to maintain 977,656 acres with increasing potential for high severity fire effects and behavior, though the effects would be mitigated to some degree by current and reasonably foreseeable projects, and any beneficial wildfires that may occur in the future. Alternative 1 would not contribute to improving the structure, composition, and patterns within the area proposed for treatment.

Effects of Other Actions

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.

Within the area considered for cumulative effects for fire ecology and air quality, other actions will contribute to some improvement in landscape conditions. However, these improvements would be much less than those predicted for the action alternatives. Improvements would be primarily localized, within individual project boundaries, and collectively do less to move the broader landscape towards desired conditions. Alternative 1 would lead to less spatial continuity between treatments when compared to the action alternatives. At the landscape scale, it would not put the ponderosa pine and associated vegetative systems on trajectories towards being resilient or sustainable.

Cumulative Effects

Under Alternative 1, the treatment area would continue develop unnatural densities and fuel loading, increasing the potential for undesirable fire behavior and effects when wildfires occur. When fires did occur, many would have potential for extreme fire behavior and could produce large areas of high severity fire effects. These impacts could extend well outside of the treatment area as fires that start within the proposed treatment area may pose difficulties for control and spread to adjacent lands. Many fires starting within the untreated project area would have potential to spread outside of the treatment area. Increased potential for extreme fire behavior would put lives, property, infrastructure, and natural resources at risk. Effects would also extend well beyond the perimeters of the fire, and would include such effects as flooding, debris flow, sedimentation, decreased water quality and quantity, decreased soil productivity, and other effects of fires burning out of their natural range of variation.

Fire Type

For those areas treated under the past, present and reasonably foreseeable actions, there would be a decrease in potential crown fire. However, the majority of the landscape would remain susceptible to crown fire and associated fire related impacts under Alternative 1.

Fire Hazard Index

Similar to fire type, reductions in fire hazard index are anticipated for areas treated under past, present and reasonably foreseeable actions. While beneficial, these reductions are not sufficient to mitigate the high fire hazard index ratings across the majority of the landscape.

Surface Fuels

Some reductions in surface fuels are anticipated, associated with the areas treated by past, present and reasonably foreseeable actions. However, for much of the cumulative effects analysis area, unnatural levels of surface fuels will continue to build up. When wildfires do occur in these areas of increased surface fuels, additional consumption and associated emissions are expected.

Air Quality & Smoke

Air quality would be unaffected by prescribed fire from the treatment area, however current and foreseeable activities will continue to produce smoke. Emissions from close to 450,000 acres of prescribed fire from current, ongoing, and reasonably foreseeable projects would 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.

Alternative 2

Effects of the Alternative

As described in the direct and indirect effects section, treatments proposed in Alternative 2 would move considerable acres toward desired conditions for fire behavior and associated fire effects across the project area.

Effects of Other Actions

Fuel treatments have been, and continue to be implemented in the WUI, closest to major population centers.

Within the area considered for cumulative effects for fire ecology and air quality, other actions will contribute to improvements in landscape conditions. Improvements include localized reductions in crown fire potential, decreases in fire hazard index values, and reduced levels of surface fuels.

Cumulative Effects

When considered with past wildfires, and past, ongoing, and reasonably foreseeable management activities, this alternative would augment the effects of proposed treatments at multiple scales, creating mosaics 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, contiguous, restored landscape across the project area.

Where past, present and foreseeable wildfires and treatments occur close to treatments proposed in the action alternatives, they serve to augment the moderating effect that the change in fuel structure is predicted to have on wildfires moving though the area by decreasing the acres where high severity fire effects are likely to occur. These combined activities also serve to augment the potential size and locations of burn units for the action alternatives because the moderated fire behavior in burned and/or thinned areas allow prescribed fire to be implemented with broader burn windows and higher intensity fire (if desired) while still meeting control and resource objectives.

Fire Type

Alternative 2 reduces crown fire potential under extreme fire weather conditions from 31% under current conditions to 12% within areas proposed for treatment. This reduction, combined with the past, ongoing, and reasonably foreseeable management activities would cumulatively reduce the overall landscape susceptibility to crown fire. When added to other treatments in the cumulative effects area alternative 2 provides for greater connectivity of treated landscapes resulting and the largest overall reduction in crown fire potential as contrasted with alternative 3. As a result, under moderate burning conditions, the majority of the landscape is projected to support surface fire. These cumulative effects provide the biggest improvement of all alternatives in overall firefighter and public safety while allowing fire to play a more natural role across the landscape, and provide opportunities to manage fires for resource benefits across a broader landscape.

Fire Hazard Index

This alternative provides for a significant reduction in moderate to extreme Fire Hazard Index (FHI) ratings, reducing the total area in these categories to 15% of the project area from 37%. When combined with past, ongoing, and reasonably foreseeable management activities, this alternative provides for additional improvements in FHI over the full cumulative effects analysis area.

Surface Fuels

Cumulative effects on surface fuels under alternative 2 provide for the greatest overall reduction in surface fuels. Cumulatively, this alternative will lead to a reduction in unnatural levels of surface fuels that have built up over time. When wildfires do occur in these areas of reduced surface fuels, consumption and associated emissions are expected to be lower than they would have been without the combined treatments.

Air Quality & Smoke

The cumulative effects under Alternative 2 include the greatest number of acres being treated with prescribed fire across the cumulative effects area. Cumulatively, this alternative combined with current and reasonably foreseeable activities will result in an annual average of more than 140,000 acres of prescribed fire (though annual amounts may vary considerably). The overall impacts from this amount of prescribed fire is expected to be more than those associated with alternatives 1 and 3. 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 2 would utilize many of the same burn windows that the nearly 450,000 acres of current, ongoing, and reasonably foreseeable prescribed fire projects would use. However, the increased acres of prescribed fire would allow more flexibility for implementation, and may make it possible to burn more acres at once with the same impacts to air quality.

Areas with potential for air quality impacts include the Colorado River Airshed, the Little Colorado River Watershed, and the Verde River Watershed. Class 1 airsheds that could be affected include Petrified Forest National Park, Sierra Anches Wilderness Area and Mazatzal Wilderness Area. As more acres are treated, there would be broader burn windows, potentially resulting in more days of prescribed fire and days of air quality impacts when added to prescribed burning occurring in the cumulative effects boundary.

Alternative 3

Effects of the Alternative

As described in the direct and indirect effects section, treatments proposed in Alternative 3 would move considerable acres toward desired conditions for fire behavior and associated fire effects across the project area.

Effects of Other Actions

Fuel treatments have been, and continue to be implemented in the WUI, closest to major population centers.

Within the area considered for cumulative effects for fire ecology and air quality, other actions will contribute to improvements in landscape conditions. Improvements include localized reductions in crown fire potential, decreases in fire hazard index values, and reduced levels of surface fuels.

Cumulative Effects

Fire Type

Alternative 3 reduces crown fire potential under extreme fire weather conditions from 31% under current conditions to 18% within areas proposed for treatment. This reduction, when combined with the past, ongoing, and reasonably foreseeable management activities will serve to reduce the overall landscape susceptibility to crown fire. Cumulatively alternative 3 when combined with prescribed fire from other projects provides for less connectivity of treated landscapes, though portions of areas not proposed for treatment remain susceptible to crown fire. As with Alternative 2, under moderate burning conditions, the majority of the landscape is projected to support surface fire. The cumulative effects will improve overall firefighter and public safety while allowing fire to play a more natural role across the landscape, and provide opportunities to manage fires for resource benefits across a broader landscape, though to a lesser degree than alternative 2. .

