Fire Behavior Assessment Team Monitoring of Treated and Untreated Fuels Around the Big Trees Sequoia Grove, Tahoe National Forest

September 25, 2022

Center photo shows prescribed burning in the Big Trees Sequoia Grove performed during the 2022 Mosquito Fire, surrounded by plot photos from a thinned, pile burned, and underburned site (left), and an untreated area (right)

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Summary

The Mosquito Fire ignited on September 6th, 2022, southeast of Foresthill, California. The eastern edge of the fire was actively burning towards the Placer County Big Trees Grove, the northernmost and smallest grove of giant sequoias (*Sequoiadendron giganteum*). The grove recently underwent a series of fuel reduction treatments, including mechanical thinning, pile burning, and underburning. Forest staff requested that the Fire Behavior Assessment Team (FBAT) prioritize monitoring of treated and untreated areas within and adjacent to the Big Trees Grove. FBAT began installing fuels, fire behavior, and fire effects monitoring plots within the primary planning area of the Mosquito Fire on September 12th. Eight plots were installed around the grove (Plots 1-8) and two plots were established on Last Chance Ridge. Pre-fire fuels and vegetation data were collected on ten plots using FBAT standard protocols. Douglas-fir (*Pseudotsuga menziesii*), sugar pine (*Pinus lambertiana*), ponderosa pine (*Pinus ponderosa),* incense cedar (*Calocedrus decurrens),* and white fir (*Abies concolor*) dominated overstory trees in these mixed-conifer stands, while firs and incense cedar dominated the midstory. Understory fuels were dominated by shrubs, primarily huckleberry oak (*Quercus vaccinifolia*) and bush chinquapin (C*hrysolepis sempervirens*). Basal area, canopy fuel loading, and bulk density were high due to the abundance of large trees at relatively high densities. Duff, litter, and 1000-hour fuels contributed the most to fuel loading in untreated stands and were at substantially higher loadings than in treated areas. Untreated stands (both around the grove and along Last Chance Ridge outside of the 2013 American Fire footprint) also had greater pole tree stem density and basal areas than treated stands.

Smoke shading and suppression activities on the east side of the fire slowed fire growth leading up to the arrival of a wet storm system that began on September 18th. The 10 plots FBAT installed on the Mosquito Fire did not burn but will be useful as reference conditions and as opportunities for understanding fuels, fire behavior, and fire effects on future fires. As well, the fuels and vegetation summaries can inform continuing fuels treatment around the Big Trees grove and, should the Mosquito Fire resume growth, fire suppression activities in similar fuels (e.g., along Last Chance Ridge). FBAT plots installed on the 2006 Ralston Fire burned in the Mosquito Fire. FBAT took the opportunity to re-sample those plots, providing information on how past fires influence subsequent fires. Impacts of the Ralston Fire on the Mosquito Fire will be reported separately.

Introduction

This report summarizes the results of the Fire Behavior Assessment Team's (FBAT's) coordinated, plot-based field measurements of vegetation and fuel loading adjacent to the Mosquito Fire. The fire ignited southeast of Foresthill, California on September 6th, 2022, and was burning on the Tahoe and Eldorado National Forests in Placer and El Dorado counties, respectively (Figures 1 and 2). FBAT identified locations within and adjacent to the Placer County Big Trees Grove as well as two additional plots on Last Chance Ridge to capture fuel and vegetation conditions both where thinning, pile burning, and underburning had been implemented and untreated areas. Wildlife habitat was another consideration for the placement of monitoring plots. As such, plots were located in areas identified as California spotted owl primary activity centers (PACs).

FBAT objectives on the Mosquito Fire were to:

1. Safely and efficiently maximize the number of plots inventoried pre- and post-fire for fuels, vegetation, fire behavior, and fire effects
2. Examine differences in forest and fuels conditions in treated and untreated areas within and adjacent to the Big Trees Grove
3. Continue to build the FBAT data archive to reflect a broad range of fuels, vegetation, treatment, and climatic conditions in support of fire and land management decision-making
4. Deliver this summary report for the benefit of land and fire managers and FBAT data archive users and facilitate plot re-measurement over the long term

FBAT completed installing 10 pre-fire field plots on September 15th. Suppression efforts and wetting rains (rain started on September 18th) slowed fire progression to the east and none of the plots burned. After installing pre-fire plots, FBAT re-measured FBAT plots that had burned on the 2006 Ralston Fire and again during the Mosquito Fire. The opportunity to collect meaningful post-fire data on FBAT plots installed on past fires was facilitated by pre-fire measurements collected during the summer of 2021.

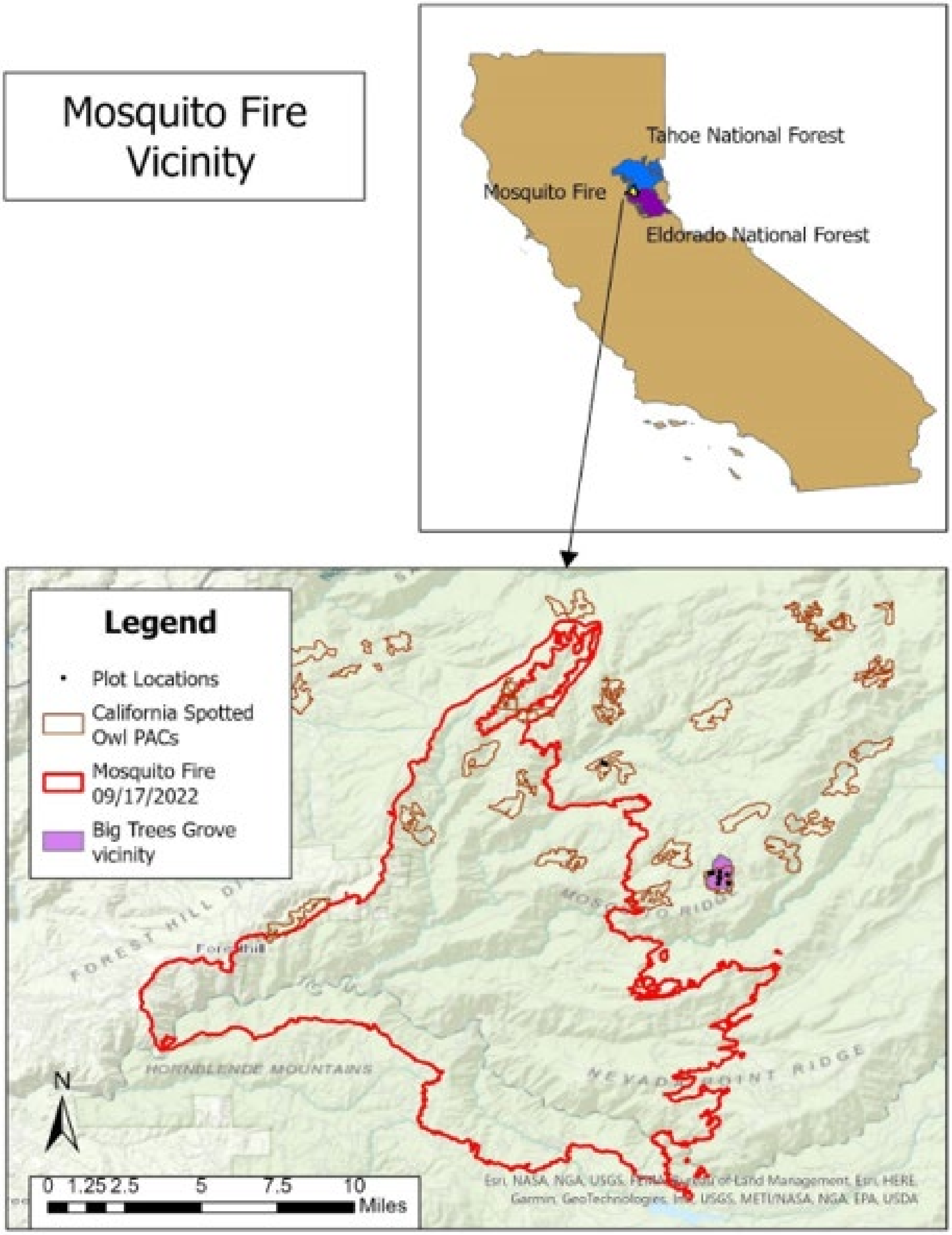


Figure 1. Vicinity map to Placer County Big Trees Grove, Last Chance Ridge, and the Mosquito Fire. The sequoias occupy about 4 acres within the larger Big Trees area.

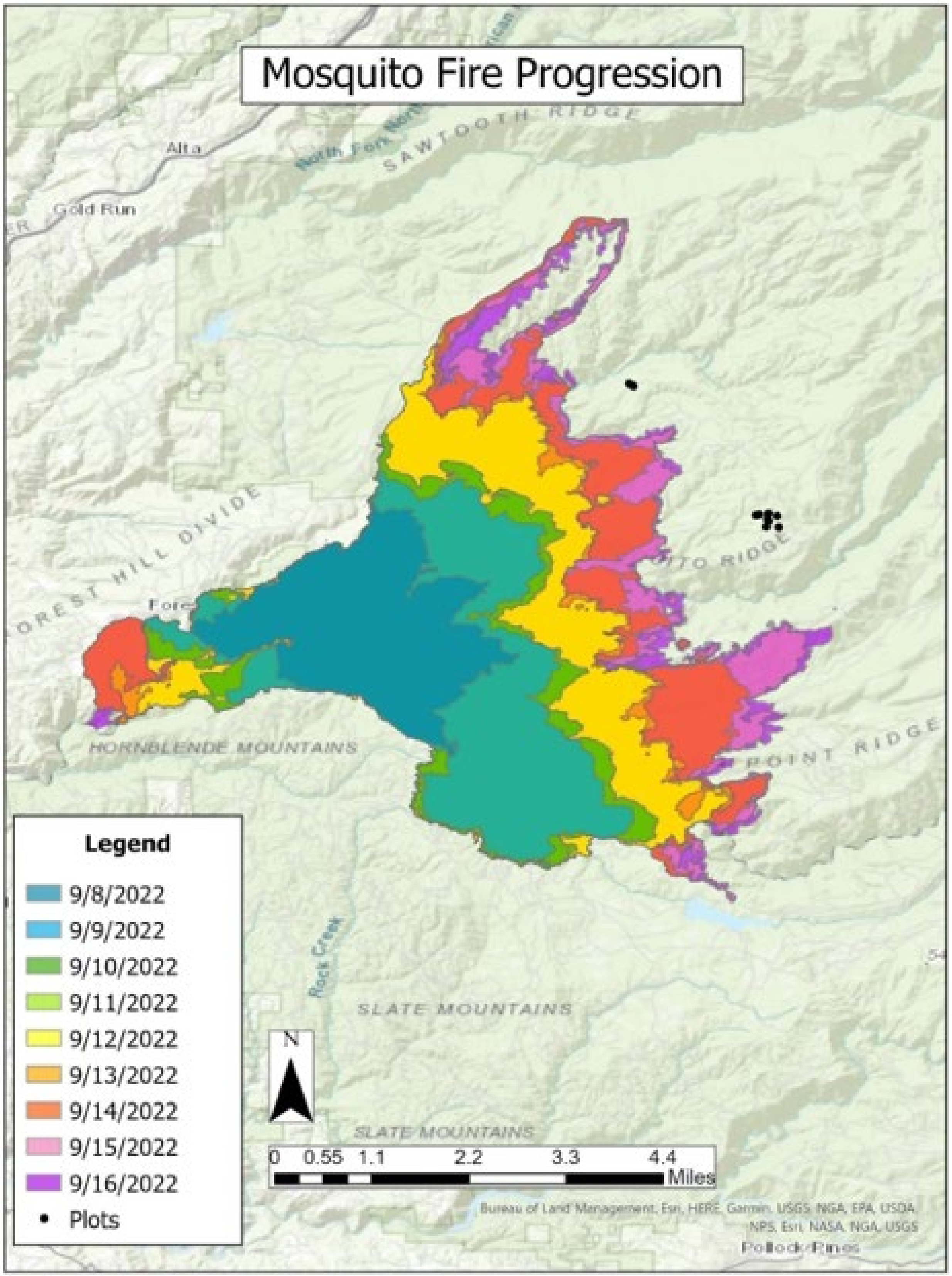


Figure 2. Fire progression map showing the majority of the growth on the Mosquito Fire.

Fire Indices and Weather Trends

Energy Release Component (ERC) is a fire danger index used to describe potential fire energy release (related to fuel consumption and fire intensity) and resistance to suppression. ERC reflects the potential worst case, total available energy (BTUs) per unit area (in square feet) within the flaming front at the head of a fire. The ERC is a function of the fuel model and fuel moisture (live and dead). Fuel loading (determined by fuel model) and moisture content of larger-diameter woody fuel have a strong influence on ERC, while the lighter fuels have less influence, and wind speed has none. ERC has lower variability across time and is the best fire danger index for indicating overall seasonal severity potential. The Burning Index (BI) estimates the potential difficulty of fire containment as it relates to the flame length at the head of the fire. BI is a function of the ERC and the Spread Component (SC). The SC is a function of live and dead fine fuel loads, fine fuel moisture, and wind that are more variable with time. Foresthill/Seed Orchard (NWS ID 041908) is the Remote Automated Weather Station (RAWS) nearest in distance and closest in elevation to the plots, likely recording weather observations more like the fire weather in the plot vicinity than other RAWS. The ERC and BI index graphs for the Foresthill/Seed Orchard RAWS are presented to illustrate the seasonal trends in fire potential for the area of the FBAT plots (Figure 3).

