Effectiveness Monitoring Committee (EMC-2019-002)

Evaluating Treatment Longevity and Maintenance Needs for Fuel Reduction Projects Implemented in the Wildland Urban Interface of Plumas County, CA

December 31, 2021

Spatial Informatics Group

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December 31st, 2021

Prepared For The Feather River Resource Conservation District and The Plumas County Fire Safe Council

Prepared by Jason Moghaddas (RPF #2774), Travis Freed (UAV Pilot and Geospatial Analyst), Gary Roller (RPF #2899), Jarrett Barbuto (UAV Pilot and Geospatial Analyst), and David Saah (Principal Investigator)

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Effectiveness Monitoring Committee
Full Project Proposal Form

Project #: EMC-2019-002 **Date:** November 15th, 2019

Project Title: EMC-2019-002 Evaluating Treatment Longevity and Maintenance Needs for Fuel 1 Reduction Projects Implemented in the Wildland Urban Interface of Plumas County, CA 1

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Project Duration (Years/Months): 1 year, 6 months (18 total months) 1

Table of Contents

TABLE OF CONTENTS

There is an online project map for this project. The map contains treatments completed in Plumas County by several entities, including the Plumas County Fire Safe Council along with 360 degree view ground and UAV photos taken in treated areas. This should be considered a "living map" which can be updated with additional content and publicly shared.

To access the map, follow this link: https://gsal.sig-gis.com/portal/apps/webappviewer/index.html?id=dcf628bcf5ae44c69ad5ec00ae7c18e7

Once able to view the map, the "Layer List" icon on the top right can be used to turn on/off different layers, and the "Legend" icon to display content by color, symbol, etc. Where 360 photos were taken, there will be a camera icon, which when clicked will connect to images hosted on the site Kuula.

Acronyms and Abbreviations

AOI	Area of Interest
CEQA	California Environmental Quality Act
CSE	Common Stand Exam
DBH	Diameter at breast height
EMC	Effectiveness Monitoring Committee
FVS	Forest Visualization Simulator
FPR	Forest Practice Rules
GIS	geographic information systems
GPS	global positioning system
HTLCB	Height to Live Crown Bass
LFTCF	LANDFIRE Total Fuel Change
LiDAR	Light Detection and Ranging
MTT	minimum travel time
NASA	National Aeronautics and Space Administration
NEPA	National Environmental Policy Act
PCFSC	Plumas County Fire Safe Council
RCD	Resource Conservation District
SIG	Spatial Informatics Group
UAV	Unmanned Aerial Vehicle
UAS	Unmanned Aerial Systems
WUI	Wildland Urban Interface

1 Background

Since 2002, the Plumas County Fire Safe Council (PCFSC) has implemented over 50 Hazardous Fuel Reduction projects, covering nearly 14,000 acres of private and public lands (Appendix 1). To date, over 16 million dollars of state, federal, and other funding have been invested on the ground in these projects across Plumas County. The treatments implemented were designed to reduce immediate fire risk to structures, reduce fire severity, and over time, improve overall community fire resilience. While there is often funding for the initial treatment planning and implementation, the opportunity to conduct long-term maintenance while treatment costs are still relatively low can be missed if not properly planned for. Science-based information is critical to the maintenance planning process. Given the scale of state and federal funding invested in PCFSC fuel treatments to date, objectively assessing the lifespan of the investment and providing landowners with anticipated maintenance needs for long-term effectiveness while vegetation can be maintained at relatively low costs compared to the initial treatment investment is critical to meeting the mission of the PCFSC, landowners, communities, and the funding agencies.

The Plumas County Fire Safe Council has convened a maintenance sub-committee to evaluate the condition of past projects. Casual observations from the group suggest that vegetative response to the initial treatment can be highly variable and site specific. In some cases, work done 10 years ago on one site has not yet reached the need for significant maintenance while a different site requires nearly the same level of work that was initially done.

After this study began, The North Complex (2020) and Dixie Fire (2021) directly impacted several projects implemented by the Plumas County Fire Safe Council. This created an opportunity to assess how the treatments were used by fire fighters as defensible space and how treatments may have affected post fire mortality. Once the fire closures were lifted, several of these burned projects were visited and evaluated using ground and UAV based imagery.

In addition to UAV and ground based imagery, several datasets were utilized to evaluate fire hazard, risk, stand structure, and post fire severity.

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2 Objectives and Scope

This project assessed the current maintenance needs for projects implemented, funded, or otherwise supported by the PCFSC. This assessment will allow critical questions (see critical questions addressed in section 3) described in the Effectiveness Monitoring Committee (EMC) Strategic Plan (Husari and Henly 2018) to be answered spatially and quantitatively over all PCFSC treated lands in Plumas County. In addition, the project assessed treatment utilization by fire fighters and post fire severity resulting from both the North Complex (2019) and Dixie Fire (2021).

The goal will be to help inform the Plumas FSC on its treatment life cycle, so it may better plan for and fund future treatments and substantiate that the Fire Safe Council has and continues to utilize "best available science" in their treatment design and long term maintenance strategy.

3 Critical Questions and Forest Practice Regulations Addressed

3.1 Critical Questions Addressed

This evaluation addressed the critical questions outlined for Theme 6 (Wildfire), as described in the Effectiveness Monitoring Committee Strategic Plan (Husari and Henly 2018). The evaluation will assess at a project level the efficacy each regulation, including the complexity or ease of implementation, its result in meeting its planned specified result, and its long term effects on potential fire behavior. The study will address the questions below as they apply to treatments in Wildland Urban Interface.

a. 1 Treating post-harvest slash and slash piles to modify fire behavior?
b. 1 Treating post-harvest slash and retaining wildlife habitat structures, including snags and large woody debris?
c. 1 Managing fuel loads, vegetation patterns and fuel breaks for fire hazard 1 reduction? 1

In addition to the questions above, the evaluation will address these specific questions below, in an effort to better quantify treatment effectiveness, longevity, and maintenance needs.

- How many years are fuel reduction treatments in the WUI effective for? 1
- Is there a variation in treatment effectiveness over time by vegetation type, type of 1 treatment, or equipment type used? 1
- What are the potential maintenance needs for existing treatments and at what 1 treatment age? 1
- Are there quantifiable differences in tree mortality within existing WUI fuel 1 treatments compared with areas adjacent to these treatments? 1
- How can the described method be efficiently applied to all Fire Safe Council 1 projects across the entire State of California? 1

3.2 Applicable Forest Practice Regulations and Exemptions

All of the fuel treatment projects implemented by the Plumas County Fire Safe Council have been implemented in the Northern Forest District. A subset of these projects have had a commercial biomass and/or saw log removal component, and were completed under an Exemption or Timber Harvest Plan approved by CALFIRE. These projects have included components of the Forest Practice Rules and exemptions listed below.