Fire Hazard Index

This alternative provides for a significant reduction in moderate to extreme FHI ratings, reducing the total area in these categories to 22% of the project area from 37%. When combined with past, ongoing, and reasonably foreseeable management activities, this alternative provides for additional improvements in FHI over the cumulative effects analysis area.

Surface Fuels

Cumulative effects on surface fuels under alternative 3 provide for considerable reduction in surface fuels. Cumulatively, this alternative will lead to a reduction in unnatural levels of surface fuels that have built up over time. However, areas left untreated will continue to accumulate unnatural fuel loading, and when wildfires do occur in these areas, elevated consumption and associated emissions are expected.

Air Quality & Smoke

Cumulatively, this alternative combined with current and reasonably foreseeable activities will result in an annual average of more than 97,000 acres of prescribed fire (though annual amounts may vary considerably). The overall impacts from this amount of prescribed fire is expected to be nearly a third less than those associated with alternative 2, but more than alternative 1.

Additionally, the potential for higher overall emissions associated with wildfires burning in areas not identified for treatment under Alternative 3 will result in more emissions in these areas than alternative 2. 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 3 would utilize many of the same burn windows that the nearly 450,000 acres of current, ongoing, and reasonably foreseeable prescribed fire projects would use over the next 10 years. However, the increased acres of prescribed fire would allow more flexibility for implementation, and may make it possible to burn more acres at once with the same impacts.

Areas with potential for impact include the Colorado River Airshed, the Little Colorado River Watershed, and the Verde River Watershed. Class 1 airsheds that could be affected include Petrified Forest National Park, Sierra Anches Wilderness Area and Mazatzal Wilderness Area. As more acres are treated, there would be broader burn windows, potentially resulting in more days of prescribed fire and days of air quality impacts when added to prescribed burning occurring in the cumulative effects boundary

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, Finney 2011 – FSIM paper). 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.

Changes in fire weather patterns are already apparent. As part of the National Fire Danger Rating System, the energy release component (ERC) is a composite measure of fire weather and fuel conditions that indicates the potential for large fire growth and dangerous fire conditions (Cohen, & Deeming 1985 – The National Fire Danger Rating System: basic equations. GTR PSW-82) Fire managers use percentile ERC values to identify days when weather has the potential to create extreme fire behavior, given an ignition or fire source. The 97^{th} percentile ERC historically has been the watch out indicator for extreme fire behavior. On average, only 3% of days per year should have an ERC value at the 97^{th} percentile or higher. When looking at the historic ERC percentiles based on the Herbert RAWS Station (station ID: 020301) from 1984 – 2001, the 97^{th} percentile was 86 (Figure 50). Looking at the years 2002 – 2017, this same value represents the 92^{nd} percentile, showing that during this most recent time period, 8% of days have the same potential for extreme fire weather that historically only occurred 3% of the time.

In general, any extended ERC value below the 80^{th} percentile would result in weather conditions that are not favorable for fires to ignite or spread. This may result in self suppression or effective human suppression, due to weather conditions (Finney 2009: Modeling containment of large wildfires using generalized linear mixed-model analysis). Again, from 1984 – 2001 this value was 65, and represents on average, there are 20% of fire growth days, or 73 days of fire growth potential. Currently this value is only at the 76^{th} percentile. This means that fire growth days that historically occurred 20% of the time now occurs 24% of the time, an increase of an average of 15 more days per year when fires could potentially ignite and spread.

Current research is showing that management techniques may only be somewhat effective at altering undesirable effects of wildfires in the future, given a warming and drying climate. Stephens et al. (2013), suggests that new strategies to adapt to increased fire should include restoration of historical stand structure, as it is effective at mitigating the effects of climate change in frequent, low severity fire regimes such as the 4FRI landscape. Lohman et al (2018) conversely found that while mechanical and prescribed fire treatment of forest stands slowed the conversion of Ponderosa Pine stands to other, more drought tolerant species or ecosystem types (i.e. grasslands) in the near future, given an extended warming/drying climate, this conversion happened after about 100 years. They call for the use of novel management strategies in managing these forests to avoid ecological degradation, including experimentation and defining achievable objectives such as maintaining function types or ecosystem services, rather than hoping to maintain current and historic forest characteristics.

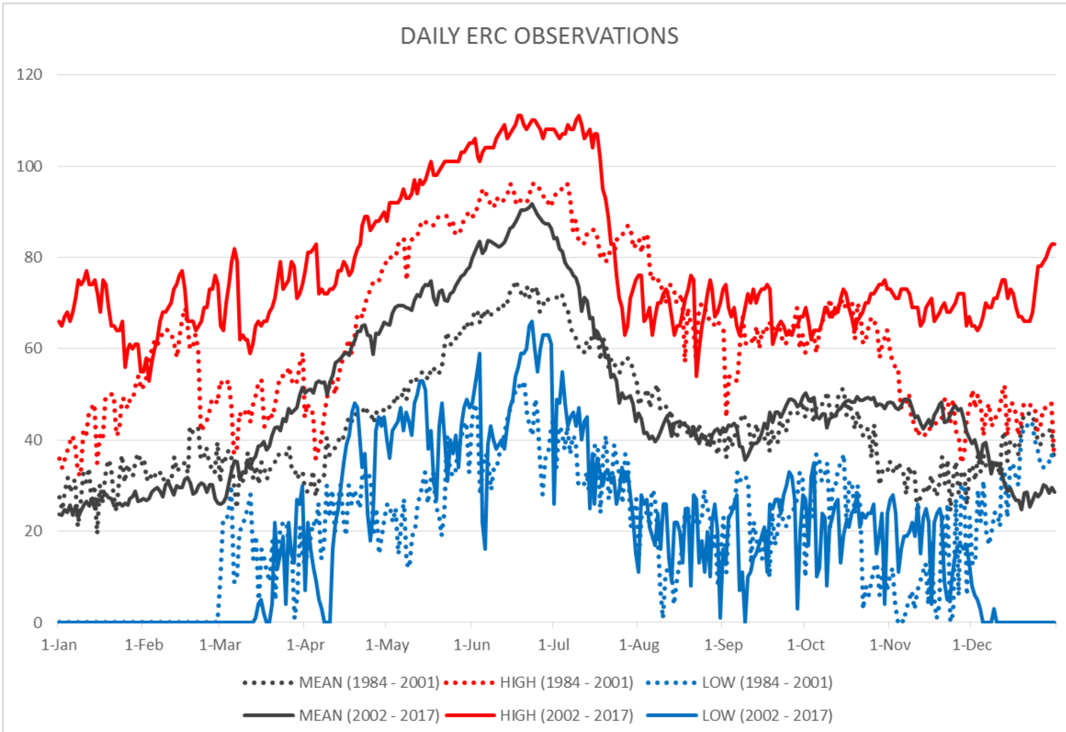

Figure 50: Shifts in Daily Observations of ERCs from the periods of 1984 – 2001 to 2002 - 2017

Carbon Sequestration

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 51). Savage and 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 52). 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 52 compares modeled emissions from a wildfire in a ponderosa pine stand between Existing Conditions, and all alternatives.

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 (Finkral and Evans 2008, Wiedinmyer and Hurteau 2010). They found that while the treatment initially produced a 30% 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 cause conditions that support uncharacteristic fire and insect outbreaks to become 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.