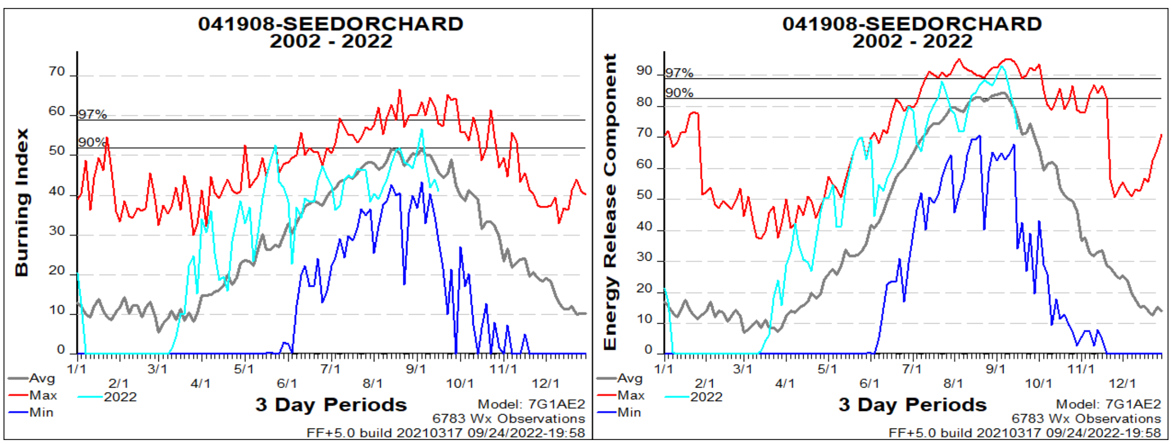


Figure 3. Fire Danger Rating index graphs for ERC and BI updated through 9/18/2022. Analysis period is from 2002-2022. The azure line indicates 2022 conditions.

Leading up to the time of the Mosquito Fire, ERC and BI had been trending higher than average in the spring. While fluctuating near average through the summer, both spiked above average in early September, just before the ignition on September 6th (Figure 4). Additionally, herbaceous, 1-hr, 10-hr, and 100-hr fuel moistures had been fluctuating around average during spring and much of the summer until dipping below average for a few weeks prior to and during the first few days of the fire (Appendix 3).

From June 13th until September 18th, the RAWS station recorded only 0.1 inch of rain (Appendix 3). Precipitation occurred over the Mosquito Fire started on September 18, bringing scattered showers and heavy rain at times throughout the area for multiple days. The precipitation amounts were enough to increase the fuel moisture content of fine down-woody fuels across Mosquito Fire area.

In the days prior to the date the Big Trees grove was underburned, September 15th, minimum relative humidity increased, and maximum dry bulb temperatures decreased (Figure 4). As well, during this period, wind speeds at the RAWS station were at or below average with the higher speeds coming from the west and southwest (Appendix 3). Moderating conditions reduced Mosquito Fire growth to the east.

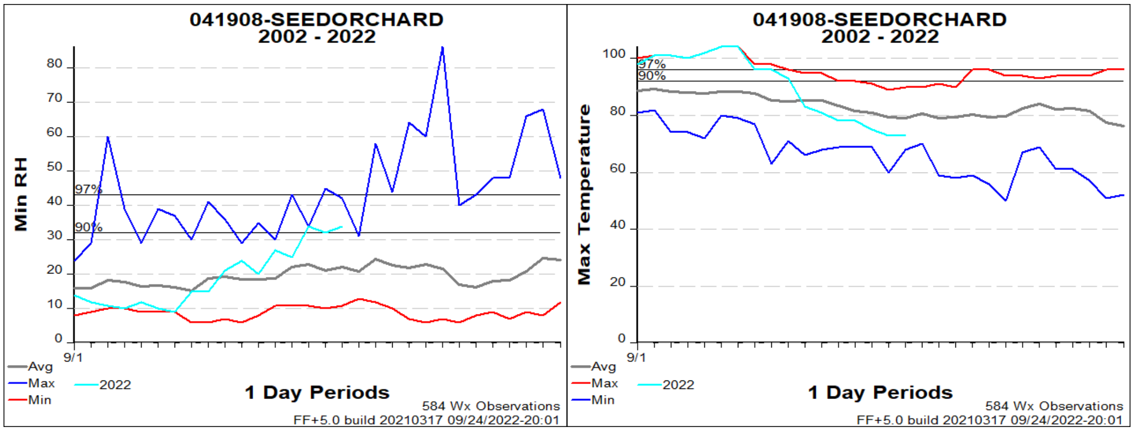


Figure 4. Fire weather graphs illustrating minimum relative humidity and maximum dry bulb temperature. Analysis period is from 2002-2022. The azure line indicates 2022 values from September 1st to 18th, 2022.

Methods

Although FBAT collected only pre-fire measurements on the Mosquito Fire, post-fire methods are included below to give the reader an understanding of the typical set of measurements. The general layout of an FBAT plot is shown in Figure 5 where measurements include: fixed radius plots for pole-sized and overstory trees; modified Brown's line transects for duff, litter, and downed woody material; belt transects for understory vegetation centered on the modified Brown's line; an array of fire arrival detectors for rate of spread; and a video camera and anemometer at 3.5 ft (FBAT 2022). Canopy cover measurements are taken at intervals along the modified Brown's lines and an instrument measuring soil heating profiles is placed at a designated position along each transect. Transect measurements are repeated post-fire and fire effects assessments are conducted on substrate, understory vegetation, and trees. The center and ends of the modified Brown's Lines are monumented with rebar to facilitate long-term monitoring. The FBAT protocol document is available at: https://www.frames.gov/fbat/home.

Pre- and Post-Fire Vegetation and Fuels

Overstory Vegetation Structure and Crown Fuels

Fixed radius plots are used to characterize crown fuels and overstory vegetation structure. This is a new protocol in 2022. In past years a variable radius plot was used. Tree species, status (alive or dead), DBH, height, canopy base height, and distance and azimuth from the center are collected for each tree before the fire. Tree heights are measured with a laser rangefinder and DBH is measured with a diameter tape. Plot radii are adjusted from 50 – 30ft for overstory trees (>6" DBH) and 50 – 20ft for pole trees as needed to sample approximately 15 of each.

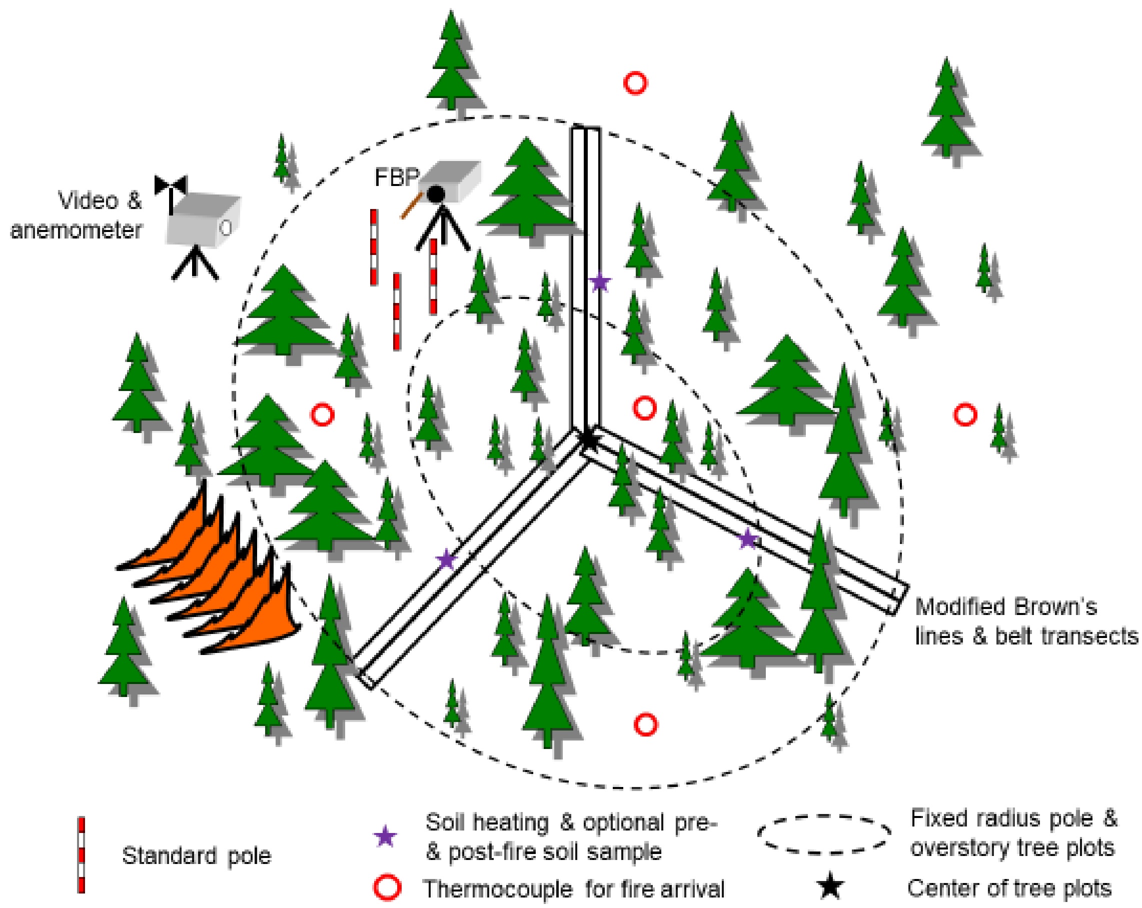


Figure 5. Plot layout. Modified Brown's lines and understory vegetation belt transects are anchored at plot center. The concentric circles represent pole and overstory tree fixed-radius plots. The thermocouples (TC) are used to determine fire arrival for calculating rate of spread (ROS), and the standards are positioned within the field of view of the video camera. The center of the thermocouple array is offset from plot center. Soil temperatures are measured at three depths at one location along each transect.

Post-fire measurements are collected for each tree, including minimum and maximum bole char, average height to which the crown is affected by the fire (i.e., injured in some way as indicated by either foliage scorch or consumption), the percentage of the crown that is affected by fire, and the percentage of the affected crown volume that is consumed (also known as "torch"). Trees are assumed to have survived the fire (at least in the short term) if any green needles are present after fire. Changes in canopy base height are estimated from the average height to which the crown is affected.

Plot data and the Forest Vegetation Simulator (FVS) (Crookston and Dixon 2005) are used to summarize tree characteristics. We use the latest software release (July 2022). Tree densities and basal areas (BA) are estimated directly from plot data. Pole and tree data from the fixed-radius plots are entered into an Access database for input into FVS. We used the California variant. Summary statistics include biomass, and quadratic mean diameter (QMD) estimated for all trees (overstory and pole) and crown height, crown base height (CBH), and crown bulk density (CBD) estimated for the overstory. Canopy base height, canopy bulk density, and canopy continuity are key characteristics of forest structure that affect the initiation and propagation of crown fire (Albini 1976; Rothermel 1991). CBH, or the bottom of the tree canopy, is important because it is an indicator of the likelihood of passive (torching) or active crown fire behavior. CBH is defined in FVS as the height where the 13-foot running mean canopy bulk density is greater than 30 lbs/acre/ft, or 0.11 kg/m^3. CBD is the mass of canopy fuel available per unit canopy volume (Scott and Reinhardt 2002). Ground-based estimates of canopy cover are made with a Moosehorn device that estimates percent cover from multiple point-intercept measurements.

Surface and Ground Fuel Loading

Surface and ground fuels are measured pre- and post-fire along three 50-foot modified Brown's lines. Surface fuel loading and fuel height are measured using the line-intercept method (Brown 1974, Van Wagner 1968). Fuel loading measurements are taken for 1-hr (<¼in. diameter), 10-hr (¼ to 1in. diameter), 100-hr (1 to 3 in. diameter), and 1000-hr (>3 in. diameter) time lag fuel classes. One and 10-hr fuels are tallied from 0 to 6 ft, 100-hr from 0 to 12 ft and 1000-hr from 0 to 50 ft. Maximum dead fuel height is recorded for the intervals of 0 to 6 ft, 6 to 12 ft and 12 to 18 ft. Litter and duff depths are measured at 1, 6, and 18 ft along each transect. These measurements are used to calculate surface and ground fuel loading (tons/acre) from bulk density estimates derived from the ratio of species-specific contributions according to tree basal area (Van Wagtendonk, Benedict and Sydoriak 1996; Van Wagtendonk, Benedict and Sydoriak 1998). Fuel consumption, estimated when post-fire data are available, is the difference between pre- and post-fire measurements.

Understory Vegetation Structure and Loading

Understory vegetation is characterized before and after the fire in a 3 ft wide belt centered on three 50-foot modified Brown's line transects (see below). The fuel and vegetation transects are in view of the video camera. Species, average height, percent alive, and percent cover (based on an ocular estimation, % of 50 ft x 3 ft area covered) are recorded for all understory shrubs, seedlings, grasses, and herbaceous plants. Biomass of live woody fuels (shrubs and seedlings) and live herbaceous fuels (grasses, forbs, subshrubs) are estimated using coefficients developed for the BEHAVE Fuel Subsystem (Burgan 1984). Calculations are completed using an Excel spreadsheet developed by Scott (2005) and adapted for use with FBAT data.