- Minimum stocking standards (14 CCR § 912.7) 1
- Logging slash and hazard reduction (14 CCR § 917) 1

3.3 Relevant Vegetation Types and Geographic Application

Fuel treatments within the WUI of Plumas County have been implemented in vegetation types common across the Sierra Nevada. These include Sierran Mixed Conifer, East Side Pine, black oak woodland, sagebrush, and montane chaparral. Representative pre/post treatment photos are shown for dominant vegetation and treatment types within the full set of projects implemented by PCFSC (photos 1-3). A detailed analysis of treatments in these types at the county (Plumas) level will have broad application to similar vegetation types with in the greater Northern and Southern Forest Districts. Monitoring findings will be generally applicable to similar vegetation types, soil types, and climate zones, within both the Northern and Southern Forest Districts. Coastal Region FPRs are included but comparisons will be more limited due to different vegetation types, local climate, and treatment practices. The methods utilized in this study can be readily used for assessing fuel treatments and prescribed burns across the state, particularly where LiDAR is available or UAVs are permitted for pre or post treatment data collection. This approach allows for collection of surface and canopy fuels data, and assessing fire hazard and risk based on that data. The closest State Forest to the study site is La Tour Demonstration State Forest, ~130 miles from Quincy, but there is not matching LiDAR coverage at that forest to conduct the same analysis.

Figure 1 Pre and post treatment example of completed fuel treatment in a mixed conifer forest.

Figure 2 **Pre and post treatment example of completed fuel treatment in a black oak dominated forest.**

Figure 3 **Pre and post treatment example of completed mastication of shrubs.**

4 Research Methods

4.1 Task 1: Organization of Individual Completed Projects by Specific Forest Practice Rules (FPRs), Vegetation Types, Treatments, and Treatment Age

Since 2002, the Plumas County Fire Safe Council has implemented over 50 projects (Appendix 1). These projects will be inventoried to develop a matrix of applicable Forest Practice Rules for the project at the year of implementation, vegetation type, treatment type, equipment type, and treatment age.

Since 1999, the Plumas County Fire Safe Council has acquired photos pre and post treatment for most/all treatments completed. These photos probably provide some of the most consistent project level recordings of stand condition prior to and after treatment. Re-capturing the images to represent current condition allows for visual assessment of change in these stands. The Project Team was given a combination of digital and printed copies of photos, with varying degrees of location information. With that information, we attempted to locate the parcel and location of the photos, and where that was feasible, the photo point was retaken.

4.1.1 Sub Task 1.1 Determining Applicable Forest Practice Rules and Exemptions by Project

All projects (Appendix 1) were reviewed in detail to determine Forest Practice Rules and Exemptions that were applicable at the year of project implementation. This information will be compiled by reviewing past Timber Harvest Plans (THPs), grant applications, reports, existing pre/post monitoring photos, as well as interviews with those involved in project planning and implementation.

4.1.2 Sub Task 1.2 Stratification of Projects by Treatment and Vegetation Type

The information reviewed for Sub Task 1.1 (above) was used to determine the treatment or suite of treatments utilized for each project. An attempt was made to stratify treatments by age class categories; <5 years old, 5-10 years, 10-15 years and 20+years old, though some projects had multiple treatment years, making this more difficult to complete than initially planned. These treatment classes were assessed in the field to determine general trends in long term performance and maintenance needs by age, treatment type (mechanical harvest, mastication, prescribed fire, hand thinning, and pile burning), and vegetation type by field sampling and observations and photo comparisons.

The projects observed in the field to date cover the full range of treatments commonly utilized in Sierra Nevada Forest and shrub ecosystems, including:

- Commercial harvest of saw log material
- Harvest, removal, and chipping of biomass

- Hand thinning of small trees and shrubs
- Mastication of shrubs, small trees, and dead and downed material
- Chipping of cut material on-site
- Piling and burning
- Under burning
- Treatment burned by the 2020 North Complex or the 2021 Dixie Fire

4.1.3 Field Sampling

Sampling occurred within communities across several regions of Plumas County. Generally speaking, these regions share similar forest and shrub vegetation characteristics and treatment methods. Regions and communities are summarized below. The sampling within the Dixie Fire and North Complex are noted in individual property descriptions.

Eastern Plumas County, including Graeagle, Portola, "C Road", and Whitehawk Ranch
Forest types in these communities are typically within pine dominated "east side" forests. While grasslands are typical in meadow areas of the eastern portion of Plumas County, there were no treatments located in pure grasslands, as much of these areas are already actively grazed by livestock.

Western Plumas County, including American Valley, Meadow Valley, Butterfly Valley, La Porte Road, Bucks Lake, Greenhorn Ranch, and Spring Garden
Forest types in these communities are typically within mixed conifer forests. Dominant shrubs include manzanita and deer brush. While grasslands are typical in meadow areas of the western portion of Plumas County, there were no treatments located in pure grasslands, as much of these areas are already actively grazed by livestock.

Indian Valley, Including Greenville, Taylorsville, and Genesee Valley
Forest types in these communities are typically within mixed conifer forest but transitioning to east side pine along the eastern edges of Indian Valley and south facing slopes of Genesee Valley. Dominant shrubs include manzanita and deer brush. While grasslands are typical in meadow areas of Indian Valley, there were no treatments located in pure grasslands, as much of these areas are already actively grazed by livestock.

4.2 Additional Assessments of Current Stand Conditions Using UAV and Ground Collected Imagery

Projects were assessed in the field using a combination of UAV acquired imagery, ground based 360 imagery, field observations, and discussions with landowners. The Dixie and North Complex resulted in flight restrictions which ceased UAV operations during these fires.

4.2.1 Description of Unmanned Aerial Vehicle (UAV) Types and Ground Based 360 Degree Camera

Quadcopter UAV

A quadcopter (Figure) is generally the lowest cost approach to acquiring imagery over a relatively small area. These UAV's can capture imagery down to an area of ~1/10th acre up to 25 acres in a single flight. The Mavic Pro® can take high resolution imagery that can be used to generate point clouds over 25 acres in a 30-minute flight (one battery). Lower resolution imagery (no point cloud) can be acquired over ~40 acres over the same duration (30 minutes). Multiple flights can be implemented to cover larger areas but generally total area for a quadcopter to cover in a day over 3 flights is ~100 acres.

Acquiring 360 Degree Images with a Quadcopter

UAV based 360 photos are typically acquired from an elevation of 300 feet above ground using a Mavic 2 Pro quadcopter drone. Typical field of view within these photos is about 20 acres directly beneath the UAV, then ~100 acres viewed oblique but high resolution. The image picks up several thousand acres to the horizon, but this can be limited where there is fog, smoke, or cloud cover. The images were processed using the program Hugin (http://hugin.sourceforge.net/), an open source panorama stitching program. Processed images are hosted on the site Kuula (https://kuula.co/about), allowing users to view, zoom and pan the image. An example from a treated area in Genesee Valley can be found here: https://kuula.co/share/NGGM1?logo=1&info=1&fs=1&vr=0&sd=1&thumbs=1

Acquiring 360 Degree Images with a GoPro Camera

Ground based 360 photos are typically acquired from an elevation of ~5 feet above ground using a Go Pro Max 360 camera. Typical field of view within these photos is about 0.5 acres, with captured images processed using xx software. (No processing required) As with UAV images, processed images are hosted on the site Kuula, allowing users to view, pan the image. In our study, UAV and ground-based images were captured in the same area, allowing users to see the UAV image but click the "insert camera icon" and view the ground based 360 image at the same collection point. An example from a treated area in Genesee Valley can be found here: https://kuula.co/share/NGG6C?logo=1&info=1&fs=1&vr=0&sd=1&thumbs=1.