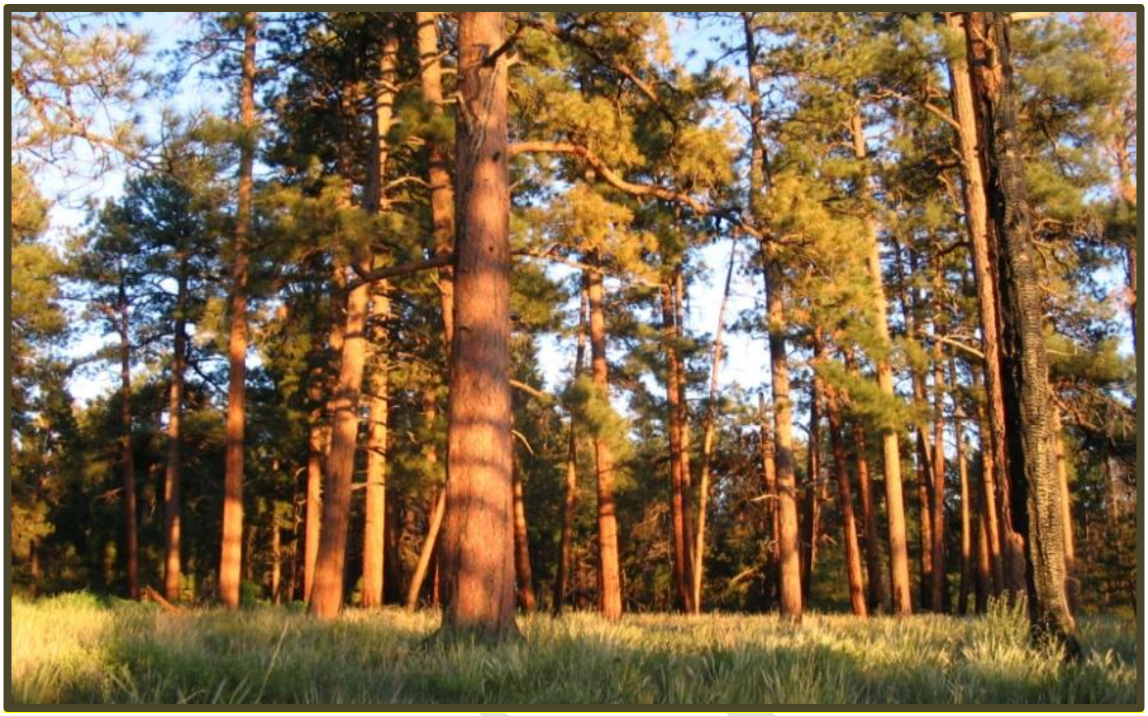

Figure 52: Top - Fifteen years after the Horseshoe Fire (photo from November 2011); Bottom – healthy ponderosa pine forest

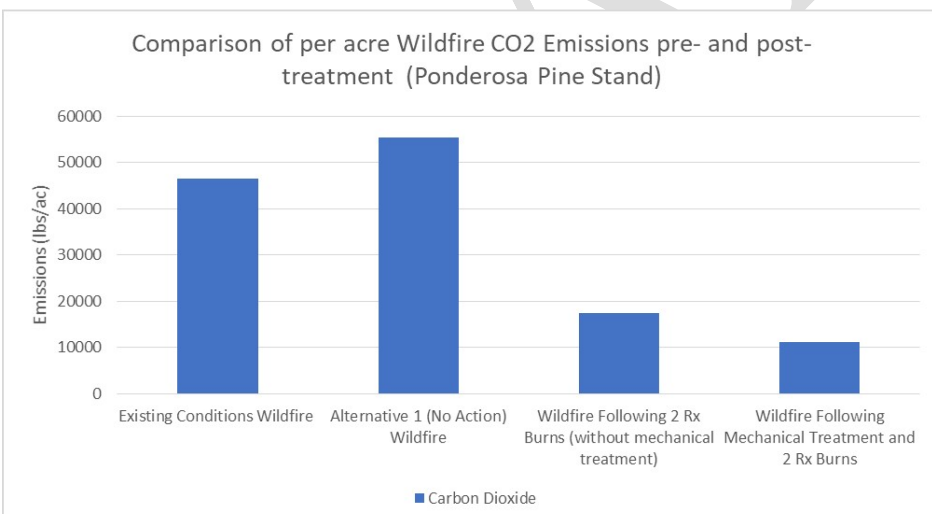

Figure 51: Carbon Dioxide Emissions for a wildfire under Existing Conditions vs. Alternatives 1 & 2. Stands in Alternative 3 would produce emissions similar to Alternative 1 if no treatment was applied, or Alternative 2 where treatments were implemented.

Restoration 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 53).

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 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 Rim Country actions improve the ability of the project area to store carbon in a stable condition.

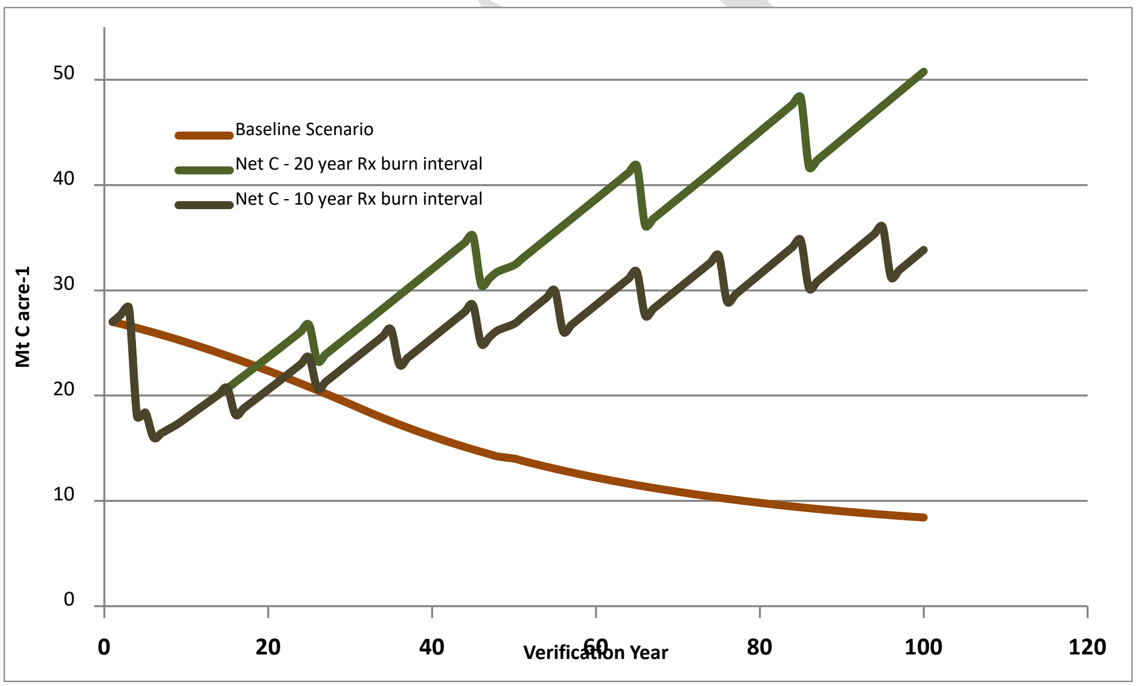

Figure 53: Modeled carbon sequestration with no treatment, and with 10 and 20 year treatment intervals (Woods et al. 2012).

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

Effects from Adaptive Management Activities

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 Rim Country 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 were reviewed. None of the recommended management actions would conflict with desired conditions and proposed actions for Fire Ecology/Fuels/Air Quality.