Fire Weather and Behavior

At each plot, thermocouples, an anemometer, and a video camera are set up to gather information on wind and fire behavior (Figure 5). The thermocouples arrayed across the plot capture date and time of fire arrival and are used to estimate rate of spread. An anemometer affixed to the camera box at 3.5 ft above ground records wind speeds leading up to the fire. Where imagery is successfully captured, it is used to determine fire type, flame lengths, and variability in direction and rate of spread of fire in relation to slope and wind, flame duration, and wind direction. The camera is triggered by fire arrival at thermistors (which act as circuit breakers) connected into a wire circuit that is placed surrounding the plot.

Rate of Spread

Rate of spread is determined both from video analysis and by calculating rate of spread from fire arrival times at thermocouples at known positions. Data loggers used for recording temperatures are buried underground with the attached thermocouple positioned at the surface of the fuel bed. Distances from the central to outer thermocouples is typically about 50 ft. Thermocouples record temperatures at two second intervals. The distances and azimuths among thermocouples are measured and these position and time of fire arrival are used to estimate fire rate of spread through the plot (Simard et al. 1984). Rate of spread can be calculated with any combination of three sensors forming a triangle. If more than one triangle of sensors triggered, all rates of spread are calculated and mean and standard deviation are available.

Photographs

Photographs on plot consist of at least 8 photograph types that are taken before a burn (pre) and after a burn (post). Two photos are taken for the three transects at 0-50 ft and 50-0 ft. Once transect photos are completed an aerial plot center photo is taken to capture the canopy. Lastly, a spherical image photo is taken from plot center using a google street or spherical function application/function on camera phones. The spherical image can then be uploaded onto a desktop, where that file can then be copied into an online application program called Marzipano (https://www.marzipano.net/tool/) to get a more detailed image of the plot features.

Fire Type

Fire type is classified as surface fire (low, moderate, or high intensity) or crown fire. Crown fire can be defined as either passive (single or group torching) or active (tree to tree crowning). Fire type is determined from video as well as from post-fire effects at each plot. For example, plots with complete consumption of tree canopy needles (torching) indicate at least passive crown fire.

Flame Length

Flame length is primarily determined from video footage. Reference poles in the video camera's field of view are marked in 1-foot increments, allowing flame length to be estimated. Flaming duration (where it is possible to measure) is based on direct video observation.

Plot Wind Speed

Wind speeds are estimated from the anemometer and video is used to estimate wind direction. The anemometers are not fire hardened and are damaged by heat during intense fires, indicating fire arrival at the anemometer. The maximum wind speed and average over 20 minutes before fire arrival is reported. If the anemometer is not damaged, the 20-minute averaging period ends after peak winds occur while the fire is near the anemometer (as indicated by arrival at nearby ROS sensors). If no peak is evident, the time of fire arrival at the nearest ROS sensor determines the end of the averaging period.

Fire Effects

Burn Severity

A rapid assessment of burn severity is completed along each transect and for the entire plot area to document the effects of fire on the substrate and understory vegetation (USDI National Park Service 2003, Appendix 2). The National Park Service (NPS) uses fire severity ratings from 1 (high) to 5 (low) when evaluating fire severity. FBAT uses the same coding matrix but reverses the scale so that it is more intuitive, with 1 representing unburned areas and 5 representing high fire severity.

Trees

Fire-effects related measurements on trees include minimum and maximum bole char heights and canopy impacts. The combination of minimum and maximum char heights can be a better reflection of fireline intensity than maximum char height alone (Inoue 1999). Canopy measurements include scorch (foliage killed but not consumed) and torch (foliage consumed) heights and the percentage of the canopy that is scorched or torched. Percentage scorch and torch values are determined using ocular estimations and heights are measured utilizing an instrument that combines a laser rangefinder and clinometer.

Soil heating

Soil temperature profiles are measured using an "iStake" (Brady et al. 2022). This device provides measurements of mineral soil temperature at 2, 4, and 6 in. (5, 10, and 15 cm) depths below the surface of the mineral soil. A high-temperature iButton logger is used at 2 inches and low-temperature loggers are used at 4 and 6 in. We collect pre-fire soil samples on the Mosquito Fire. Duff and litter depth are measured at the soil stake location to correlate the ground fuel load with soil heating.

Results and Discussion

A complete set of pre-fire measurements were collected in plots 1-10. No post-fire measurements were collected because the plots did not burn.

Site Description

All field plots were located within the Tahoe National Forest portion of the Mosquito Fire. Most plots (plots 1-8) were placed in and near the Placer County Big Trees Grove (Figure 6), with two plots in adjacent stands on Last Chance Ridge (Figure 7). All plots sampled during this assignment were in California spotted owl Primary Activity Centers (PACs). Although there are some giant sequoias in the grove and sequoia seedlings were observed, the area is predominately a mixed-evergreen forest within the Northern Sierra Lower Montane Forest Eco-Region (Figure 1). We chose plots to represent conditions within the 2018 underburn surrounding the roughly 4-acre unit containing the sequoias (Figure 6). Prior to the underburn, white fir up to 6 inches diameter were cut, piled, and burned within the treatment area. The plots in untreated fuels have no recorded fire history. Selective logging near some plots was done before the PACs were established. General plot information is provided in Table 1. The 2013 American Fire appeared to burn as a surface fire at Plot 10, likely from a burnout operation along Last Chance Road. Plots were on gentle slopes and aspects were mostly south to southwestern, or north to northwestern aspects. Local slopes and aspects are variable. Elevation ranged from 4475 to 5680 feet.

Table 1. Site descriptions for ten FBAT plots sampled on the Mosquito Fire. Latitude and Longitude datum is WGS 84. Elevations are from GPS.

Plot	N Lat.	W Lon.	Slope (%)	Aspect (deg)	Elev. (ft)	Data Collection Date
1	39.05747	120.56811	45	320	5677	9/12/22
2	39.05310	120.57231	30	190	5329	9/12/22
3	39.05938	120.57261	24	318	5369	9/12/22
4	39.05621	120.57188	20	350	5279	9/13/22
5	39.05815	120.57510	20	210	5204	9/13/22
6	39.05774	120.57636	20	230	5152	9/14/22
7	39.05853	120.57161	30	180	5276	9/14/22
8	39.05300	120.56750	35	250	5518	9/14/22
9	39.10947	120.62548	35	350	4595	9/15/22
10	39.11044	120.62720	25	340	4477	9/15/22

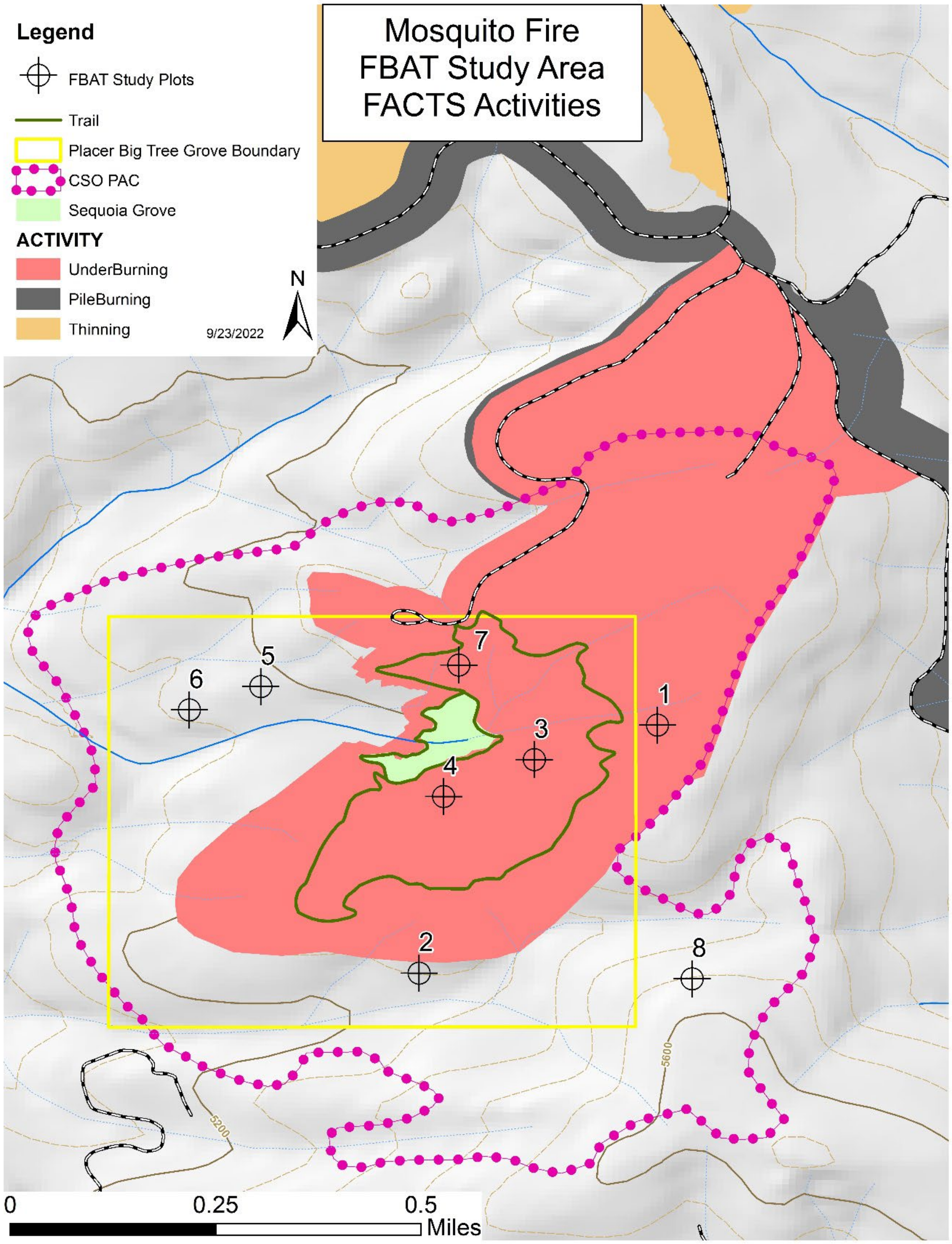


Figure 6. FBAT plot locations in and near the Big Trees Grove on the east side of the Mosquito Fire. The area coded as uncerburned had trees thinned up to a DBH of 6" that were then hand piled and burned. The pile burning treatment was followed by an underburn.

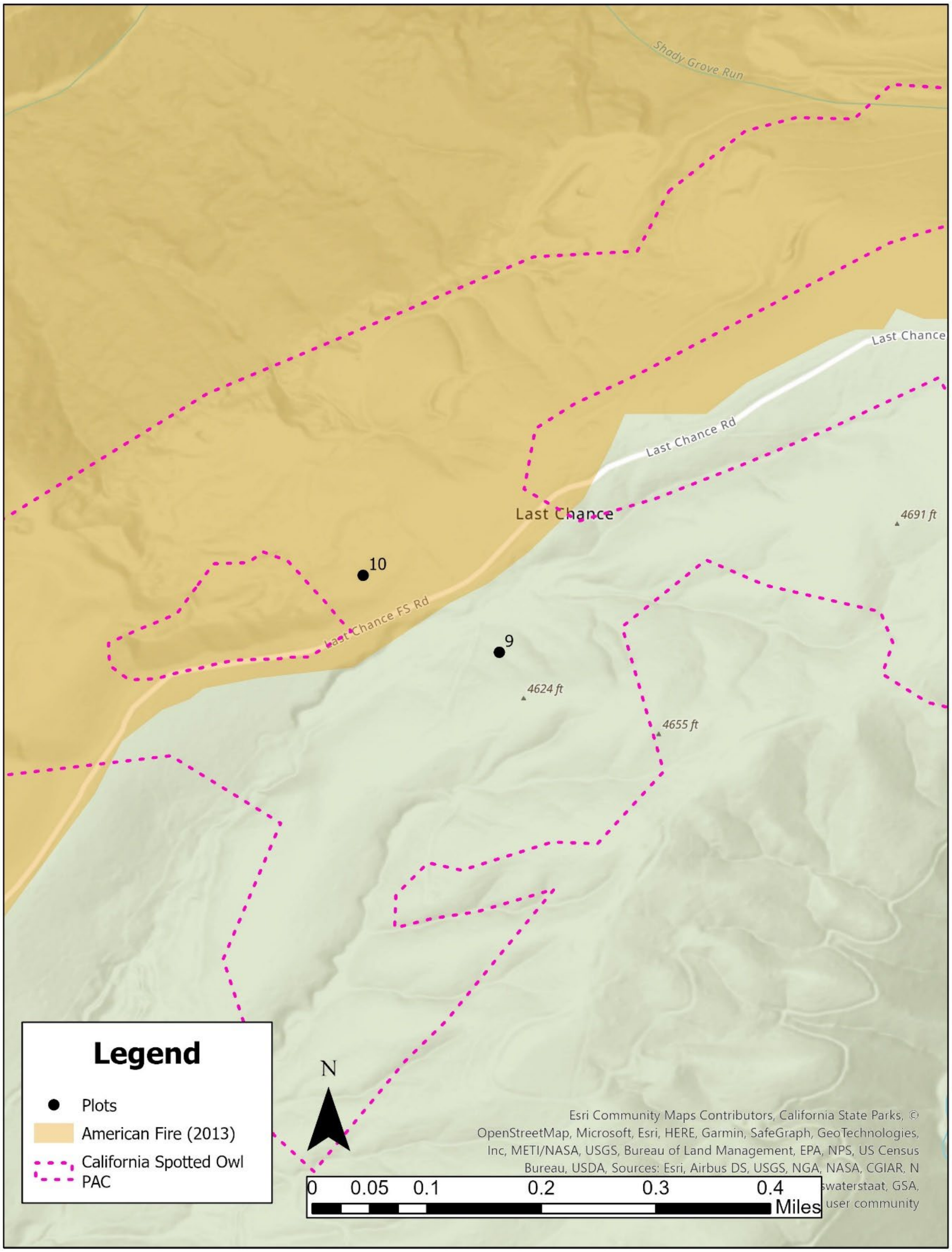


Figure 7. FBAT plots 9 and 10 on Last Chance Ridge.