Figure 4 The Mavic Pro® Quadcopter UAV

Fixed Wing UAV

A fixed wing UAV (Figure) allows data capture over a larger area when compared to a quadcopter. The Ebee can take high resolution imagery that can be used to generate vegetation cover and topography over 200 acres in a 45-minute flight (one battery). Higher resolution imagery 100 acres over the same duration (45minutes), which can be used to generate 3d point clouds and Digital Surface Models (DSMs). Multiple flights can be implemented to cover larger areas but generally total area for an Ebee® to cover in a day over 3 flights is ~300-600 acres depending on resolution of imagery taken. Due to the relatively small size of treatment units, the Ebee was not needed for additional data collection.

Figure 5 The Ebee® Fixed wing UAV

4.3 Assessment of Post Fire Burn Severity, Fire Hazard, Canopy Cover, Height to Crown Base, and Post Dixie Fire and North Complex Fire Severity

The original proposal planned to utilize LiDAR acquired by the Plumas National Forest to assess stand structure within project treated by the Plumas County Fire Safe Council. Due to the delayed availability of the LiDAR derived data sets and are noted errors by PNF staff, we utilized publicly available structure data from SALOs California Forest Observatory (Salo Sciences, 2021), The Region 5 Funded Community Wildfire At Risk Information (USDA Forest Service 2021a), and USFS burn severity data sets for the North Complex and Dixie Fires (USDA Forest Service 2021b).

Fire severity, canopy cover, height to crown base, and fire hazard were assessed at the property level, and for non-forested lands for the 500 feet beyond the property boundary, and the 1,000 feet beyond the property. Assessment in these "bands" around the property allowed for

localized comparison of treated and untreated areas for stand structure and post fire effects which could be further validated with on-site ground and UAV imagery.

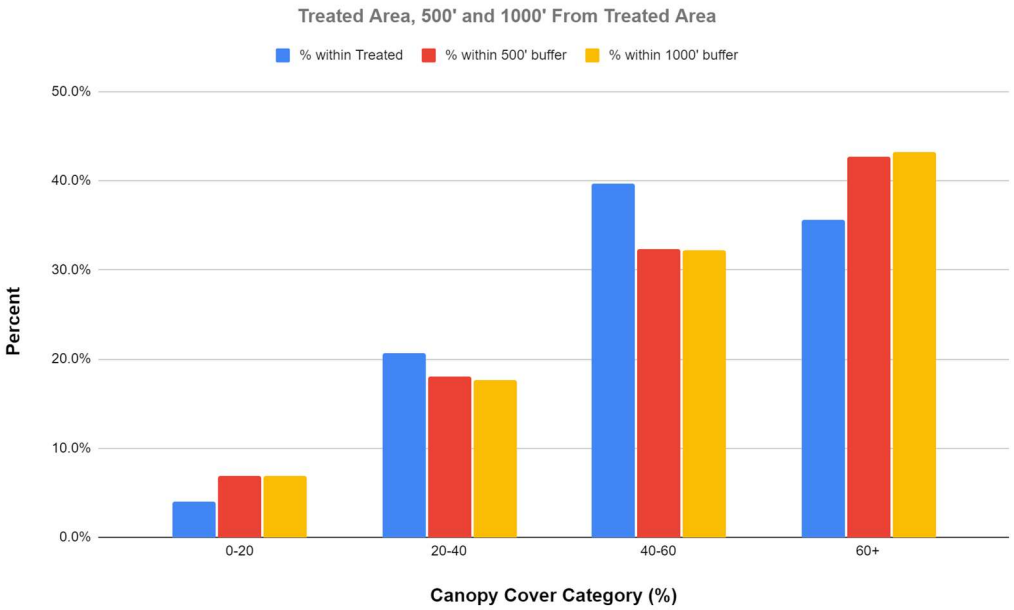
5 Results

5.1 Post Treatment Stand Structure and Fire Hazard

Canopy Cover

Canopy cover between treatment the treatment types of mastication and commercial thinning were similar, with these treatments having an average canopy cover between 50%-52%. This likely due to both treatments removing primarily smaller diameter trees from the understory and leaving the dominant trees as the residual forest stand. Units that were hand thinned had a higher average canopy cover of 65%, which is expected as hand thinning treatments typically remove smaller material (up to 6 or 8 inches in diameter) when compared with mastication or commercial thinning. Canopy cover for treated areas was generally lower in the 20-40% and 40-60% cover categories compared to areas within 500 and 1,000 feet from treated areas. Untreated areas within 500 and 1,000 feet from treatments had relatively more area in the higher canopy cover (>60%) category (Figure 6).

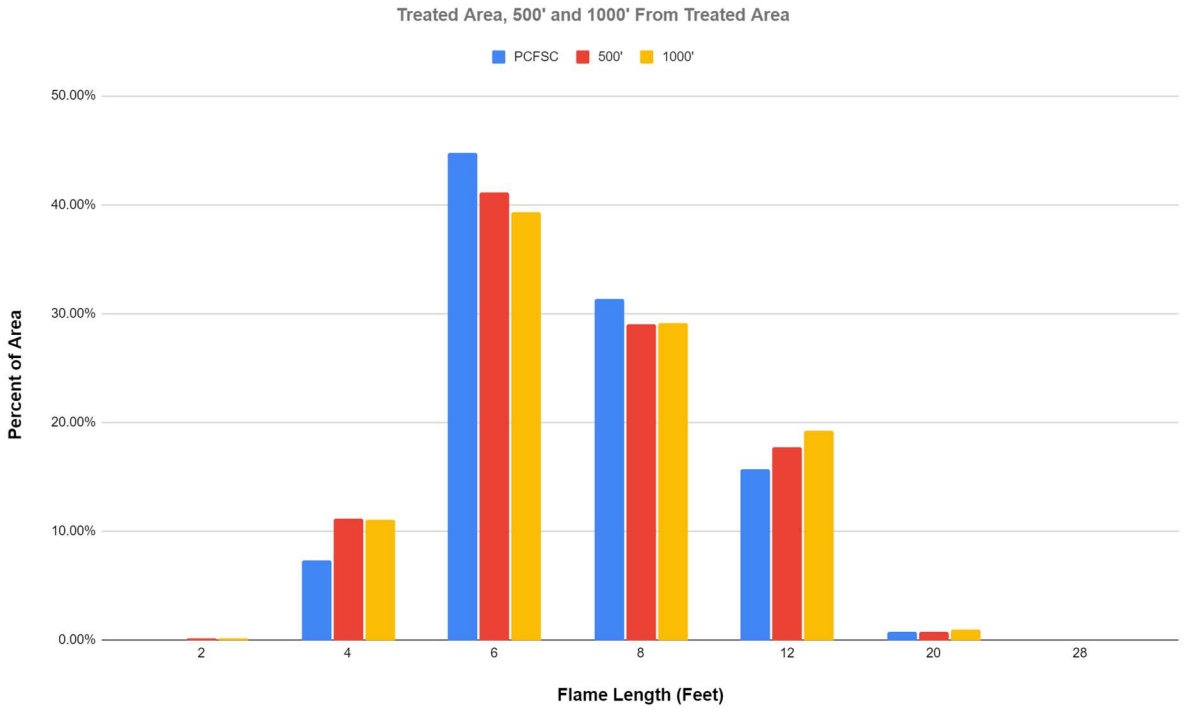
Figure 6. Canopy cover category class within treatments and within 500 and 1,000 feet from treated areas