Monitoring

Monitoring would be a critical component in the success of the Rim Country. 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 which 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 fire behavior that produced the desired fire effects? If monitoring data show treated areas do not meet desired conditions, there would 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 (such as large and/or old ponderosa pine, and large Gambel oak), and the response of surface vegetation for several years following treatments and/or wildfire.
- Were there any AQI exceedences? This would be automatic feedback from ADEQ monitors to track this. If there are AQI 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 would 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.

Discussion of Literature

Over the last several years, there have been a series of publications with different conclusions about the role of fire in ponderosa pine forests in Arizona. Williams and Baker compiled a large set of historical data that consists of records made by land surveyors for the General Land Office (GLO) in the late 1800s and early 1900s. Surveyors marked trees around corner points that delineated square miles and quarter-miles, sometimes making additional comments about the country they were walking through. This research provided new data in the form of estimates of forest density, species, and diameters of trees at the time of the survey (Williams and Baker 2012). Based on the density and size class data, they devised a method for determining past fire regimes, concluding that the proportion of high-severity fire in recent fires was less than or similar to the proportion in historical fires (Williams and Baker 2012). They also concluded that, historically, high severity fire was more prevalent across the ponderosa pine in Arizona than had been indicated by previous research (cited elsewhere in this report). Williams and Baker (2012) calculated that the historical fire regime in ponderosa pine forests on the Mogollon Plateau included 62.4% of the area had evidence of only low-severity fire, 23.1% of the area with mixed-severity fire, and 14.5% of the area with high-severity fire (Williams and Baker 2012). They also concluded that the historical fire rotation for high-severity fire was 828 years across the Mogollon Plateau, thus these fires were infrequent. Williams and Baker (2013) calculated the historical fire regime in ponderosa pine forests on the Coconino Plateau included 58.8% of the area with evidence of only low-severity fire, 38.7% of area with mixed severity fire, and 2.5% of area with high-severity fire (Williams and Baker 2013, Table 2). Fulé et al. (2013) responded with concerns about Williams and Baker’s (2012) methods and conclusions about high severity fire.

There is some variability in historic reports of fire severity across the landscape, even from single sources, which can be difficult to interpret. For example, in discussing ponderosa pine forests, Leiberg et al. 1904 (p. 23) say: “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…conditions are chiefly attributable to the numerous fires which have swept over the region within the last two hundred years, carrying with them the inevitable consequences of suppression and destruction of seeding and sapling growth…”. They also said: “The light stands in many cases represent tracts which were burned clear, or nearly so, one hundred or one hundred and twenty years ago, and now are stocked chiefly with sapling growths, ranging in age from 35 to 90 years."

In evaluating the available research that is specific to fire regimes in ponderosa pine in Arizona and the project area, many people feel that ecological, social, and economic values are not consistent with the pre-restoration disturbance regime of large, high severity fires, especially under changing climate. However, ecological restoration in the project area will lead to a restored fire regime with historical levels of low, mixed, and high-severity fire, even if the details of the historical levels remain under on-going study.

Additional publications have been produced in response, and this is expected to be an area of ongoing discussion in the literature. However, in evaluating the majority available research that is specific to fire regimes in ponderosa pine in Arizona and the project area, the preponderance of scientific evidence indicates that the restoration of ponderosa pine in northern Arizona the ecological, social and economic value is not consistent with a present-day disturbance regime of large, high severity fires, especially under changing climate (Fulé et al. 2013).

. Ponderosa pine has distinct variations within its geographic range (Oliver and Ryker 1990), and the populations of ponderosa pine in northern Arizona have some fundamental genetic differences from pines in other areas within the range of Ponderosa species (Conkle and Critchfield 1988). There are differences in the openness of crown growth, number of needles, and other characteristics. These two populations should not be expected to have identical fire regimes, even if the study was restricted to ponderosa pine.

Ecosystem restoration treatments are often designed to recreate presettlement fire regimes, stand structures and species compositions while fuel treatment objectives are primarily to reduce fuels to lessen fire behavior or severity—this is known as ''hazard reduction (Reinhardt et al. 2008).

Finney (2001, 2007), and Finney et al. (2007) focused on 'fuels management', which is useful for managing fire behavior when that is the primary concern. However, treating only 20% of the landscape, which Finney has shown can be effective in managing fire behavior, would not achieve restoration on a landscape scale. An analysis that focuses on where treatments would best minimize fire behavior may or may not be support restoration objectives across the landscape (which includes conservation of large and old trees, enhancing large oak, enhancing aspen clones, and other treatments).

Glossary (including acronyms)

GO TO MTBS WEBSITE FOR SOME DEFINTIONS – check their glossary

PAC: Protected activity center for the Mexican Spotted Owl (habitat type)

PFA: Post-fledgling Family Areas for Goshawks (habitat type)

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 (**Error! Reference source not found.**). 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: 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, causal agent, the relative influence of each causal agent and how they interact. The attributes researchers choose to represent a regime will vary depending on a researcher’s area of interest (Skinner and Chang 1996). 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 earths surface and deposit it elsewhere.

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 Severity A qualitative evaluation of immediate 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, top-killed 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 Lo**a**d: 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 (**LRMP**)**:** 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 90th percentile temperature for a given location is 90°F, it means that for 90% 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.

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/ 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, e.g. 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 (details in the Silviculture report).

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.

Wildland-urban interface (WUI) includes those areas of resident populations at imminent risk from wildfire, and human developments having special significance. These areas may include critical communication sites, municipal watersheds, high voltage transmission lines, church camps, scout camps, research facilities, and other structures that, if destroyed by fire, would result in hardship to communities. These areas encompass not only the sites themselves, but also the continuous slopes and fuels that lead directly to the sites, regardless of the distance involved. (FSM 5140.5)

Woody Debris: the dead and downed material on the forest floor consisting of fallen tree trunks and branches.

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Appendix B: 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 rarely uses the exact numbers as measured in the field 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.

Data Sources and Models Used:

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

Nexus

Version 2.1 – Nexus 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 Vegetation Simulator (FVS)

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, USDOI Bureau of Land Management, and USDOI 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/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 (Dixon 2003; Rebain 2016). For more details on the FVS-FFE modeling, see the Silviculture Specialists' 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

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 Wagners 1977 crown fire initiation model, Rothermels 1991 crown fire spread model, and Nelsons 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:

- Modeling results assume that all mechanical treatments occurred in 2012, and prescribed fires occurred across all areas proposed for treatment in 2015 and again in 2019. In reality, the treatments would be spread out over the life of the project. This means that desired conditions across the entire landscape may not occur concurrently.
- 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

Fire Area Simulator Version 4.1.055. This was used to generate initial 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 fire (Finney 2004). In the context of this analysis, Farsite was only used to edit the .lcp files used in FlamMap.

FireFamilyPlus (FF+)

Version 4.2– Used to determine percentile weather

FireFamilyPlus 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 Rodeo/Chediski 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 area.

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 projected 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

Inputs:

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 2005):

Fine fuel load (T/a)

- Potential FL (very dry)
- Potential ROS (very dry)
- Coarse fuel load (T/a)
- Species (deciduous vs. Conifer; aspen dominant)

Process:

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 were no treatments 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

Rationale: 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

Rationale: CC isn't sufficient to be able to carry a fire through the canopy, so it isn't a timber model (<30% CC) but CBH may be low enough to initiate cf in whatever woody veg there is (CBH<18.00). 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)

Rationale: 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 Service.

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:

Rationale: 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:

(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

Rationale: 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 continuous.

122:

(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

Rationale: 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.