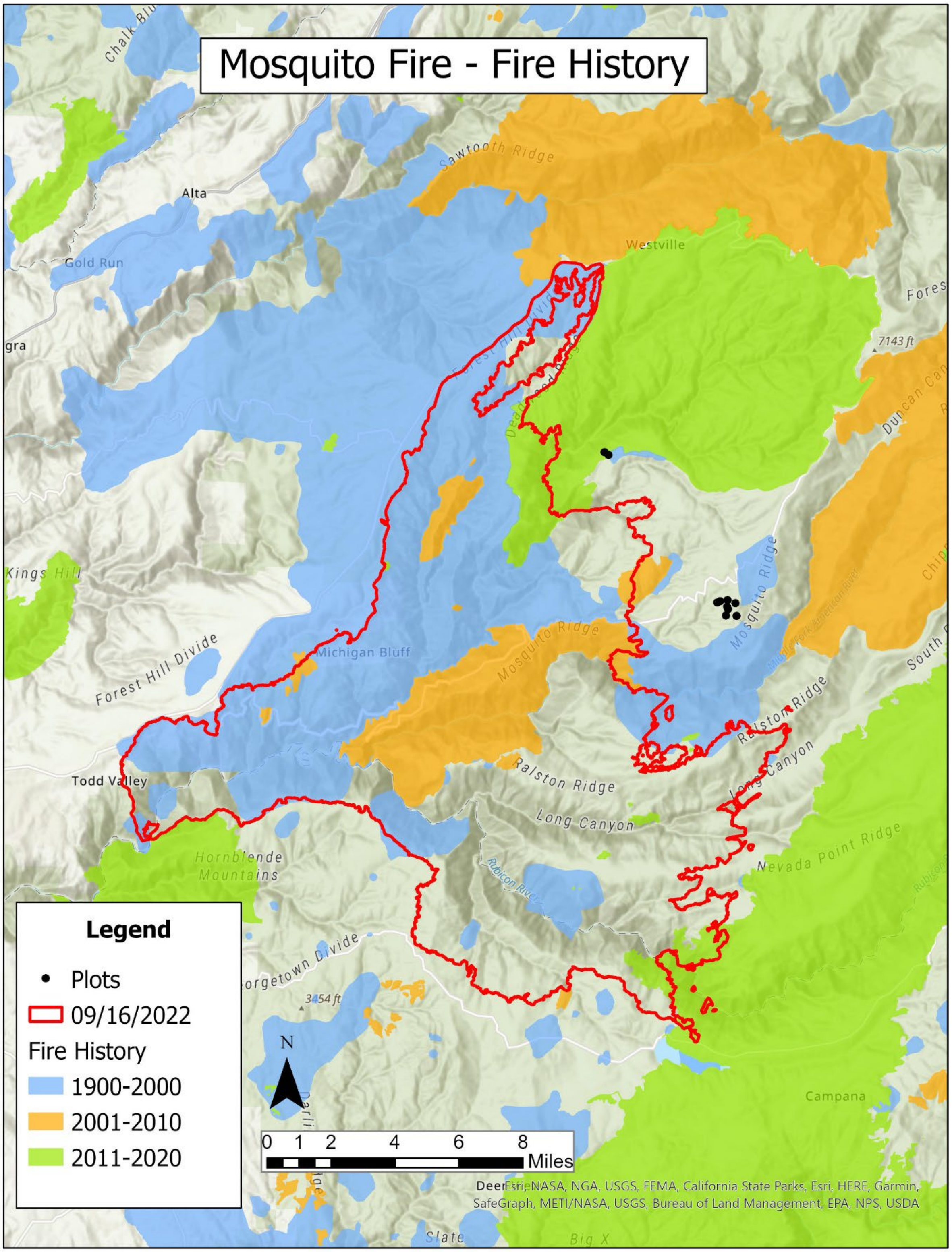


Figure 8. Wildfire history in the vicinity of the FBAT plots. The mapped fire perimeter is from September 16th.

Treatment histories are described in Table 2 and, for plots in the vicinity of the Big Trees grove, Figure 6. Plots within the underburn area (Figure 8) were mechanically thinned to reduce white fir densities, which were then hand piled and burned. Treatment history was confirmed with Tahoe NF fuels staff. Plot 10 on last chance ridge burned in the 2013 American Fire.

Table 2. Recent treatment activities for each plot based on field observations by FBAT during plot surveys and older treatment history from the FACTS database. All plots were in California spotted owl PACs. Note that there had been logging around some of the treated plots, likely from the mid-1900s, although we found no documentation.

History	Plot ID	Observed Activity	Historical wildfire
Treated	1	Thin to 6”, pile burn, underburn (2018)	None recorded
	3	Thin to 6”, pile burn, underburn (2018)	None recorded
	4	Thin to 6”, pile burn, underburn (2018)	None recorded
	7	Thin to 6”, pile burn, underburn (2018)	None recorded
Untreated	2	None	None recorded
	5	None	None recorded
	6	None	None recorded
	8	None	None recorded
	9	None	None recorded
Wildfire	10	None	American Fire 2013

Plot Descriptions

The following plot descriptions are intended to support data use and plot re-sampling as funding allows. Center and end-of-transect re-bar were left on the plots. No plots burned. Parking for Plots 1-7 was at the Big Trees parking lot (N39.05938, W120.57261).

Plot 1

The plot is located 0.3 miles Southeast of the parking lot on a northwest aspect. Plot 1 is also east of a fuels treatment area were the overstorey was thinned and then underburned. The thinning focused on mostly white fir. Residual material was scattered or removed. The plot observed moderate to high overstory mortality and a low percent cover, with a noticeable sequoia seedlings population established.

Plot 2

Plot 2 was located along the "Forest View Loop Trail" and was perched on a south facing aspect. The plot was chosen because it was outside the fuels treatment area and had significant litter and duff layers. Plot 2 displayed no signs of recent fire.

Plot 3

With a north aspect, plot 3 was located within the treatment area that was thinned and prescribed burned. In addition to the normal suite of instruments and measurements, plot 3 had an additional time-laps camera installed overlooking a few large sequoias.

Plot 4

Plot 4 is located upslope and to north of Big Trees Loop Trail within the fuels treatment area.

Plot 5

Plot 5 is roughly Northwest of the Big Trees grove on north side of a drainage that runs through the grove. The plot is on a gently descending ridgeline and has a heavy brush component.

Plot 6

This plot is located west of Big Trees project area and interior of the Big Trees Loop Trail. It is downslope from plot 5, and closer to the creak that flows through the grove. There is no visible evidence of recent fire on any of the trees within the plot. Large sugar pines and small firs comprise most of the stand composition. The plot has a large shrub component through most of the plot. The plot also has a large log that crosses transect and was felled sometime in the past.

Plot 7

Plot 7 is upslope from Big Trees grove, above the Big Trees Loop Trail and is approximately 100 yards from the parking area. The plot is also located within the fuels treatment area, and a time-laps camera was deployed as well.

Plot 8

From a parking area located at N39.05394, W120.56517, plot 8 is located in the owl Primary Activity Center (PAC). The plot is dominated by fir and oaks with sugar pines along the periphery, with no evidence of logging or recent fire.

Plot 9

Plot 9 is located south of a parking area with an interpretive sign next to a spring on Last Chance Rd. This plot is also located within an owl PAC and is set on a north aspect. The overstory is dominated by ponderosa pine and fir and the understory has huckleberry oak shrub. Parking: N39.11028, W120.62633.

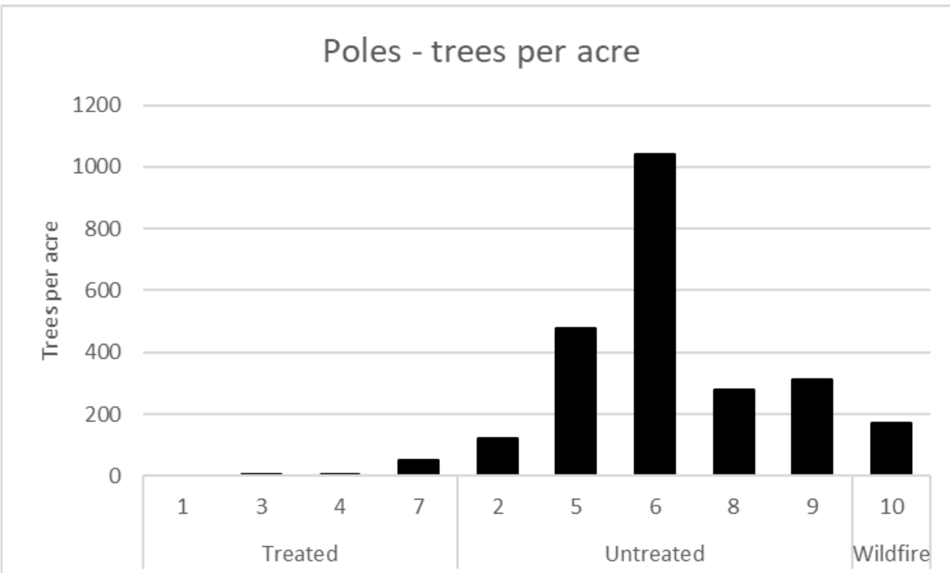
Plot 10

Plot 10 is settled on a north slope on the side of a ridge. To access the plot the best parking is: N39.11028, W120.62633. The plot was set in an owl PAC. Many of the tree boles had charring, evidence of past fire. The site is near a water source that had numerous cattle and game trails which could lead to cattle influencing the area. Numerous pieces of metal and possible archeological material were found throughout the plot.

Pre-Fire Vegetation and Fuels

Overstory Vegetation Structure and Crown Fuels

An important feature of untreated fuels was the greater densities and basal areas of pole-size (<6") trees than were present in treated areas (Figure 9). This not only indicates success of the fuel treatment operations but also highlights the risk of high intensity fire posed by untreated midstory fuels under a scenario where fire arrives at the grove from down-drainage. Crown bulk densities were at or above a recognized threshold for high likelihood of a stand supporting crown fire in about 50% of the plots (0.11 kg/m^2), with increased midstory in untreated stands further increasing the risk (Scott and Reinhardt 2002).



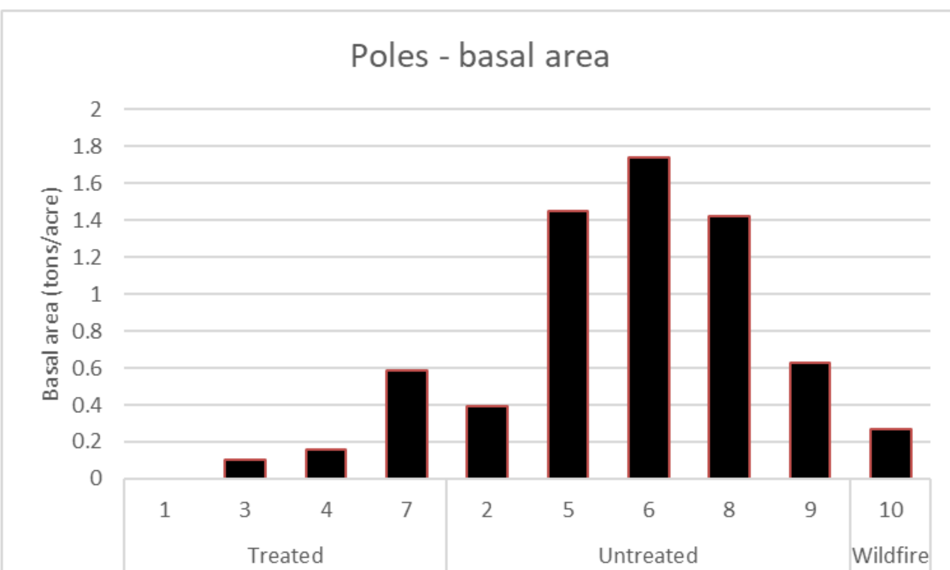


Figure 9. Comparison among treated sites and untreated sites and the plot burned in the 2013 American Fire. Treated and untreated plots are significantly different for both trees per acre and basal area.

Table 4. Pre-fire canopy characteristics for plots inventoried on the Mosquito Fire. Outputs of FVS, based on plot data, are indicated. Abbreviations: quadratic mean diameter (QMD), basal area (BA), tree height (TH), height to live crown (HLC), and canopy bulk density (CBD). BA is estimated for overstory trees from plot data. QMD, tree foliage loading, and CBD are FVS outputs for overstory and poles. Average TH and HLC were estimated from overstory data.