Flame Length

Flame lengths for treated areas were assessed using statewide data available from the Wildfire Communities at Risk dataset (USDA Forest Service, 2021a). Treated areas had predicted flame lengths of 12 feet or less with the majority of treatments having predicted flame lengths of less than 8 feet (Figure 7). The analysis of adjacent areas within 500 or 1,000 feet indicates those areas had more percentage of area with 12 foot flame lengths, but also 4 foot flame lengths. This may be an artifact of local vegetation types but also it should be noted that local fuel treatments may not be well represented in state or national level databases. Improving integration of these treatments, and their potential effects is discussed in the recommendations section 6.2 ("Defensible Space").

Figure 7 Flame Lengths within treatments and within 500 and 1,000 feet from treated areas



5.2 Maintenance

Chiono et al. (2012) conducted a detailed study of the development of stand structure and surface fuel loads within 51 individual treatments implemented across Plumas County by the Plumas County Fire Safe Council and others. In this study, they noted no significant differences in several measures, including basal area, trees per acre, canopy cover, height to crown base,

shrub cover, and surface fuel loading (1, 10, 100-hour fuels) in treatments between treated stands 2-4 years old, 5-7 years old, and 8-15 years prior to measurement. An additional study by Stephens et al. (2012) found similar results, with trees per acre, canopy cover, and basal area showing no significant increase 7 years after treatment. A recent study by Vaillant et al. (2015) also found that surface fuel accumulation can reach near pre-treatment levels within 8 years of treatment. Our observations in the field yielded similar results, with accumulations litter and surface fuels observed as the most notable change since treatment, along with incidental tree mortality, even in older treatments. Generally speaking, a relatively small time investment, when compared with initial treatment creation, in maintenance, particularly of accumulated litter, surface fuels, and small tree or dead tree removal, could prolong effectiveness of existing treatment open the opportunity to expand them onto adjacent ownerships and parcels not previously treated

Based on field assessments, maintenance needs for individual projects generally fell into major categories of previously masticated, previously commercially treated, or burned (by wildfire).

Unburned Properties

Properties Previously Treated with Biomass or Sawlog Removal

Previously treated properties up to 20 years old generally had limited shrub growth. This trend of limited shrub growth in treatments up to 15 years old was noted by Chiono et al (2012) as well. Where the primary fuel is accumulated litter or deadfall, this material can be raked/piled and burned or hauled off site. Sites should be evaluated to individual dead trees which pose falling risk to the structure or spotting issues should they ignite in a wildfire.

Properties Previously Treated with Mastication

While mastication did moderate fire behavior, it was noted that masticated fuels posed more difficulty for fire line construction, potentially slowing down production rates. Typically where masticated fuels were up to ~2" deep, fire line production rates were not impacted. The PSFSC may want to consider additional removal of masticated materials to a depth of less than 6" and ideally <2" on new mastication projects. In addition, projects with completed mastication should be considered for additional material removal, with a priority of removing masticated material within 100 feet of all structures.

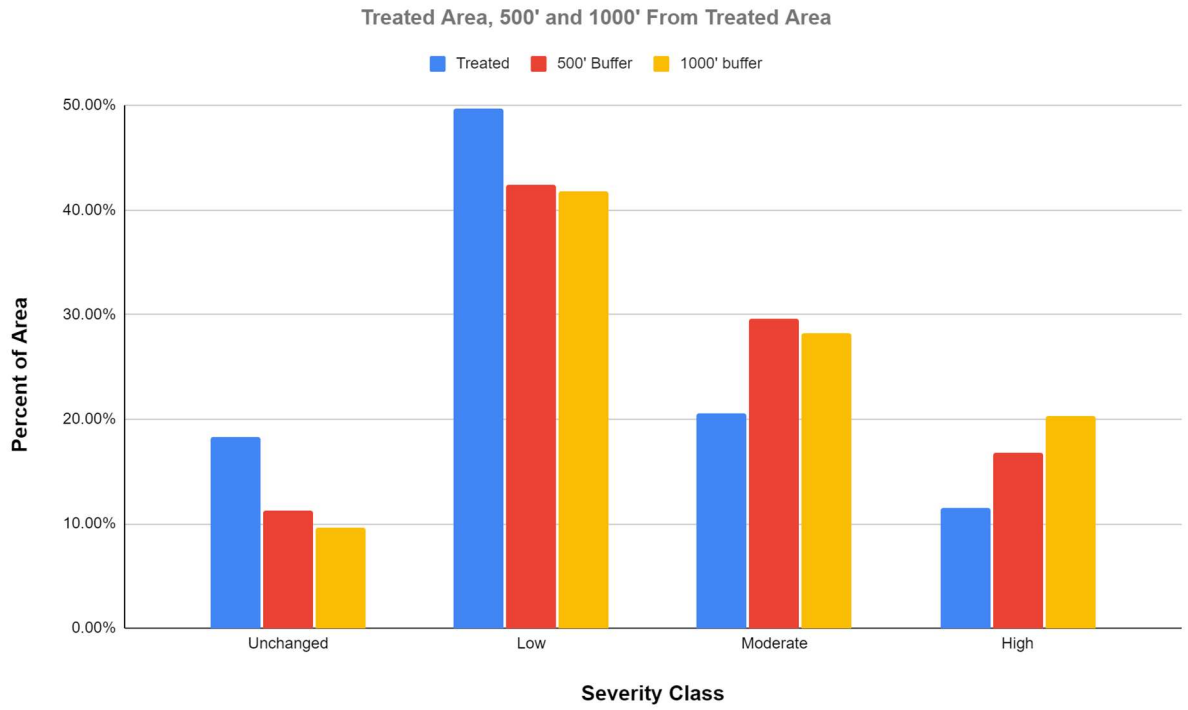
Properties that Burned in The Dixie Fire or North Complex

Generally where these properties burned with low severity, maintenance needs are to fall/remove standing dead trees and rake or pile accumulated litter. Where parcels burned with high severity, it is recommended to remove dead trees where possible via existing vegetation cleanup programs or private contracts with a licensed timber operator.