SH (shrub)

Shrub/PJ are the main component defining 141, 142, and 145.

141:

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

Rationale: 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.

142:

Herbaceous <0.15

OR

Herbaceous <0.165 AND (tpa quga <5”) >300<400)

Rationale: 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:

(TPA PJ<5”) > 200 AND CBH < 10 AND CC > 25

Rationale: 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.

TU/TL (Timber Understory/Timber Litter)

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)

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

> Rationale: 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.

TL (Timber Litter): Not as above.

161:

(tpa pj <5” + mixed conifer <5”) < 152 AND (quga <5”) <1500

Rationale: 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.

162:

(tpa pj <5” + mixed conifer <5”) > 150 < 500

OR

(tpa quga <5”) > 1500 < 3000 AND (tpa pj <5” + mixed conifer <5”) > 150 < 500

Rationale: 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.

165:

(tpa pj <5” + mixed conifer <5”) > 500 AND (tpa quga <5”) >3000

Rationale: 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.

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:

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)

Rationale: 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.

182:

(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

Rationale: 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.

183:

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

Rationale: 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.

184:

(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

Rationale: 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).

185:

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

Rationale: 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.

186:

(tpa potr <5”)>600 AND (tpa potr >5”) >50

Rationale: 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.

187:

(100 hr + 1000 hr) > 15. 99 AND (tpa pj <5” + tpa mixed conifer <5”) <50

Rationale: 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.

188:

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

> Rationale: 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.

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.

Landfire 2014

LF_1.4.0 – 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 is the only existing source of the type of data needed for this type of analysis that is consistent across ownership boundaries. It is a combination of Landsat8 images and plot data, with well over 1,000,000 plots. Landfire data was combined with Lidar data to create the ‘base’ data used for fire modeling.

Lidar data

This set of data was collected in 2013, 2014. It was converted into data sets with a resolution of 30m x 30m that was compatible for fire modeling, and used to inform the assignation of fuel model, canopy height, canopy bulk density, and canopy cover.

Fire Hazard Index

Seven datasets were used to identify areas of high probability for severe fire effects and/or extreme behavior. These datasets are crown fire potential, fireline intensity, heat per unit area, fuel model, slope, soils with high erosion hazard, and WUI areas. Pixels were rated according to the matrix below. The total points possible are 12.

As a general rule, the amount and size of plants top-killed by fire increases with an increase in either the rate of heat energy released (fire intensity) or total amount of heat energy released (heat/unit/area). Estimates of the rate and amount of this heat release are thus important descriptors of fire behavior (Wade 2013). Thus, two measures of energy were used, and are described below.

Heat per unit area (hua): 'hua' is the total amount of heat released in a given area of the flaming fire front, usually expressed as Btu per square foot, though in this process kJ/m^2 was used. All of the heat given off in the ***flaming*** front is included in this value, regardless of the length of time that the flaming front persists. This allows a better estimate of ***burn severity*** (fire effects to soil) than the more commonly used fireline intensity (see description below). Heat released after the flaming front has passed (smoldering combustion) is not included in heat per unit area. Categories used are based on an index developed for the Flagstaff Watershed Protection Project by Mary Lata (Fire Ecologist, 4FRI); Tom Runyon (Hydrologist/BAER, Coconino National Forest), and Wes Hall (Prescribed Fire Specialist, Coconino National Forest). Heat/unit/area is given in kJ/m^2 as follows: high soil burn severity was assumed at or above 60,500 kJ/ m^2; moderate heat/unit/area was assumed between 8,700 – 60,499 kJ/m^2.

Fireline intensity (fli). This is the amount of heat given off by a fire along each foot of the leading edge of the fire each second, usually expressed as Btu per linear foot of fireline per second. This measure is useful for evaluating control objectives because there is almost a 1:1 correlation between fli and Flame Length (FL) (Stratton 2009). This also can give an indication of scorch, or how imminent crown fire might be since flame lengths of half the canopy base height can ignite the canopy. Thresholds set for the expected fire severity (effects to vegetation) at different fireline intensities are based on fireline intensity levels documented in a case study of a wildfire on the Coconino National Forest (Campbell *et al.* 1977), these levels are:

Moderate severity at 2,500 – 10,000 BTU/sec/ft. This correlates with Flame Lengths of at least ~35'.

High severity >=10,000 BTU/sec/ft. This correlated with Flame Lengths of over 90'.

Crown Fire. This is when a fire burns the canopy of trees.

<u>Active Crown Fire</u>: Causes 100% mortality in most conifers in the Rim Country project area. The two exceptions are Alligator Juniper (*Juniper depeanna*) and Chihuahua Pine (*Pinus leiophylla*), both of which may sprout if top-killed or damaged by fire. Additionally, active crown fire is difficult to control since direct attack is not possible, and spotting is common.

<u>Passive Crown Fire</u>: Passive crown fire at some levels is a normal part of the fire ecology in ponderosa pine and related systems. Nonetheless, when it occurs in proximity to active crown fire, or if there are large areas that have potential for passive crown fire, small shifts in wind may cause it to become active, or result in spotting. As such, it was given a value of 1 in the rating process below.

<u>Surface Fire</u>: This was not given any points because, in general, it is not a threat for

control and, without further information on hua or fli, wouldn't be expected to produce undesirable fire effects.

Fuel Model. The fuel model on a given pixel is an indicator of potential fire behavior and effects. Fuel models can represent the type of fire behavior and effects that could be expected in a given location.

Soil – High Erosion Hazard. Soil and water are fundamental to every terrestrial ecosystem on earth. When soil is damaged to the point that it is vulnerable to erosion by water or wind, the potential effects to an ecosystem may be considered permanent since, with changing climates, it is unknown how long the soil-forming process would take, and what soil/s would be formed. Soil is one of the ecological characteristics that defines the potential of a site, and there is a symbiotic relationship between soil and the flora and fauna that inhabit an ecosystem. So permanent or long term changes to the soil are likely to change the potential of a site.

Wildland Urban Interface. All areas buffered as WUI (1 mile to the southwest of private land, and 0.25 mile around the rest of the boundary) that show potential for active crown fire or high fireline intensity as modeled will be considered to have the highest rating for fire hazard.

Slope. Slope is a factor in the permanence of second order fire effects because of the potential for surface layers to be lost to erosion. Surface soil layers are critical to site potential, and can take 100s of years to reform, if they can reform. A 30% slope was used as a generalized threshold at which many soils become vulnerable to erosion.

Crown fire	Active	3	Includes conditional crown fire
	Passive	1	Single tree or group torching
Heat per unit area	High	2	>60,500 kJ/m^2
	Moderate	1	8,700 – 60,499 kJ/m^2
Surface fire intensity(fli)	> 10,000 (high)	3	BTU/ft/sec Indicates fl > ~90 ft. (Stratton 2009)
	2,500 – 9,999 (moderate)	2	BTU/ft/sec Indicates fl > ~30 ft.
Slope >30%		1	Increases likelihood of negative impacts to onsite resources (seed bank, soil, etc) as well as potential downslope effects (debris flows, etc)
Fuel Model		1	145, 147, 165, 185, 187, 188, 201 (SH5, SH7, TU5, TL5, TL7, TL9, SB1)
Soil - High Erosion Hazard		1	TEU soil types indicating a severe erosion hazard

Scoring: To be rated at all, there must be active or passive crown fire or high or moderate fireline intensity.