	Plot	Density (trees/ac)		QMD (in)[3]	BA (ft^2/ac)[1]	Canopy Cover (%)		TH[1] (ft)	HLC[1] (ft)	Tree foliage loading (tons/ac)[3]	CBD[3] (kg/m^3)
		Over-story[1]	Pole[2]			FVS[3]	Moose-horn				
Treated	1	150	123	23.3	350	58	85	79	48	6.4	0.10
	3	83	6	22.6	213	37	46	59	31	3.3	0.05
	4	231	478	8.9	118	39	77	37	23	3.3	0.12
	7	165	277	17.5	265	52	77	67	41	3.3	0.06
Untreated	2	354	6	19.7	735	86	85	71	38	10.5	0.21
	5	61	1040	11.4	350	61	77	77	28	4.9	0.08
	6	144	50	6.9	298	78	100	50	18	7.1	0.21
	8	243	311	8.0	179	58	85	41	26	4.9	0.11
	9	121	169	12.9	343	64	77	85	49	4.7	0.05
Wildfire	10	158	123	22.6	858	79	77	114	73	8.5	0.10

[1]≥6 in DBH; [2]<6 in DBH; [3]FVS output

Overstory, midstory, and the subcanopy of the sampling area was mixed conifers (Figure 10). Plots in the vicinity of the Big Trees grove (Plots 1-8) all had Douglas fir and most had substantial basal areas of large sugar pines. Plots 9 and 10 were located on Last Chance Ridge and their overstory composition includes ponderosa pine, Douglas-fir, and sugar pine, with a minor component of incense cedar in plot 10. The thinning to 6" targeted midstory white fir as a means of reducing ladder fuels.

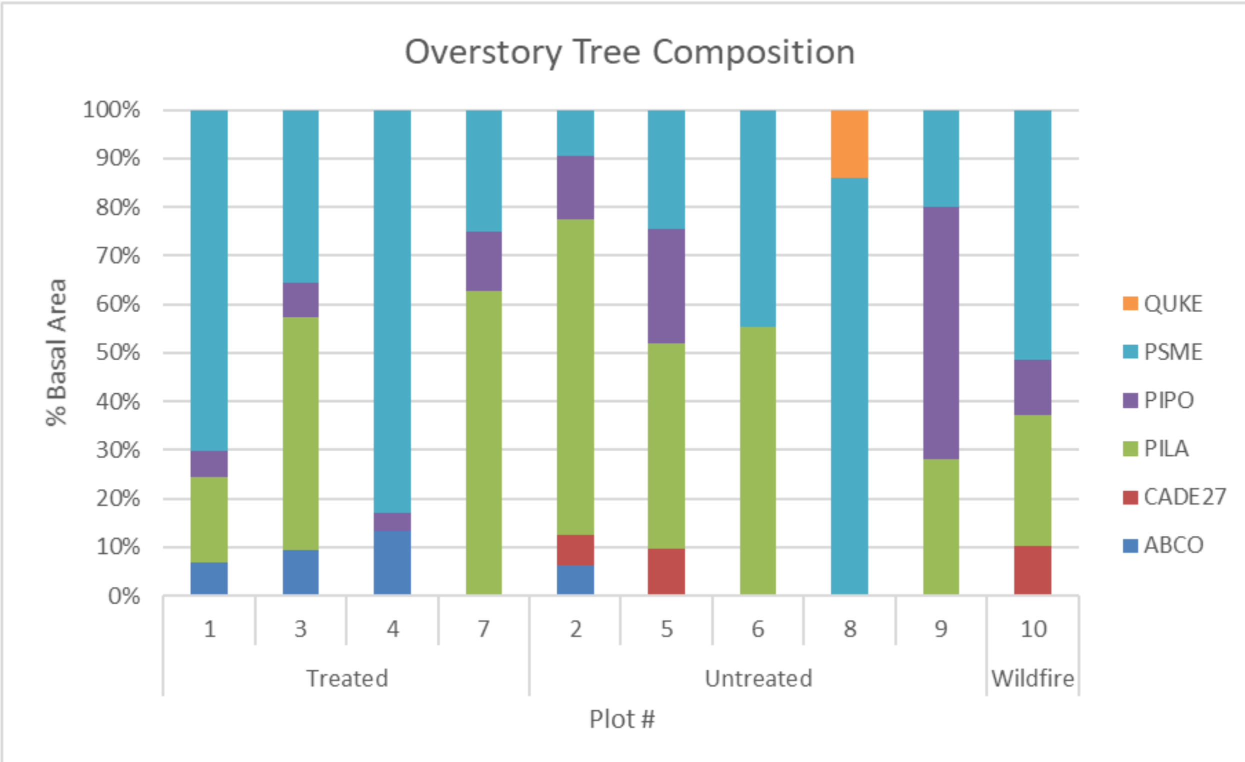


Figure 10. Overstory tree species composition on fixed radius tree sampling plot. QUKE = California black oak (*Quercus kelloggii*), PSME = Douglas fir (*Pseudotsuga menziesii*), PIPO = ponderosa pine (*Pinus pondersosa*), PILA = sugar pine (*Pinus lambertiana*), CADE27 = incense cedar (*Calocedrus decurrens*), and ABCO = White fir (*Abies concolor)*.

Surface, Ground, and Understory Vegetation Characteristics

Duff, litter, and 1000hr fuels contribute most to overall surface fuel loading (Table 5) as is typical for FBAT plots from previous fires in the Sierras Nevada Mountains. As such, these fuels are key for overall energy generation and smoke emissions. Plots 9 and 10 have the highest 1000hr fuel loads (55.18 and 55.41 tons/acre respectively). Large diameter dead and down Douglas fir logs contribute substantially to the 1000hr fuel loadings. Transects crossing multiple large 1000hr fuels can greatly increase estimated loading. Plots are located in areas with few snags for safety, possibly reducing loading by excluding snag debris. Making up a relatively small proportion of fuel loading are 1hr, 10hr, and 100hr woody fuels followed by forbs, shrubs, and seedlings. Plots contained minimal grass fuels. FBAT plans to explore the use of Terrestrial Laser Scanning (TLS) in combination with standard protocols to provide better estimates of duff, litter, 1000hr loading, and consumption. In terms of surface fire intensity, fuel arrangement is critical and fine fuels like litter, 1–100-hour woody fuels, and understory vegetation are important beyond their relatively low loading. The plots outside of the fuels treatment area demonstrated a higher brush component and fuel loading but variability in loading across untreated plots was large. Canopy fuels in these high basal area stands had relatively high predicted loadings, on par with litter loading (Table 5).

The understory on the plots included grasses, herbs, seedlings, and shrubs. Species included: sugar pine, (*Pinus lambertiana*), bush chinquapin (*Chrysolepis sempervirens*), huckleberry oak (*Quercus vaccinifolia*), spreading dogbane (*Apocynum androsaemifolium*), western brackenfern (*Pteridium aquilinum*), deerbrush (*Ceanothus integerrimus*), giant sequoia (*Sequoiadendron giganteum*), *Iris* sp., black oak (*Quercus kelloggii*), Pacific dogwood (*Cornus nutalli*), incense cedar (*Calocedrus decurrens)*, Douglas-fir (*Pseudotsuga menziesii)*, mahala mat (*Ceanothus prostratus*), and common snowberry (*Symphoricarpos albus*).

Table 5. Surface fuel loads and fuel bed depths for plots inventoried pre-fire on the Mosquito Fire (carrier fuels are surface fuel that are readily available for combustion not including duff and 1000-hour fuels).

	Status	Plot	Loading (tons/acre)										Fuel Bed Height (in)
			Duff	Litter	1hr	10hr	100hr	1000hr	Grass & Forb	Shrub & Seedling	Total	Total Carrier Fuels	
Treated	Pre	1	2.2	4.0	0.53	1.30	1.98	12.39	0.000	0.009	22.4	7.8	0.6
	Pre	3	6.3	3.9	0.55	0.95	1.10	13.38	0.001	0.146	26.3	6.7	1.0
	Pre	4	11.0	8.6	0.53	1.95	2.62	7.27	0.001	0.171	32.2	13.9	1.6
	Pre	7	4.7	2.1	1.19	2.25	1.95	18.31	0.000	0.092	30.6	7.6	0.7
Untreated	Pre	2	35.4	12.3	1.24	2.32	2.69	27.05	0.000	0.027	81.0	18.6	4.9
	Pre	5	32.3	7.0	0.98	2.26	1.26	47.98	0.000	0.747	92.5	12.2	3.2
	Pre	6	22.7	6.9	0.98	3.44	4.06	28.08	0.000	0.616	66.8	16.0	2.6
	Pre	8	51.2	14.0	0.99	3.58	6.18	38.13	0.000	0.010	114.1	24.7	4.8
	Pre	9	51.8	8.3	0.90	1.46	2.20	55.18	0.001	1.265	121.2	14.2	5.1
Wildfire	Pre	10	61.1	12.3	1.07	2.83	6.52	55.41	0.000	0.032	139.3	22.8	4.8

Fuels Synthesis

Overall loadings from surface fuels through the canopy were higher on the untreated plots (Figure 11, Table 6). As well, densities and basal areas of pole-sized trees (<6" DBH) were substantially reduced by the treatments around the Big Trees grove. In untreated areas surrounding the grove, midstory fuels would increase risk of crown fire and crown heating, particularly for a fire spreading up-drainage into the grove. The biggest differences in loadings between treated and untreated plots (Table 6) were for duff, litter, and coarse woody debris (1000hr woody fuels). Differences were not significant for some fuel categories (Table 6) because of high variability among plots. For instance, substantial shrub cover was present on some untreated plots, but not all of them.

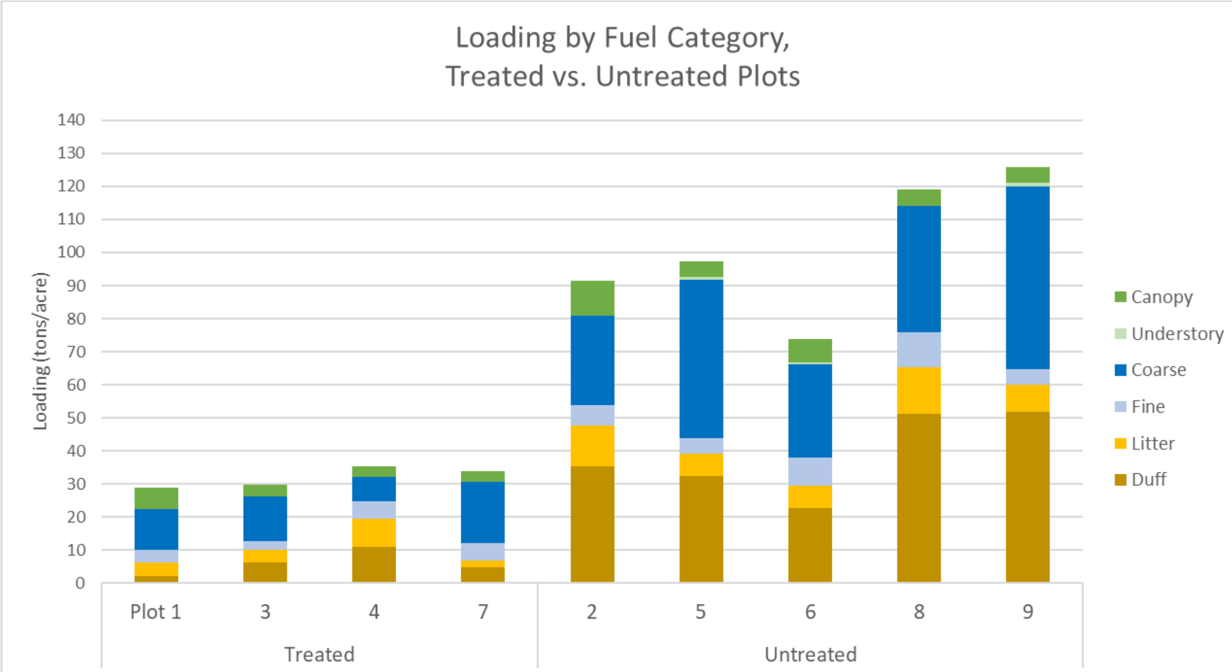


Figure 11. Fuel loading by fuel category, comparing treated and untreated plots.

Table 6. Fuel loading by category and overall on plots in treated (thinned, pile burned, and underburned), and untreated plots. Significant differences between treated and untreated plots is indicated by bold font. Canopy foliage loading includes both poles and overstory trees.