5.3 Post Fire Severity

The North Complex and Dixie Fire burned several treatments implemented by the Plumas County Fire Safe Council. For both fires, areas that were treated generally had a higher percentage of "unchanged" or "low severity" fire then the adjacent 500 and 1,000 foot forested areas (Figure 8). In addition, moderate and high severity fire increased further from the treatment boundary in the adjacent 500 and 1,000 foot forested areas. While some treatments did burn with high severity, generally treatments that were impacted by the fires flanks or actively used for burnout operations burned with lower severity than adjacent untreated areas (see section 5.4). These findings are consistent with previous post fire fuel treatment effectiveness assessments (Safford et al. 2012; Moghaddas et al. 2018)

Figure 8. Fire severity class within treatments and within 500 and 1,000 feet from treated areas



5.4 Use of Residential Area Fuel Treatments as Defensible Space in the North Complex (2020) and Dixie Fires (2021)

One hundred feet of Defensible Space is required for all structures in California that are within "Mountainous, Forest-, Brush-, and Grass-Covered Lands" (PRC4291). Defensible space is a buffer between buildings on a property and the grass, trees, shrubs, or any wildland area that surround it are reduced via a combination of mowing, chipping, piling, under burning, harvesting, or mastication. This space is needed to slow or stop the spread of wildfire and can help protect a structure from catching fire—either from embers, direct flame contact or radiant heat. Proper defensible space also provides firefighters a safe area to work in, to prepare and

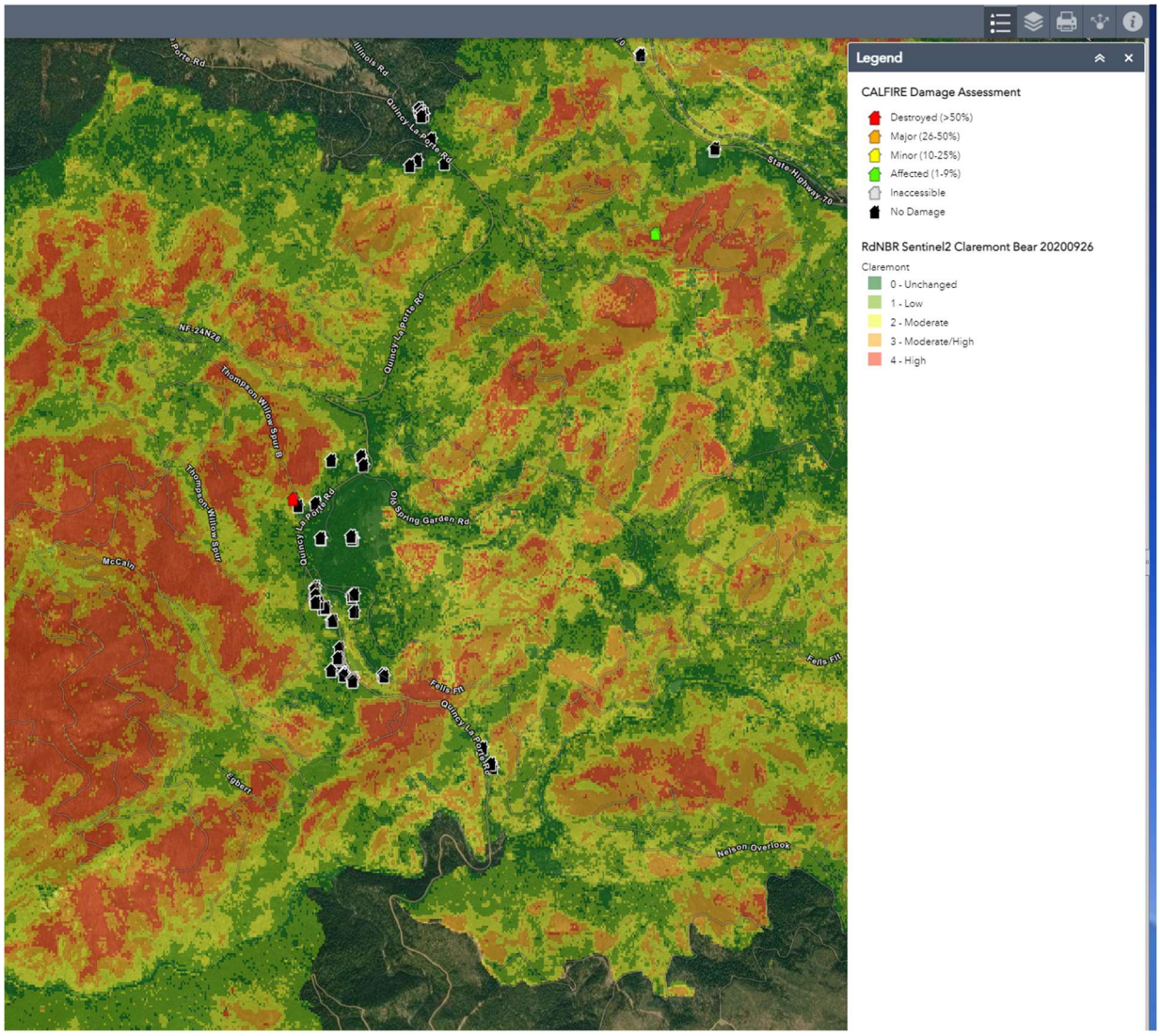
defend your home (CALFIRE 2021). It is critical to emphasize that defensible space is most effective when utilized by fire fighters to help prepare and take defensible action to protect home during a wildfire (Syphard and Keeley 2019). Preparation of homes can include removal of flammable material such as firewood, stored fuel, or vegetation away from the home as well as installation of hose lays and water sources around the home or neighborhood.

5.4.1 Use of Defensible Space on the 2020 North Complex

The 2020 North Complex included 17 lighting fires which were ignited fires on August 17th, 2021. By September 5th, all of these fires, except The Bear and Claremont Fires, were contained. The Bear and Claremont Fires merged to form a single fire. The Claremont Fire directly threatened the communities of East Quincy and homes and structures along the La Porte Road. The La Porte Road area had several continuous fuel treatments that had been completed between in ~2014. These treated areas were directly used by firefighters to prepare structures, set up hose lays, initiate backing fires, and safely stay on the properties for extended period, including during night operations. It should be noted that in areas with masticated fuels, fire fighters on scene during the fire noted that spot fires ignited in masticated fuels were more difficult to suppress compared with needle cast. In addition, due to the long residency time of fire in masticated fuels, very frequent patrols were required. Masticated fuels did help slow fire spread, but the surface fuels could have been removed post mastication to facilitate suppression efficiency and reduce post wildfire mortality. Similar findings for masticated fuels have been noted by (Knapp et al. 2011, Stephens and Moghaddas 2005a). As a result of these efforts, with the exemption of a small building lost in the Cutler Meadows area, no additional structures were lost along La Porte Road. In addition, fire severity was generally lower in treated areas relative adjacent untreated areas.