1	hua mod OR passive cf
2	mod fli hua mod + passive crown fire OR hua mod + slope OR hua mod + fuel model OR hua mod + erosion haz OR passive crown fire + slope OR passive crown fire + fuel model OR passive crown fire + erosion haz
3	active crown fire OR high fli OR passive crown fire + mod hua + slope OR passive crown fire + mod hua + fuel model OR passive crown fire + mod hua + erosion haz OR passive crown fire + high fli OR passive crown fire + slope + fuel model OR passive crown fire + slope + erosion haz OR passive crown fire + fuel model + erosion haz OR mod fli + mod hua OR mod fli + slope OR mod fli + fuel model OR mod fli + erosion haz
4	active cf + mod hua OR active cf + slope OR active crown fire + fuel model OR active crown fire + erosion haz OR high fli + mod hua OR high fli + slope OR high fli + fuel model OR high fli + erosion haz OR passive cf + mod hua + slope + fuel model OR passive cf + mod hua + slope + erosion haz OR

	passive cf + high hua + slope OR passive cf + high hua + fuel model OR passive cf + high hua + erosion haz OR mod fli + slope + fuel model OR mod fli + slope + erosion haz OR mod fli + fuel model + erosion haz
5	active cf + high hua OR active cf + mod hua + slope OR active cf + mod hua + fuel model OR active cf + mod hua + erosion haz OR active cf + mod fli OR active cf + slope + fuel model active cf + slope + erosion haz OR active cf + fuel model + erosion haz OR passive cf + high hua + high fli OR passive cf + high hua + slope + fuel model OR passive cf + high hua + slope + erosion haz OR passive cf + high hua + fuel model + erosion haz OR high fli + high hua OR high fli + mod hua + slope OR high fli + mod hua + fuel model OR high fli + mod hua + erosion haz OR high fli + high fire fli OR high fli + slope + fuel model OR high fli + slope + erosion haz OR high fli + fuel model + erosion haz OR mod fli + slope + fuel model + erosion haz
6	active cf + high hua + slope OR active cf + high fli OR active cf + high hua + fuel model OR active cf + high hua + erosion haz OR active cf + mod hua + slope + fuel model OR active cf + mod hua + slope + erosion haz OR active cf + mod hua + fuel model + erosion haz OR passive cf + high hua + high fli OR

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7	active cf + high hua + mod fli OR active cf + high hua + slope + fuel model OR active cf + high hua + slope + erosion haz OR active cf + high hua + fuel model + erosion haz active cf + mod hua + slope + fuel model + erosion haz OR active cf + mod hua + high fli OR active cf + high fli + mod hua OR active cf + high fli + slope OR active cf + high fli + fuel model OR active cf + high fli + erosion haz active cf + mod fli + slope + fuel model OR active cf + mod fli + slope + erosion haz OR active cf + mod fli + fuel model + erosion haz OR high fli + high hua + slope + fuel model OR high fli + high hua + slope + erosion haz OR high fli + high hua + fuel model + erosion haz OR high fli + mod hua + slope + fuel model + erosion haz OR mod fli + high hua + slope + fuel model + erosion haz
8	active cf + high hua + high fli OR active cf + high hua + mod fli + slope OR active cf + high hua + mod fli i + fuel model OR active cf + high hua + mod fli + erosion haz OR active cf + mod hua + mod fli + slope + fuel model active cf + mod hua + mod fli + slope + erosion haz OR active cf + mod hua + mod fli + fuel model + erosion haz OR passive cf + high hua + high fli + slope + fuel model OR

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9	active cf + high hua + mod fli + slope OR active cf + high hua + mod fli i + fuel model OR active cf + high hua + mod fli + erosion haz OR active cf + mod hua + high fli + slope OR active cf + mod hua + high fli + fuel model OR active cf + mod hua + high fli + erosion haz OR active cf + extreme fli + slope + fuel model + erosion haz
10	active cf + high hua + high fli + slope + fuel model OR active cf + high hua + high fli + slope + erosion haz OR active cf + high hua + high fli + fuel model + erosion haz OR active cf + mod hua + high fli + slope + fuel model + erosion haz
11	active cf + high hua + high fli + slope + fuel model + erosion haz
12	WUI + high fli OR WUI + active cf

The scores in the table above were further classified into:

Score from above	Rating	Comments
1, 2	1 – average need for treatment	From a fire perspective, some passive crown fire is not a problem, and moderate hua is a moderate need for treatment. The larger the contiguous area, the greater the need.
3, 4, 5, 6, 7	2 – Moderate need for treatment	Either extreme fire behavior/effects, or multiple factors are included in this rating, but the inclusion of passive crown fire.
8, 9, 10, 11	3 – High need for treatment	This is the level at which it is possible to have the highest levels of all the fire behavior metrics.
12	4 – Greatest need for treatment	The greatest need for treatment is where there is potential for extreme fire behavior in close proximity to WUI.

Modeling Assumptions

Fire Behavior, surface fuels, and canopy fuels modeling

Percentile weather fire modeling

Modeling percentiles of fire weather and fuel characteristics is used to model various fire indices, such as Energy Release Component, Burning Index, or Spread Component, modeling straight weather percentiles is not a good tool for planning. Sometimes fire behavior is modeled, but it is more useful for some research questions, or in instances that do not involve implementing site-specific management. Percentile weather and fuel conditions are the conditions for which a specific number of days per year are above or below a given percentile. For example, if one were to model the 97th percentile for a given area, the relative humidity (rh) and fuel moistures use represent levels for which on 97% of days per year it is higher. So, if the 97th percentile rh is 10%, it means that for 97% of the days per year, minimum humidity is at or greater than 10%. If the 97th percentile temperature is 80°F, it means that, for 97% of days per year, temperatures are at or lower than 80°F, and so on. The chances of the 97th percentile relative humidity; temperature; wind speed;1, 10, 100, 1000 hr, foliar, woody, and herbaceous fuel moistures, and wind direction all occurring on the same day are very small. Therefore, results of such modeling usually over-predict fire behavior. Even for extreme fire behavior, such as occurred in the Wallow, Schultz, and Rodeo/Chediski fires, the percentiles for weather and fuel parameters were not the same on any given day. Therefore, for this EIS, fire behavior was characterized based on the conditions under which the Schultz Fire burned on June 20th, 2010. McHugh (2006) states the process of modeling includes the following:

"Define the modeling objective or question

• Model selection based on modeling objective or question

• Spatial and temporal data development required by selected model

• Gather supporting spatial and temporal data

• Data critique and analysis of developed data

• Calibration of the model to a past event(s)

• Simulations, evaluation and critique of results, and documentation

• Gaming-out, and what-if scenarios of fuel treatment location and prescription

• Evaluation, write-ups, and presentation of results

…Calibration of modeling scenarios to past events is critical. Calibration provides a mechanism for testing interactions of the data and model, allows one to evaluate model and data performance in predicting or matching to past documented fire events, provides insight into the respective fire models and how the interactions of data and user-defined model settings can affect modeled outputs. Additionally, and most importantly, it provides a means to evaluate the relevancy and accuracy of the data and instill confidence in future modeling projections."