	Mean loading (tons/acre)		
Fuel stratum	**Treated**	**Untreated**	**P-value**
Duff	**6.1**	**38.7**	**0.001**
Litter	**4.7**	**9.7**	**0.022**
Fine woody	4.2	6.9	0.056
Coarse woody	**12.8**	**39.3**	**0.002**
Understory	0.1	0.5	0.078
Canopy foliage	4.1	6.4	0.073
Overall	**31.2**	**101.5**	**<0.001**

FBAT Contact

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FBAT website: https://www.frames.gov/fbat/home

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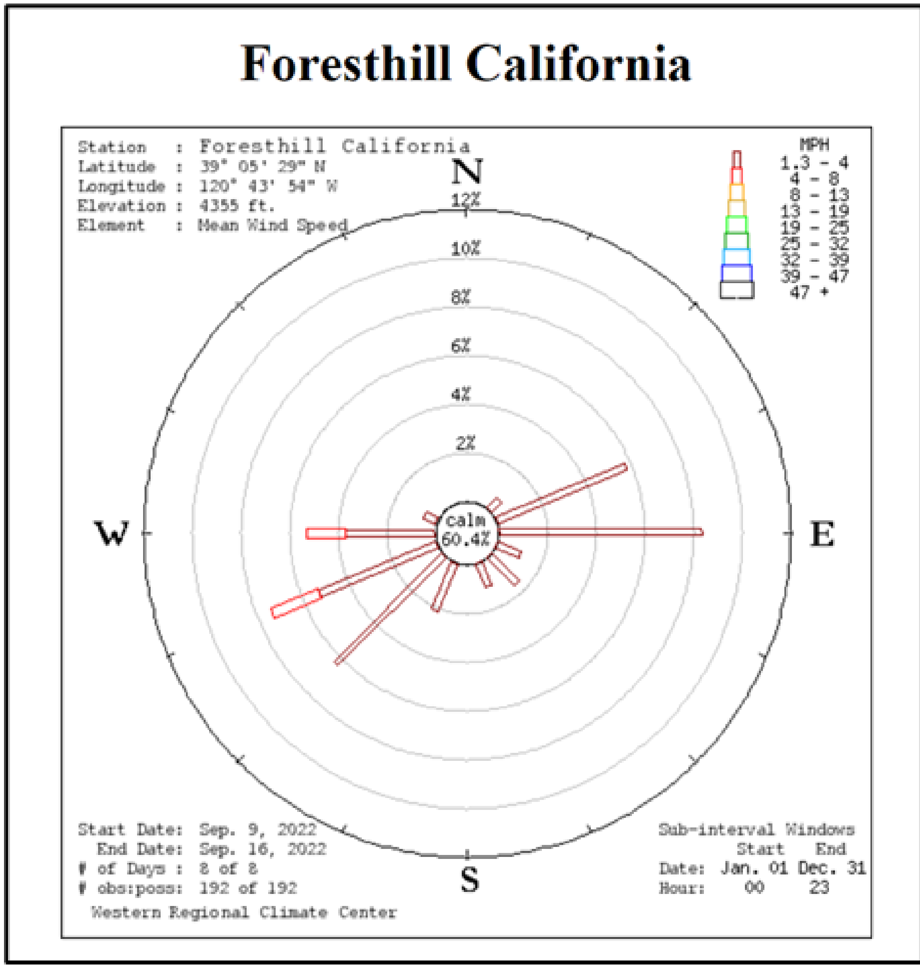
Appendix 1 - Substrate and Understory Vegetation Severity

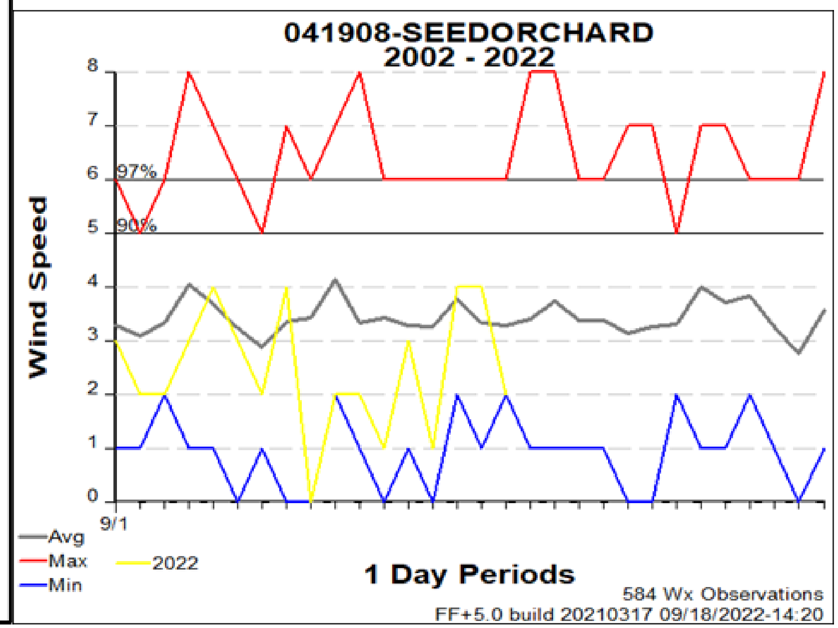
Definitions of ordinal severity levels from the NPS Fire Monitoring Handbook. NOTE: FBAT reverses the scale in data collection and reporting because its more intuitive. That is, 1 = unburned and 5 = heavily burned.

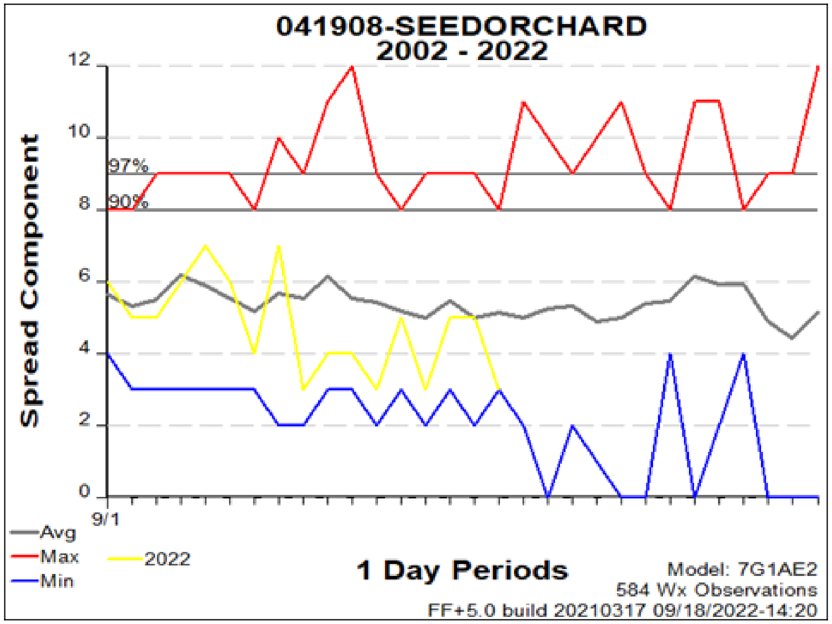
Table 28. Burn severity coding matrix.

	Forests		Shrublands		Grasslands	
	Substrate (S)	**Vegetation (V)**	**Substrate (S)**	**Vegetation (V)**	**Substrate (S)**	**Vegetation (V)**
Unburned (5)	not burned	not burned	not burned	not burned	not burned	not burned
Scorched (4)	litter partially blackened; duff nearly unchanged; wood/leaf structures unchanged	foliage scorched and attached to supporting twigs	litter partially blackened; duff nearly unchanged; wood/ leaf structures unchanged	foliage scorched and attached to supporting twigs	litter partially blackened; duff nearly unchanged; leaf structures unchanged	foliage scorched
Lightly Burned (3)	litter charred to partially consumed; upper duff layer may be charred but the duff layer is not altered over the entire depth; surface appears black; woody debris is partially burned; logs are scorched or blackened but not charred; rotten wood is scorched to partially burned	foliage and smaller twigs partially to completely consumed; branches mostly intact	litter charred to partially consumed, some leaf structure undamaged; surface is predominately black; some gray ash may be present immediately postburn; charring may extend slightly into soil surface where litter is sparse, otherwise soil is not altered	foliage and smaller twigs partially to completely consumed; branches mostly intact; less than 60% of the shrub canopy is commonly consumed	litter charred to partially consumed, but some plant parts are still discernible; charring may extend slightly into soil surface, but soil is not visibly altered; surface appears black (this soon becomes inconspicuous); burns may be spotty to uniform depending on the grass continuity	grasses with approximately two inches of stubble; foliage and smaller twigs of associated species partially to completely consumed; some plant parts may still be standing; bases of plants are not deeply burned and are still recognizable
Moderately Burned (2)	litter mostly to entirely consumed, leaving coarse, light colored ash; duff deeply charred, but underlying mineral soil is not visibly altered; woody debris is mostly consumed; logs are deeply charred, burned-out stump holes are common	foliage, twigs, and small stems consumed; some branches still present	leaf litter consumed, leaving coarse, light colored ash; duff deeply charred, but underlying mineral soil is not visibly altered; woody debris is mostly consumed; logs are deeply charred, burned-out stump holes are common	foliage, twigs, and small stems consumed; some branches (>.6–1 cm in diameter) (0.25–0.50 in) still present; 40–80% of the shrub canopy is commonly consumed.	leaf litter consumed, leaving coarse, light gray or white colored ash immediately after the burn; ash soon disappears leaving bare mineral soil; charring may extend slightly into soil surface	unburned grass stubble usually less than two inches tall, and mostly confined to an outer ring; for other species, foliage completely consumed, plant bases are burned to ground level and obscured in ash immediately after burning; burns tend to be uniform
Heavily Burned (1)	litter and duff completely consumed, leaving fine white ash; mineral soil visibly altered, often reddish; sound logs are deeply charred, and rotten logs are completely consumed. This code generally applies to less than 10% of natural or slash burned areas	all plant parts consumed, leaving some or no major stems or trunks; any left are deeply charred	leaf litter completely consumed, leaving a fluffy fine white ash; all organic material is consumed in mineral soil to a depth of 1–2.5 cm (0.5–1 in), this is underlain by a zone of black organic material; colloidal structure of the surface mineral soil may be altered	all plant parts consumed leaving only stubs greater than 1 cm (0.5 in) in diameter	leaf litter completely consumed, leaving a fluffy fine white ash, this soon disappears leaving bare mineral soil; charring extends to a depth of 1 cm (0.5 in) into the soil; this severity class is usually limited to situations where heavy fuel load on mesic sites has burned under dry conditions and low wind	no unburned grasses above the root crown; for other species, all plant parts consumed leaving some or no major stems or trunks, any left are deeply charred; this severity class is uncommon due to the short burnout time of grasses
Not Applicable (0)	inorganic preburn	none present preburn	inorganic preburn	none present preburn	inorganic preburn	none present preburn