On September 8th, 2021, the eastern flank of the merged Bear and Claremont Fires the fire crossed the Middle Fork of the Feather River near Horseshoe bend and made a several mile run to Lake Oroville, pushed by high (45 MPH) winds. Within the path of this wind driven head fire, which eventually killed 16 people and destroyed over 2400 structures (Figure 9 and see online severity map https://sig-gis.com/north-complex-web-app/). The North Complex was declared 100% contained on December 3rd, 2020 (NWCG 2021).

Figure 9 Eastern portion of the Claremont Fire in the La Porte Road Area (Claremont-Bear Fire Severity SIG 2021)



5.4.2 Use of Defensible Space on the 2021 Dixie Fire

The Dixie Fire was reported on July 13, 2021, with the Fly Fire reported on July 22nd, 2021-both fires merged together and continued to be called the Dixie Fire throughout the incident. The Dixie fire was characterized by extensive extreme fire behavior, with extreme fire behavior observed and night and burning downslope, resulting in high flame lengths and high fire severity. Several fire fighters on the incident noted individual trees torching as a result of a few embers igniting their crowns, or flames even burning up bark and lichen igniting green tree crown. This was likely due to the extremely low live fuel moistures reported on the incident (CALFIRE 2021).

The community of Indian Falls was directly impacted by the head of the fire on 07/24/2021 and while there were existing treatments to the east of the neighborhood, the fire approached from

the west under extreme conditions, resulting in extensive structure loss. As seen in the North Complex run through Berry Creek, conditions within Indian Falls did not allow fire fighters a safe place to conduct direct structure protection, though they did begin suppression actions soon after the passage of the main fire front (Dupras, 2021). Similar results were seen in other areas including the town of Greenville, which was nearly completely destroyed on August 4th, and individual homes in the Diamond Mountain Road Area the following week-where extreme, wind driven fire behavior, prevented the effective usage of defensible space and extensive structure loss occurred.

Within Indian Valley, specifically along North Valley Road to the intersection of Diamond Mountain Road, past fuel treatments were impacted by the main fire or utilized both during burnout operations and by landowners taking suppression actions on their own properties to extinguish spot fires originating from the Town of Greenville as it burned (Meyers, 2021). These treatments generally were impacted by flanking or backing fires moving north to south down the face of Keddie Ridge. Along North Valley Road, east of Pecks Valley Road, no structures were lost.

Between the communities of Taylorsville and Genesee Valley, there were extensive fuel treatments along the Genesee Road and western edge of Genesee Valley. Along this road, these treatments allowed fire fighters more time and a relatively safer area to prepare homes and conduct burnout operations, resulting in no structures lost in this area. Similar results occurred in Genesee Valley, where continuous, multi owner fuel treatments along the Beckworth-Genesee Road allowed fire fighter access for structure protection, burnout operations, mop up, and patrol. Local fire fighters on scene noted that in some areas, defensible space conditions were so favorable that hose lays setup to fight the fire were only used for mop-up after burnout operations were complete. It should be noted that Dixie Fire did cross the valley in an un-grazed portion of grassland, but on actively grazed portions, the fire did not get established or spread (Foster, Personal Communication). On the South Side of Genesee Valley, there were no structures lost, but generally higher post fire mortality, particularly in untreated stands.

While properly maintained defensible space and home structure characteristics can help reduce home loss or reduce fire severity when unstaffed, research shows that those homes which receive additional direct protection from fire fighters have the greatest chance of survival (Syphard and Keeley 2019). The challenge is that defensible space cannot be safely staffed by personnel when it is threatened by wind driven fire or extreme fire behavior such as was observed on the North Complex run through Berry Creek or the Dixie Fire run from Round Valley Reservoir through the town of Greenville. Where defensible space was continuous (i.e. covering multiple parcels compared with single, isolated parcels) and not threatened directly by the head of the fire, it was more consistently utilized by fire fighters to prepare the structure, set up hose lays, defend the structure from embers and the approaching fire, and to conduct burnout operations.

These findings are consistent with previous work on fuel treatments actively used by fire fighters during wildfires on the Plumas National Forest (Dailey et al. 2008; Kerr, 2007; Fites et

al. 2007). Local fuel treatments have been utilized to increase suppression effectiveness, facilitate safer ingress/egress, and enhance visual contact between crews on past wildfires (Moghaddas and Craggs, 2007). It is important to emphasize that fuel treatments are not designed to stop all fires under all conditions – the purpose of this report is not to make this assertion. It should also be noted that these observations from the Dixie Fire and North Complex reflect what was seen on specific portions of these incidents, and should be considered in the context of other observations from similar events and treatments across the Sierra Nevada Region

5.5 Applicable Forest Practice Regulations and Exemptions

Of all projects implemented by the Plumas County Fire Safe Council, a subset of them had a commercial component which included the harvest and sale of saw logs (Typically trees >10" DBH) and/or biomass (Typically trees <10" DBH). These projects were completed under Timber Harvest Plans or exemptions and subject to the California Forest Practice Rules below.

- Minimum stocking standards (14 CCR § 932.7)
- Logging slash and hazard reduction (14 CCR § 937)

With respect to minimum stocking standards (14 CCR § 932.7), all projects met minimum stocking standards after completion. Fuels reduction projects all consisted of a "thinning from below" approach, which typically removed the smaller diameter trees, retaining larger diameter trees.

The Forest Practice Rules require that activity generated slash (limbs and tops) be lopped and scattered to a depth of no more than 24 inches in depth. For all cases that fell under the Forest Practice Rules in this study, the properties were treated using a mechanical whole tree harvest system. The mechanical whole tree harvest system typically results in limited activity generated slash, other than breakage during skidding, as the whole trees are yarded to a separate landing for processing. Depending on the operation, terrain, and tree size, whole harvest trees can be suspended above ground to limit limb breakage during skidding. Overall, Plumas County Fire Safe Council treatments met or exceeded activity fuel reduction requirements. In addition, properties treated nearly 20 years ago now in a condition where basic maintenance can be conducted primarily using rakes or chainsaws to clean up accumulated litter or limb, clear small residual trees.

In terms of logging slash and hazard reduction, all projects met or exceeded standards described for (14 CCR § 917). This is primarily due to the harvesting equipment utilized in these projects. All of these projects utilized a whole tree harvest system for both saw log and biomass removal. The whole tree system allows the operator to easy fall trees without impacting residual trees, limiting branch breakage and fuel accumulation. Whole trees are skidded to landing where branches and tops are removed from sawlogs, and eventually chipped and hauled to a facility for utilization as fuel. This is in contrast to harvest methods that use "lop

and scatter" of slash within the unit, leaving tops and limbs to decay. Given the dry conditions in the Sierra Nevada, decay time can be long (Stephens and Moghaddas 2005b; Van Wagner, 1972), resulting in this fuel being available to burn in a wildfire for several years after it is deposited (Figure 10-Note this photo is not from a Plumas County Fire Safe Council Project).