There are indices, such as Energy Release Component (ERC), or Burning Index (BI), which are usually referenced by percentiles, and there are specific weather variables for each of these percentiles. Using the 97^{th} percentile ERC or BI, and the parameters associated with them is not the same as modeling the 97^{th} weather percentiles. Fuel moistures are the primary inputs for calculating ERC, and wind and slope are not included, though they are critical components in evaluating and/or modeling fire behavior. We used FireFamilyPlus to analyze 20 years of data (1998 – 2016) from the Heber, Pleasant Valley, and Lakeside RAWS. In order to include other RAWS in the project area and/or in the vicinity of the Rodeo/Chediski fire, we included the Payson RAWS and the Promontory RAWS but, there were only 7 years of contiguous data from the Payson RAWS (2009 – 2016) and 12 years of contiguous data from the Promontory RAWS (2004 – 2016). We determined 97th percentile weather parameters based on all contiguous data up to 20 years (1998) in each of five RAWS in the vicinity of the Rodeo/Chediski Fire. Three critical weather factors that are recorded by RAWS, are used in modeling fire, and are significant variables in fire behavior on the ground were evaluated to determine if all three occurred at the 97th percentile or greater on the same day. These variables were: Maximum Temperatures (MxT), Minimum Relative Humidity (MinRH), and Wind Speed (WS). Not a single day of all the years of data indicated all three indices at or above the 97th percentile on the same day.

Table 28. 97th percentiles for critical weather factors at five RAWS stations.

		Days at or above 97th percentile						97th percentile WS + 97th of MxT OR MinRH	
		WS		MxT		MinRH			
	Days of data	days	% days	days	% days	days	% days	days	% days
Heber	6,653	102	2%	151	2%	488	7%	6	0.1%
Lakeside	6,832	107	2%	198	3%	314	5%	4	0.1%
PV	6,804	212	3%	270	4%	337	5%	11	0.2%
Payson	2,882	68	2%	152	5%	143	5%	4	0.1%
Promontory	4,601	21	0%	147	3%	221	5%	1	0.0%
All	27,772	510	2%	918	3%	1,503	5%	26	0.1%

Wind is the single most important fire weather factor for wildfire spread in and near the Rim Country project area. There are two aspects of wind that are considered in modeling fire: steady wind speed and wind gusts. Wind gusts are tricky because the strength and unpredictability of gusts is included by adjusting the steady wind speed upwards. Additionally, they are not always recorded by weather stations. Wind speeds at or above the 97th percentile occurred on 510 (2%) of the 27,772 days included in this analysis. 97th percentile wind speed ranged from 13 at Promontory to 17 at Lakeside. 97th percentile winds co-occurred with one of the other two other variables on less than one percent of the time. Using percentile weather conditions to model fire gives it equal value with other variables (such as MinRH, MxT, and fuel moistures) which, though important, are not as important as wind, thus, giving less accurate information on where and how fires are likely to burn on the landscape.

Appendix C: Design features, Best Management Practices, and Mitigation

Table 29 Design features and mitigation measures for all action alternatives

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		X	ERTs are recommended by the ADEQ as techniques that can be effective for minimizing impacts to sensitive receptors.

	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.			
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		X	Minimize impacts from mechanical treatments on vegetation and soil.

	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.			
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.
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.

FE12	When practicable, damage or mortality to old trees, and large trees would be mitigated or avoided 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	There is a deficit of old trees 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.
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.

FE16	Range and fire managers will coordinate grazing schedules and prescribed fires on allotments within burn units to ensure there is sufficient surface fuel to allow burn objectives to be met. If grazing cannot cease long enough for sufficient fuel to build up to meet objectives, planned prescribed fires will be postponed until there can be sufficient fuel to meet objectives.		X	To improve the ability of prescribed fire managers to meet objectives when implementing prescribed fires.
FE17	CWD will be managed to achieve forest plan direction, though it may take more than one entry when the current conditions are deficit (i.e. are below forest plan guidelines).	X		To provide levels of CWD to address the need for habitat (cover), soils (organic material and limited areas of high burn severity), and fire (limited areas of high burn severity and a high resistance to control).

Daily Burn Accomplishment Form **Contact Number:**

Updated 10/18/05 **Contact Name:**

***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	
ACREAGE BURNED: Area blackened for broadcast burns only, not to	
ACREAGE ERT(s) USED: Area in which emission reduction techniques	
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	

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

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 MODEL:		**FIRE REGIME**	
HARVEST DATE: (If Applicable)		**PRIMARY DUFF TYPE:** 1) Black (Litter	

***SOUND AND ROTTEN* (Woody Fuels Only** – Do		***ROTTEN* (Woody fuels only**	
0.0 – 0.25 IN FUELS:		**>3.0 IN FUELS:** (T/A)	
0.26 – 1.0 IN FUELS:		***OTHER* (*Do not include these fuels in***	
1.01 – 3.0 IN FUELS:		**STUMP 20+ IN**	
***SOUND* (Wood fuels only** – Do not include piles		**SHRUB /BRUSH**	
3.01 – 9.0 IN FUELS:		**GRASS /HERB**	
9.01 – 20 IN FUELS:		**AVERAGE LITTER**	
>20.0 IN FUELS: (T/A)		**AVERAGE DUFF**	
FUELS			

NUMBER OF PILES PER ACRE: Provide the average number of piles per	
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)	
PRIMARY SPECIES: (%)	
SECONDARY SPECIES: (<50%) 1) Ponderosa Pine, 2) Douglas Fir, 3)	
SECONDARY SPECIES: (%)	
QUALITY: 1) Clean, 2) Dirty, 3) Real Dirty	
DIMENSIONS: (FT) Provide the average width and height of round piles, as	**W** **H**
PACKING RATIO: 1) Ponderosa Pine <10 IN, 2) Short needle conifer,	

Appendix D: Smoke and emission modeling

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 would end up and at what concentrations is premature. That modeling would 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. Rx: (a burn only treatment in Ponderosa Pine - montane, Ponderosa Pine – Evergreen Oak and Dry mixed conifer 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 30).

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% lower fuel loading.

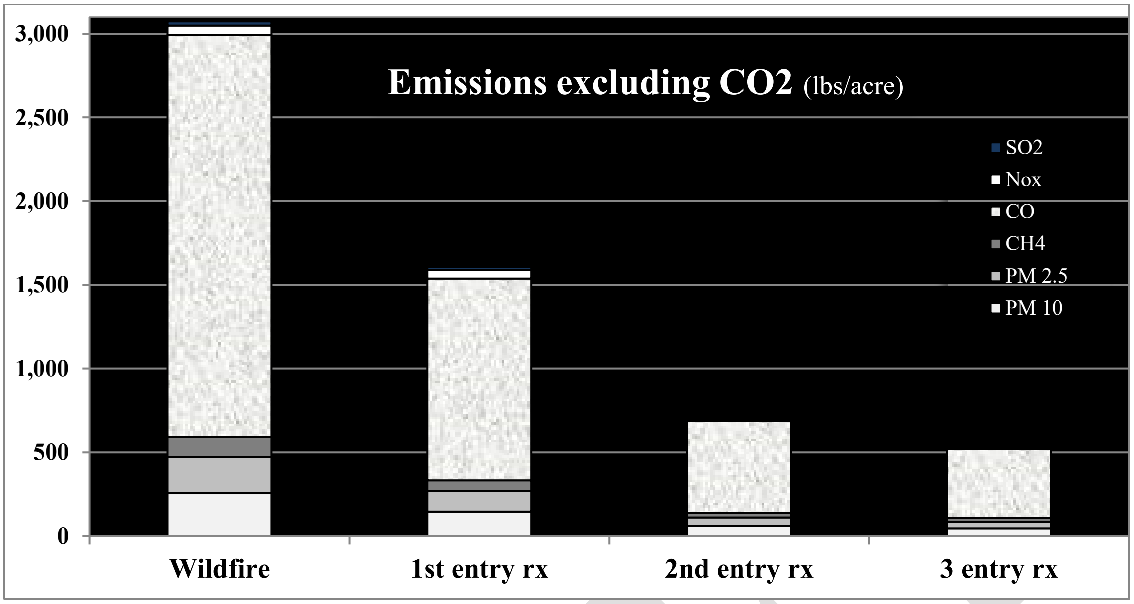

Figure 54. Modeled emissions from a typical stand with no treatment prior to burning

Table 30. Inputs used for emissions modeling.