Appendix 2 - Fire Weather and Fire Danger Indices



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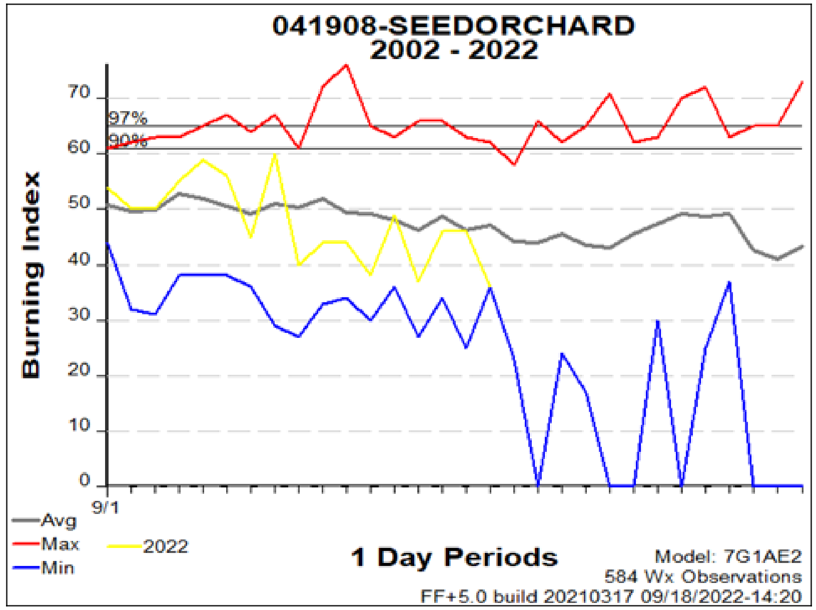
2002 - 2022
Spread Component
97%
90%
9/1
Avg
Max
Min
2022
1 Day Periods
Model: 7G1AE2
584 Wx Observations
FF+5.0 build 20210317 09/18/2022-14:20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2002 - 2022
Burning Index
97%
90%
9/1
Avg
Max
Min
2022
1 Day Periods
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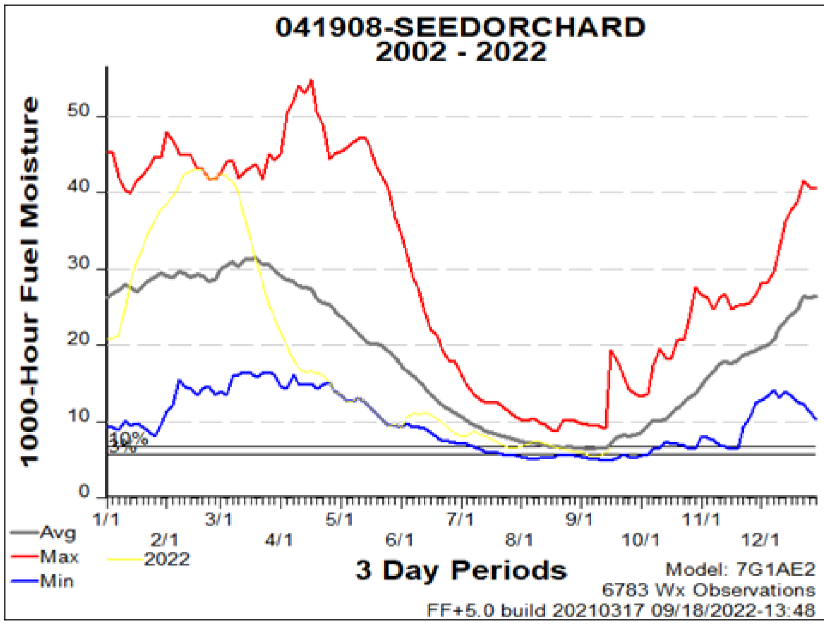
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2002 - 2022
1000-Hour Fuel Moisture
10%
3%
1/1
2/1
3/1
4/1
5/1
6/1
7/1
8/1
9/1
10/1
11/1
12/1
Avg
Max
Min
2022
3 Day Periods
Model: 7G1AE2
6783 Wx Observations
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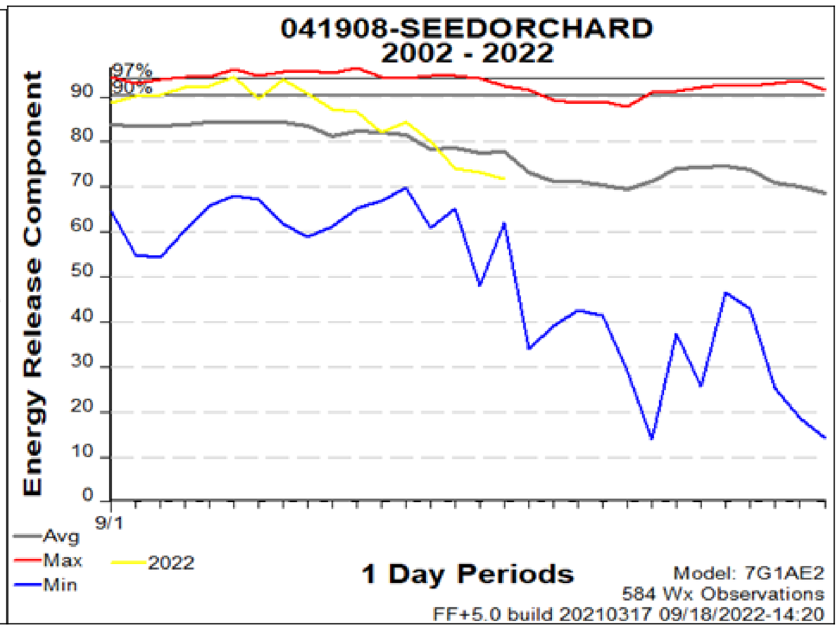
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Energy Release Component
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90%
9/1
Avg
Max
Min
2022
1 Day Periods
Model: 7G1AE2
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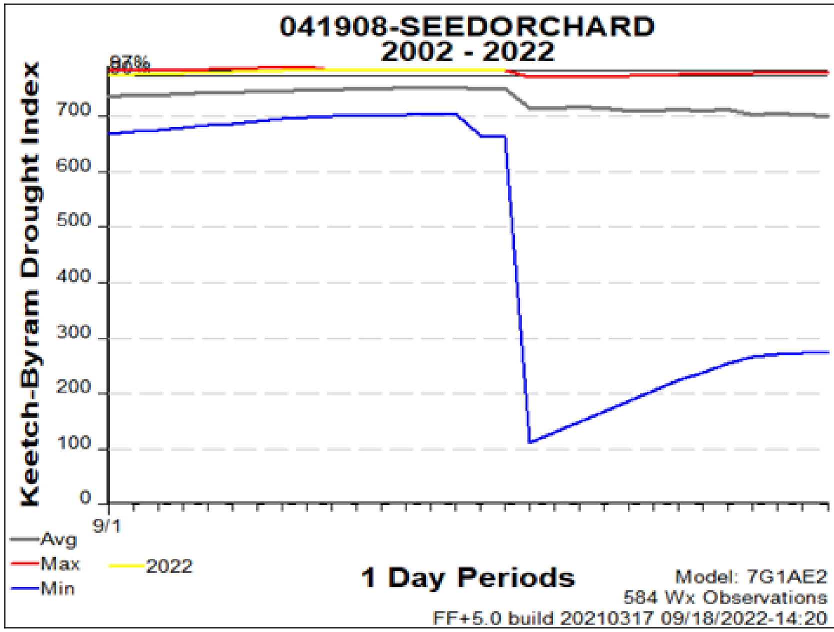
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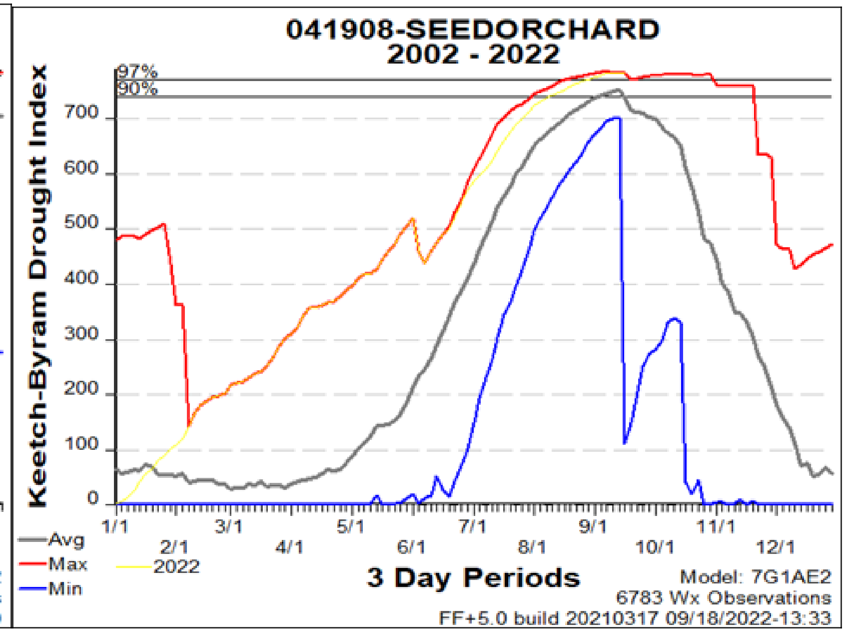
2002 - 2022
Keetch-Byram Drought Index
97%
90%
700
600
500
400
300
200
100
0
9/1
Avg
Max
Min
2022
1 Day Periods
Model: 7G1AE2
584 Wx Observations
FF+5.0 build 20210317 09/18/2022-14:20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2002 - 2022
Keetch-Byram Drought Index
97%
90%
700
600
500
400
300
200
100
0
1/1
2/1
3/1
4/1
5/1
6/1
7/1
8/1
9/1
10/1
11/1
12/1
Avg
Max
Min
2022
3 Day Periods
Model: 7G1AE2
6783 Wx Observations
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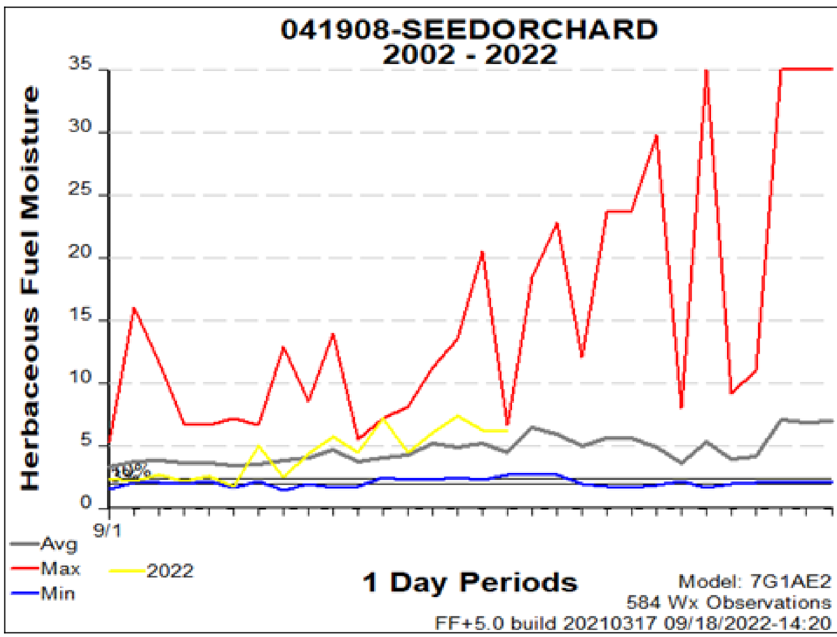
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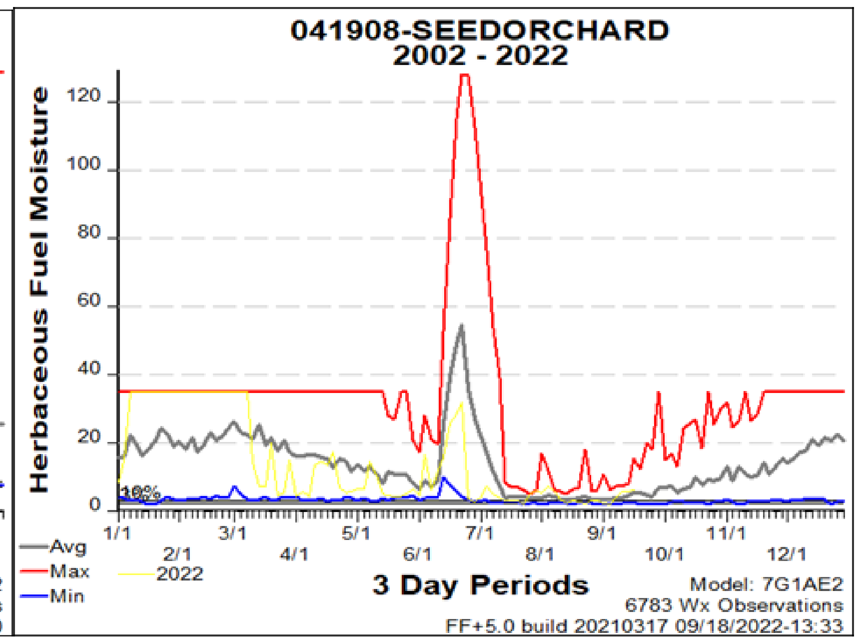
2002 - 2022
Herbaceous Fuel Moisture
35
30
25
20
15
10
5
0
9/1
Avg
Max
Min
2022
1 Day Periods
Model: 7G1AE2
584 Wx Observations
FF+5.0 build 20210317 09/18/2022-14:20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2002 - 2022
Herbaceous Fuel Moisture
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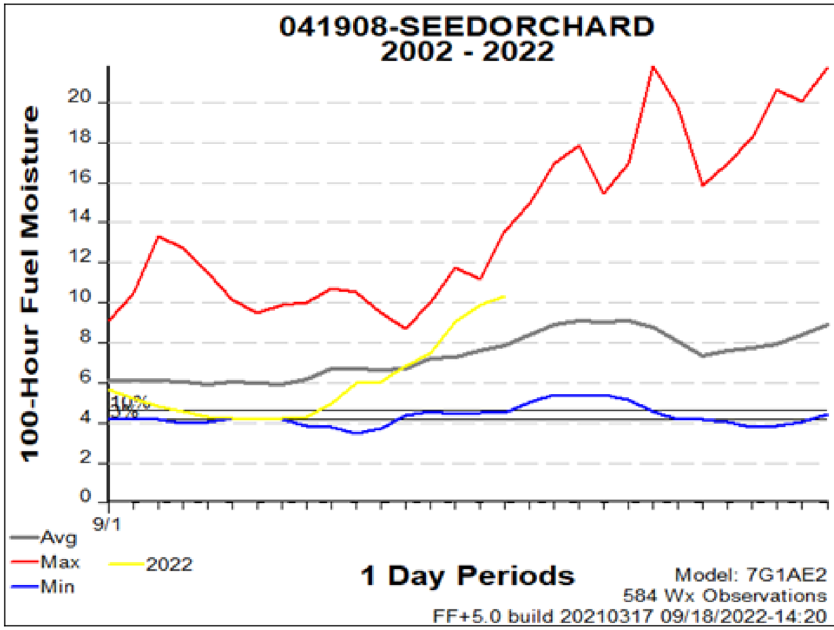
100
80
60
40
20
0
1/1
2/1
3/1
4/1
5/1
6/1
7/1
8/1
9/1
10/1
11/1
12/1
Avg
Max
Min
2022
3 Day Periods
Model: 7G1AE2
6783 Wx Observations
FF+5.0 build 20210317 09/18/2022-13:33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2002 - 2022
100-Hour Fuel Moisture
9/1
Avg
Max
Min
2022
1 Day Periods
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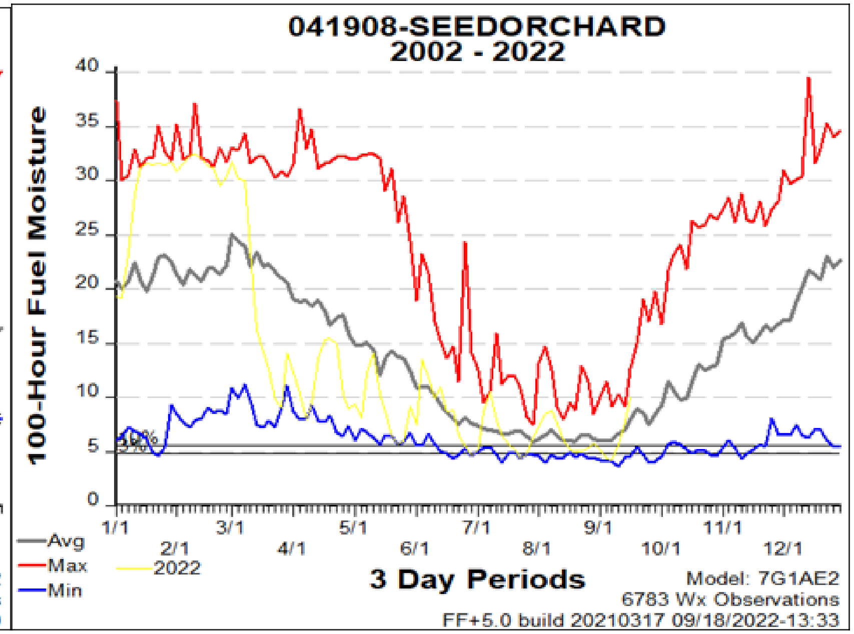
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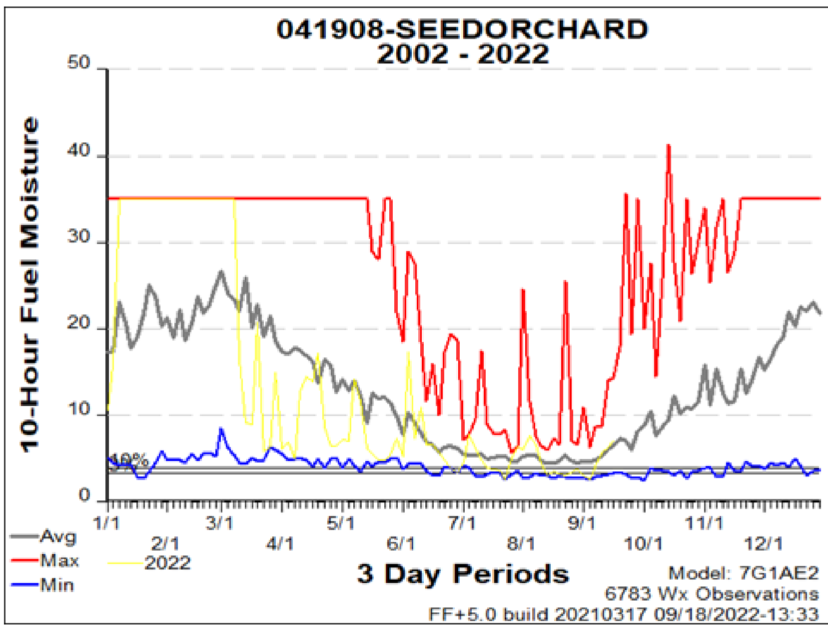
2002 - 2022
100-Hour Fuel Moisture
1/1
2/1
3/1
4/1
5/1
6/1
7/1
8/1
9/1
10/1
11/1
12/1
Avg
Max
Min
2022
3 Day Periods
Model: 7G1AE2
6783 Wx Observations
FF+5.0 build 20210317 09/18/2022-13:33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2002 - 2022
10-Hour Fuel Moisture
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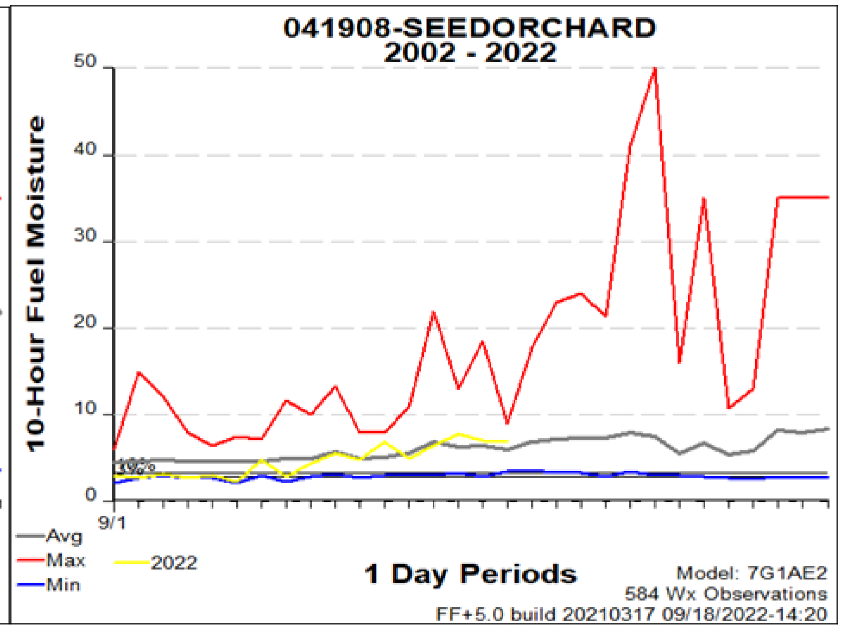
3/1
4/1
5/1
6/1
7/1
8/1
9/1
10/1
11/1
12/1
Avg
Max
Min
2022
3 Day Periods
Model: 7G1AE2
6783 Wx Observations
FF+5.0 build 20210317 09/18/2022-13:33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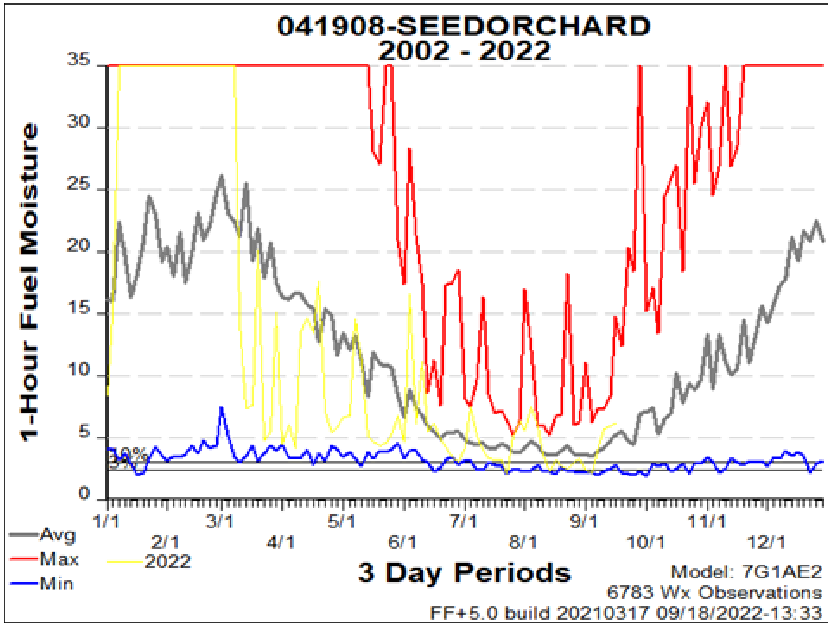
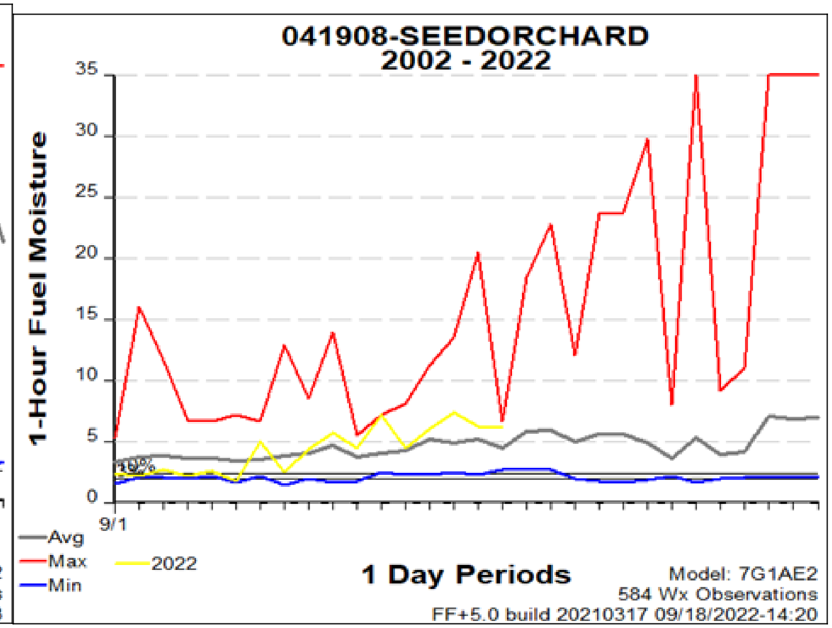
2002 - 2022
10-Hour Fuel Moisture
9/1
Avg
Max
Min
2022
1 Day Periods
Model: 7G1AE2
584 Wx Observations
FF+5.0 build 20210317 09/18/2022-14:20