Figure 10. Lopped and scatted slash created in ~2010 and condition in 2021. Note this photo is not from a Plumas County Fire Safe Council Project

5.6 Critical Questions Findings

This evaluation addressed the critical questions below.

- **How many years are fuel reduction treatments in the WUI effective for? What are the potential maintenance needs for existing treatments and at what treatment age?** Treatments in our study area that were commercially thinned from below with both biomass and sawlog removal, and that utilized a whole tree harvest system were shown to be remain effective for at least 15 years (Chiono et al. 2012), and in our study, sites up to 20 years old still retained residual tree spacing with limited shrub and fuel accumulation. In these stands, where the primary maintenance needs are

removal of accumulated litter, branches, and occasional dead removal, investments in maintenance could prolong the treatment effectiveness for at least another decade.

- **Is there a variation in treatment effectiveness over time by vegetation type, type of treatment, or equipment type used?** The greatest difference in equipment type was seen in the post treatment surface fuel characteristics of treatments that used a masticator, versus those that utilized a whole tree harvest system or had pile or under burning completed. Masticated units typically had relatively more fuel, though that fuel was compacted. As noted in previous sections, masticated fuels did pose more of a challenge to fire fighters on both the Dixie Fire and the North Complex.

- **Are there quantifiable differences in tree mortality within existing WUI fuel treatments compared with areas adjacent to these treatments?** Yes. Generally completed fuel treatments that were exposed to the flanks of both the North Complex and Dixie Fires burned with lower severity then untreated areas. It should be noted that treated areas exposed to the head of the Dixie fire burned at high severity.

- **How can the described method be efficiently applied to all Fire Safe Council projects across the entire State of California?** Developing a best or standard practices guide for treatments across vegetation types and regions of the state, including standard prescriptions, would help Fire Safe Councils develop consistent treatments which can be easily scaled in communities less familiar with fuel treatment implementation. Such a guide could include photos, references, and guidelines with text and photos easily applied by contractors, local Foresters, and organizations leading fuels reduction projects.

6 Recommendations

6.1 Forest Practice Rules

The Current Forest Practice Rules generally define applicable and repeatable guidelines to be used for implementation of fuel treatments. One important note, is that the activity fuel treatment depth of 24 inches will generate significant flame lengths under wildfire conditions (Stephens and Moghaddas, 2005b), and consideration should be given to reduce the depth or loading of all treatments implemented within the Wildland Urban Interface.

6.2 Defensible Space

Given that active utilization of defensible space by fire fighters is a key component in its effectiveness, making sure this space is ready and easy to use by fire management personnel is important. Fire fighters and others who worked on the Dixie Fire and North Complex noted a few things that could be improved based on observations during these fires, allowing defensible space to be better utilized, including:

- **Systematic mapping of local fuel treatments by all entities.** Often US Forest Service or private industrial timberland treatments are mapped in CALMAPPER or FACTS and available to Incident Management Teams via the Interra System (https://www.intterragroup.com/), but smaller treatments from HOA's, Fire Safe Councils, Resource Conservation Districts (RCDs), or other private lands are not included in these treatment map datasets. This creates a barrier to easily integrating these local treatments into operational planning, especially for fire management staff unfamiliar with the local area.

- **Remind homeowners to keep Defensible Space clear of flammable debris and liquids.** There may be defensible space treatments around a house or community, but the effectiveness of these treatments can be offset by things such as firewood stacked near a home or on a deck, attached shed, attached wooden fences, or vehicles next to the home that may result in lower survival when impacted by a wildfire. During the Dixie Fire, some homes had many flammables observed within 100 feet of the structure. Flammables included BBQ propane tanks, debris under wooden decks, fuel stored in plastic containers, and paint. Managing these flammables during structure preparation can decreases the amount of time fire fighters can spend setting up hose lays or even safely defending the property once it is impacted by embers. The conditions around a residence beyond vegetation can influence the decision to actively protect a structure by responding fire resources. When resources are limited, fire crews have a short time to triage structure protection based on what they can easily see and assess quickly under stressful and often smoky conditions with limited visibility. The more landowners can

do to help responding fire fighters be successful in protecting a structure, the higher that structures potential for survival.

- **Help the public understand that fuel treatments/defensible space may not be effective under extreme fire conditions when fire fighter safety is at risk.** It is important to convey to the public that even if there is a fuel break near their home or defensible space in their neighborhood, it may not be staffed, and they still may lose their home, as under extreme conditions or when resources are limited, these areas and structures near/within them may be directly impacted by embers or the main fire.

- **Early evacuations are key.** On the Dixie Fire, responding fire fighters spent considerable time encouraging some homeowners to evacuate. This effort diverted resources away from fire protection actions. The sooner people evacuate, the more time fire fighters can prepare a home or community to be impacted by embers or the main fire.

- **Masticated fuels.** Where mastication is used as a primary treatment, consider a follow up removal or reduction of accumulated surface fuels via pile burning or gathering and hauling offsite of material on smaller parcels. Residual masticated fuels should be kept to less than 6" and potentially 2" inches or less post mastication to facilitate handline and dozer line construction and reduce fire line intensity and resulting tree mortality.

- **Expansion of Defensible Space.** Fire fighters have noted that under the extreme wildfire conditions we are seeing today, 100 feet of defensible space may not be enough to safely prepare and defend a home or clusters of homes. Consider expanding defensible space distances and encouraging multiple home owners to create continuous defensible space across their property lines.

- **Post Fire Interviews needed for fire fighters on scene to validate assumptions about fire behavior, defensible space, structure survival.** A system to interview fire fighters or allow them to post geotagged photos and video from the fire to be used to future analysis should be established. This report contained information from fire fighters directly involved in both the Dixie Fire and North Complex. The details provided by fire fighters who observed fire behavior, structure ignition, and use of defensible space are invaluable as this information cannot be obtained using traditional "pre-post" fire assessments of vegetation or structure loss.

- **Consider resilience beyond just wildfire when creating projects.** Consider managing stands at residual tree densities that help make them more resilient not just to wildfire but to potential mortality caused future periods of prolonged drought.

6.3 Treatment Maintenance

- **Maintenance of fuel breaks.** Extensive resources are often invested in the initial establishment of new fuel breaks within and around communities, but over time, their effectiveness is diminished as live and dead vegetation accumulate. Regular maintenance of these treatments can extend their effectiveness over time and cost relatively less then re-establishing these treatments once they are overgrown. Where prescribed fire is used for maintenance, it is important to balance effective fuel consumption with creation of new mortality or opportunities for brush to establish. On smaller residential parcels, accumulated needles and branches may be more easily raked and/or piled and burned or hauled away. Recommend maintaining treatment areas of oldest age first.