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 E: Additional Concepts Applied to Analysis

A basic understanding of some concepts is important for interpreting the details of this analysis; these are summarized below.

Wildfire Risk

Wildfire risk is the spatial interaction of wildfire hazard with highly valued resources and assets, and the subsequent effects of this interaction (Finney et.al. XX, Scott 2006; Thompson and Calkin 2011; Miller and Ager 2012, Scott et al 2013). Wildfire hazard is a physical situation with potential for wildfire to cause beneficial or negative impacts to values and resources (Scott et al 2013). Wildfire hazard consists of two components: likelihood and intensity.

Wildfire likelihood (i.e. burn probability), is influenced by a complex integration of topography, fuels, weather, suppression operations and ignition occurrence. Wildfire likelihood is very useful in fuel treatment prioritization as it identifies lands more likely to burn relative to others within a given area. For the current analysis, wildfire likelihood is not modeled because it is assumed that fuel treatments occurred simultaneously across the landscape.

Within this report intensity is characterized by Crown Fire Potential and an integrated Fire Effects Index (see below). These indices represent the maximum expected intensity of wildfire under a single specified extreme weather scenario.

Wildfire Risk assessments can be broken down into two primary assessments: exposure assessments and effects assessments. An exposure assessment is the spatial interaction of a resource or asset with the wildfire hazard. Exposure can be quantified by the number of acres (or another other relevant measure) that is expected to come in contact with wildfire of a given intensity. In this report, the exposure of highly valued resources are quantified and discussed in the specialist report for that resource. For example, the exposure of Mexican Spotted Owls is quantified in the wildlife specialist report (JUSTIN XX). The resources and assets that will be analyzed in this report are:

Fire management, WUI, old growth trees, ERUs, general watershed response and air quality.

An effects assessment takes this one step further and assessed the potential for benefits (gains) or costs (losses) to the resource or asset. In this DEIS, the effects assessments are qualitative and are discussed in the specialist report for that resource. The resources and assets for which effects will be qualified in this specialist report are:

Fire management, WUI, old growth trees, ERUs, general watershed response and air quality.

Ecological Restoration Units (ERUs), cover types, and ecosystem components analyzed

In the Southwest, the US Forest Service has developed a framework of ecosystem types, or "Ecological Response Units" (ERUs), to facilitate landscape analysis and strategic planning. The framework represents all major ecosystem types in the region, and a coarse stratification of biophysical themes. ERUs are map unit constructs; technical groupings of finer vegetation classes of the National Vegetation Classification. The suite of vegetation classes that make up any given ERU share similar disturbance dynamics, plant species dominants, and theoretical succession sequence (potential vegetation) (Wahlberg *et al.* 2017 (in draft)). For the most part, ERUs were used as the major classification for cover types (Figure 2). However, additional ecosystem components were added for components of ERUs for which data indicated a distinct type (aspen, grasslands, or riparian), or which are a significant enough component of multiple ERUs to warrant specific information. Gambel oak and Interior Chaparral, large and/or old trees, surface fuel loading, and understory vegetation are also evaluated because of their significant contribution to the landscape.

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 1 describes commonly referenced fire regimes that are used in this analysis (Barrett *et al.* 2010). While severity is not a reference to mortality, there is often a correlation (see discussion, next section). Over 92% of the treatment area was historically a Fire Regime 1 or II, with some aspen and PJ that is more likely to be Fire Regime III, IV or V.

Fire Return Interval (FRI) vs. Maintenance 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 over a period of time. Frequent fire regimes are more common in areas, such as ponderosa pine, where dead biomass, (such as pine needle litter) is produced faster than it can decompose and/or where plant populations depend on frequent fire to regulate distribution and density (such as seedlings and woody species). Departure from the fire return intervals to which ecosystems are adapted produce somewhat predictable results in both fire behavior and fire effects. As such, it is a characteristic of a fire regime that can be useful on a landscape scale for evaluating the health of an ecosystem.

There is evidence that shows that a FRI that is longer than what occurred historically, or naturally, can maintain a relatively open, crown-fire resistant forest structure (Fulé and Laughlin 2007; Fulé 2012-2013), although other components of the area, such as species composition, would be affected. This 'maintenance' FRI does not represent a fully restored ecosystem. As referenced here, 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 uncharacteristically severe fire effects in these areas. It is not intended to represent a FRI that would maintain historic habitat/plant communities. Its true range would 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 and Fulé 2008).

Reintroducing fire

When fire is reintroduced into frequent fire-adapted ecosystems (such as ponderosa pine and dry mixed conifer), from which it has been withheld for decades, the objectives of the first entry burn, and usually the second as well, will be different from maintenance burning (which is not the same as the Maintenance Fire Return Interval described above). The primary objective of the first entry burn is to begin to restructure the fuel profile. Even if the area was thinned before the burn, surface fuel loading, canopy base heights, and ladder fuels may still be highly departed from what would be healthy and sustainable. The ***first entry*** burn will kill or top kill most ladder fuels (shrubs and/or small trees), and lethally scorch a lot of needles in the lower canopy. Within a year or two, most scorched needles, along with some twigs and branches, will fall and produce a litter layer that is heavier, and often more contiguous, than would be natural (though still less than before the first entry burn). Over the year or two following the first burn, some surface vegetation may begin to grow, but some will still be suppressed due to the litter cover (FIGURE 3, FIGURE 4).

Additionally, within a few years, there may be a slightly higher load of woody debris from the killed and top-killed ladder fuels. If the initial entry burn included some mixed severity, there may also be a slightly higher than historical dead/down fuel layer. Note the almost 100% cover of needles in FIGURE 4 resulting from the shedding of needles from the lower canopy being shed.

The ***second entry*** burn will more completely reset the fuel structure, consuming most of the fallen scorched needles and decreasing excessive woody debris that will be produced as branches and trees killed by the fire fall to become part of the surface fuel loading.

Because of the focus on fuel structure for the first two burns, the timing/seasonality of those burns is less important than for maintenance burns. Once an area is in a condition for maintenance burning, seasonality is more important because of the timing of the rainfall, temperatures, photoperiods, and interactions with other flora/fauna with which native vegetation evolved

Fire Intensity versus Fire Severity

Fire intensity and fire severity are often confused, though both are commonly used in descriptions of fire regimes, behavior, and effects. Fire severity is about the *effects* of a fire while fire intensity is about the *behavior* of a fire. Fire intensity was used as one input in the Fire Hazard Index. Fire intensity is a *quantitative* measure of the fire itself, usually defining energy release rates. 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 (Agee 1996; Keeley 2009), and is generally evaluated after fire has burned though an area (Andariese and Covington 1986).

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 5). Death usually follows quickly from complete crown scorch in ponderosa pine, but may take several years following girdling (Van Wagner 1972).

Crown fire is always high severity fire, but high severity 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) and/or heat is trapped under a closed canopy, producing a lethal level of crown scorch (FIGURE 5). When surface fire burns in a forest with a closed canopy, sufficient heat can build up under the canopy to lethally scorch trees.

Historically, ponderosa pine forests of the southwest supported, low severity surface fires. 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). Discussions of severity for existing conditions were based on fire type, surface fuel loading, and vegetation type.