041908-SEEDORCHARD
2002 - 2022
1-Hour Fuel Moisture
35
30
25
20
15
10
5
0
10%
3%
1/1
2/1
3/1
4/1
5/1
6/1
7/1
8/1
9/1
10/1
11/1
12/1
Avg
Max
Min
2022
3 Day Periods
Model: 7G1AE2
6783 Wx Observations
FF+5.0 build 20210317 09/18/2022-13:33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2002 - 2022
1-Hour Fuel Moisture
35
30
25
20
15
10
5
0
10%
9/1
Avg
Max
Min
2022
1 Day Periods
Model: 7G1AE2
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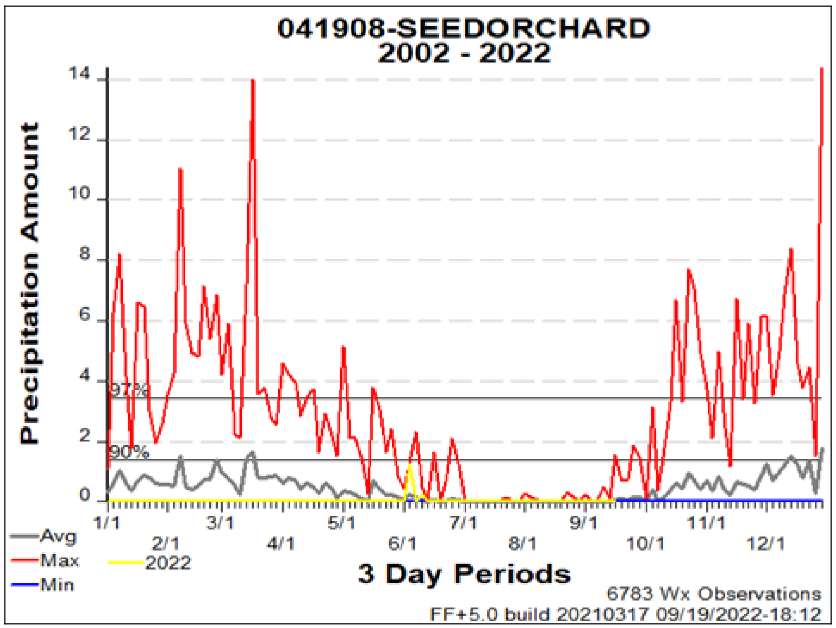
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2002 - 2022
Precipitation Amount
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12
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6
4
2
0
97%
90%
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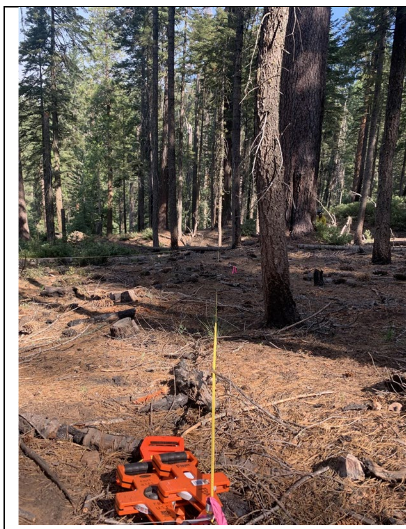
2/1
3/1
4/1
5/1
6/1
7/1
8/1
9/1
10/1
11/1
12/1
Avg
Max
Min
2022
3 Day Periods
6783 Wx Observations
FF+5.0 build 20210317 09/19/2022-18:12

Appendix 3: Pre- and Post-fire Plot Photographs

		
Plot 1 Transect 1, 50-0 Pre	Plot 1 Transect 2, 50-0 Pre	Plot 1 Transect 3, 50-0 Pre

		
Plot 2 Transect 1, 50-0 Pre	Plot 2 Transect 2, 50-0 Pre	Plot 2 Transect 3, 50-0 Pre

		
Plot 3 Transect 1, 50-0 Pre	Plot 3 Transect 2, 50-0 Pre	Plot 3 Transect 3, 50-0 Pre

		
Plot 4 Transect 1, 50-0 Pre	Plot 4 Transect 2, 50-0 Pre	Plot 4 Transect 3, 50-0 Pre

		
Plot 5 Transect 1, 50-0 Pre	Plot 5 Transect 2, 50-0 Pre	Plot 5 Transect 3, 50-0 Pre

		
Plot 6 Transect 1, 50-0 Pre	Plot 6 Transect 2, 50-0 Pre	Plot 6 Transect 3, 50-0 Pre

		
Plot 7 Transect 1, 50-0 Pre	Plot 7 Transect 2, 50-0 Pre	Plot 7 Transect 3, 50-0 Pre

		
Plot 8 Transect 1, 50-0 Pre	Plot 8 Transect 2, 50-0 Pre	Plot 8 Transect 3, 50-0 Pre

Plot 9 Transect 1, 50-0 Pre

Plot 9 Transect 2, 50-0 Pre

Plot 9 Transect 3, 50-0 Pre

Plot 10 Transect 1, 50-0 Pre

Plot 10 Transect 2, 50-0 Pre

Plot 10 Transect 3, 50-0 Pre