- **Establish, expand, and support local green waste programs.** Within many residential areas of Plumas County (i.e. Quincy, Portola), forest vegetation and debris is abundant but open burning is not allowed. Residents noted that dump hauling logistics, bagging, and other costs limited their ability to bring large amounts of vegetation to the dump. Consider expanding residential green waste programs that pick-up material at homes in bins for easy disposal, even if for a limited time period (months before and after fire season)

- **Mastication Treatments.** While mastication did moderate fire behavior, it was noted that masticated fuels posed more difficulty for fire line construction, potentially slowing down fire line production rates. Typically, where masticated fuels were up to ~2" deep, fire line production rates were not impacted. The PCFSC may want to consider additional removal of masticated materials to a depth of less than 6" and ideally <2" on new mastication projects. In addition, projects with completed mastication should be considered for additional material removal, with a priority of removing masticated material within 100 feet of all structures and potentially within WUI areas.

7 Scientific Uncertainty and Geographic Application

This analysis of fuel treatments in Plumas County has broad application to similar vegetation types within the greater Northern Forest Districts. Monitoring findings will be generally applicable to similar vegetation types, treatments, ages, elevations, soil types, and climate zones, within both the Northern Forest District.

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Appendix 1: Table of Fire Safe Council Projects

APPENDIX 1: FIRE SAFE COUNCIL PROJECTS

Fiscal Year	Agency Source	Grant Project Name	Project Type	Acres
02-03	USFS - EAP	Hazardous Fuel Reduction Demo	HFR-Treatment	63.3
02-03	RAC/USFS- Title II	50 acres HFR-Plumas Eureka	HFR-Treatment	50.0
03-04	RAC/USFS- Title II	Indian Falls Community HFR DZ	HFR-Treatment	39.8
03-04	RAC/USFS- Title II	Camp Layman HFR	HFR-Treatment	50.0
03-04	RAC/USFS- Title II	Cromberg HFR	HFR-Treatment	155.0
03-04	RAC/USFS- Title II	Quincy CSD HFR	HFR-Treatment	13.0
03-04	USFS -Comm Protect	Delleker North HFR	HFR-Treatment	131.0
04-05	RAC/USFS- Title II	C Road1 HFR	HFR-Treatment	65.8
07-08	RAC/USFS- Title II	C Road1 HFR -Supplemental	HFR-Treatment	31.6
04-05	USFS -Comm Protect	C Road1 HFR	HFR-Treatment	24.6
04-05	RAC/USFS- Title II	Red Clover (Genesee)	HFR-Treatment	73.2
04-05	RAC/USFS- Title II	Canyon Dam HFR	HFR-Treatment	550.0
05-06	RAC/USFS- Title II	Grizzly Creek HFR	HFR-Treatment	87.0
05-06	RAC/USFS- Title II	Whitehawk HFR	HFR-Treatment	105.0
05-06	RAC/USFS- Title II	Greenhorn Ranch HFR	HFR-Treatment	25.5
06-07	CA FSC-FS Comm Prot	WACC HFR	HFR-Treatment	17.0
06-07	CA FSC-FS Comm Prot	Eastern Plumas HFR	HFR-Treatment	121.0
05-06	RAC/USFS- Title II	Eastern Plumas HFR	HFR-Treatment	50.0
06-07	RAC/USFS- Title II	Little Grass Valley	HFR-Treatment	111.0
06-07	CDF Prop 40	Massack HFR	HFR-Treatment	125.0
07-08	RAC/USFS- Title II	La Porte Pines	HFR-Treatment	5.0
07-08	RAC/USFS- Title II	Taylorsville Campground HFR	HFR-Treatment	27.0
07-08	CA FSC-FS Comm Prot	Indian Valley HFR	HFR-Treatment	183.5
06-07	CDF Prop 40	La Porte Road I HFR	HFR-Treatment	119.0
07-08	Sierra Nevada Conservancy	Grizzly Creek HFR	HFR-Treatment	10.0
08-09	CA FSC-FS Comm Prot	Gold Mountain HFR	HFR-Treatment	187.0

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Fiscal Year	Agency Source	Grant Project Name	Project Type	Acres
09-10	CA FSC-FS Comm Prot	Crescent Grade HFR	HFR-Treatment	129.0
10-11	PNF Stevens Funds	Long Valley II HFR/Whitehawk II HFR/C Road HFR	HFR-Treatment	192.9
-	Landowner Contributions	C-Road Narrows	HFR-Treatment	25.0
10-11	RAC/USFS- Title II	Crescent Grade HFR	HFR-Treatment	38.0
10-11	RAC/USFS- Title II	Long Valley II HFR	HFR-Treatment	50.0
12-13	RAC/USFS- Title II	La Porte Road II HFR (Cutler Meadows)	HFR-Treatment	65.2
11-12	CDF Prop 40	La Porte Road II HFR (partial/ Non Product)	HFR-Treatment	73.1
12-13	Sierra Nevada Conservancy	La Porte Road II HFR (partial/Biomass)	HFR-Treatment	74.6
11-12	PNF Stevens Funds	Dwyer Tree Farm & Lee Summit (SW lands)	HFR-Treatment	135.0
12-13	PNF Stevens Funds	Bufords Place-East Quincy (Sopher Wheeler Lands)	HFR-Treatment	92.0
12-13	PNF Stevens Funds	Barry Creek Units A-C (Graeagle Land & Water)	HFR-Treatment	59.4
12-13	PNF Stevens Funds	East Shore Lake Almanor	HFR-Treatment	9.8
14-15	PNF Stevens Funds	W.Quincy Hwy 70	HFR-Treatment	51.3
13-14	RAC/USFS- Title II	Crescent Grade HFR Phase II	HFR-Treatment	68.4
14-15	PG&E	Cutler HFR	HFR-Treatment	16.0
14-15	PG&E	Crescent Grade HFR Phase II	HFR-Treatment	30.0
14-15	CAL FIRE SRA FPF	American Valley HFR	HFR-Treatment	135.0
15-16	PNF Stevens Funds	Dixie Valley Collaborative HFR	HFR-Treatment	72.6
16-17	Sierra Nevada Conservancy	Wolf and Grizzly Creek Municipal Watershed Protection	HFR-Treatment	500.0
16-17	PNF Stevens Funds	Mohawk Vista/C-Road HFR	HFR-Treatment	167.9
16-17	Sierra Nevada Conservancy	Bucks Lake HFR	HFR-Treatment	342.5
16-17	PNF Stevens Funds	Gold Mountain HFR	HFR-Treatment	110.9
18-19	Sierra Nevada Conservancy - Prop 1	Butterfly Twain Fuels and Forest Health	HFR-Treatment	454.9

APPENDIX 1: FIRE SAFE COUNCIL PROJECTS

Fiscal Year	Agency Source	Grant Project Name	Project Type	Acres
18-19	Sierra Nevada Conservancy - Prop 1	Little Grass Valley Reservoir Watershed Protection	HFR-Treatment	480.0
18-19	CAL FIRE CCI Forest Health	Plumas Collaborative Forest Health	HFR-Treatment	7859.0
18-19	CAL FIRE CCI Fire Prevention	Portola HFR	HFR-Treatment	152.0
18-19	PNF Stevens Funds	American Valley II HFR	HFR-Treatment	160.0
				13,965

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