2013 Aspen Fire
Sierra National Forest

Fire Behavior Assessment Team Summary Report

Active fire picture captured from video taken at Plot 4, below the 7S05G Road off of Stump Springs Road. Two four-foot tall reference poles are visible.

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Introduction
Wildland fire management is dependent upon good fire behavior and resource effects predictions. Existing prediction models are based upon limited data from wildfire in the field, especially quantitative data. The Fire Behavior Assessment Team (FBAT) collects data to improve our ability to predict fire behavior and resource effects in the long-term and provides short-term intelligence to the wildland fire managers and incident management teams on fire behavior, fuel, and effects relationships. Increasing our knowledge of fire behavior is also important to fire fighter safety; the more we know the more we can mitigate hazards and prevent accidents, as well as making steps towards improvement in natural resource management.

This report contains the results of a one week assessment of fire behavior, vegetation and fuel loading and consumption, and fire effects to vegetation and soil resources for Division D that evolved to be Division F on the Aspen fire. The Aspen fire started by lightning on July 22th, 2013 below Stump Springs Road north of Aspen Springs on the Sierra National Forest in the vicinity of the San Joaquin River between Huntington Lake and Mammoth Pool Reservoir and west and north of the Kaiser Wilderness on the High Sierra Ranger District. Fire behavior, pre- and post-vegetation and fuel conditions were measured at six sites nearby Stump Springs Road from July 26 to August 4, 2013. Fuel Moisture samples were gathered in one area on Division D/F and processed at the District Office. The Calaveras Wildland Fire Module joined and trained with FBAT on fire behavior equipment and fuels/vegetation inventory techniques and were utilized throughout the Aspen Fire during FBAT efforts and for other incident objectives.

Objectives
Our objectives were to:

1. Characterize fire behavior and quantify fuels for a variety of fuel conditions. A key consideration was which sites could be measured safely given access and current fire conditions.
2. Gather and measure representative vegetation and fuel samples to calculate moisture content to support emission and fire behavior modeling.
3. Assess fire severity and effects at the study sites based on immediate pre- and post-fire fuel and vegetation measurements.
4. Cross-train and work with the STF Calaveras Wildland Fire Module during the field study, as well as collaborate with Regional and Washington Office level ecologists as available.
5. Produce a summary report based on preliminary analysis for fire managers and the Sierra National Forest.

Applications
This information will be shared with managers to evaluate the behavior and effects of the Aspen fire, to inform future land and resource management planning objectives, to calibrate modeling outputs, or for comparison during future fire decision making. The information from the Aspen fire (and the entire growing FBAT dataset) is also valuable when shared with: firefighters to improve situational awareness; managers to improve predictions for future fire and silviculture planning; and scientists for improving emissions and/or fire behavior modeling.

Video from two of the FBAT sites with daytime burning were used in the PSW Region video podcast series on ecological restoration released in December 2013: http://www.fs.usda.gov/detail/r5/news-events/audiovisual/?cid=stelprdb5443943

Approach/Methods

FBAT selects study sites to represent a variety of fire behavior and vegetation/fuel conditions. Site selection priorities are also based on safe access and areas that would most likely be burned over within the timeframe that FBAT was at the incident. Within each site, data is gathered on both fuels and fire behavior (Figure 1). Pre- and post-fire fuels and fire behavior measurements were taken at six sites near Stump Springs Road between July 26 and Aug. 4, 2013 within what was called Division D (later called Div. F) of the Aspen fire. The map (Figure 2) displays daily fire progression and approximate site locations.

Figure 1: Schematic of FBAT fuels and fire behavior site set up. Flame symbol is randomly located.

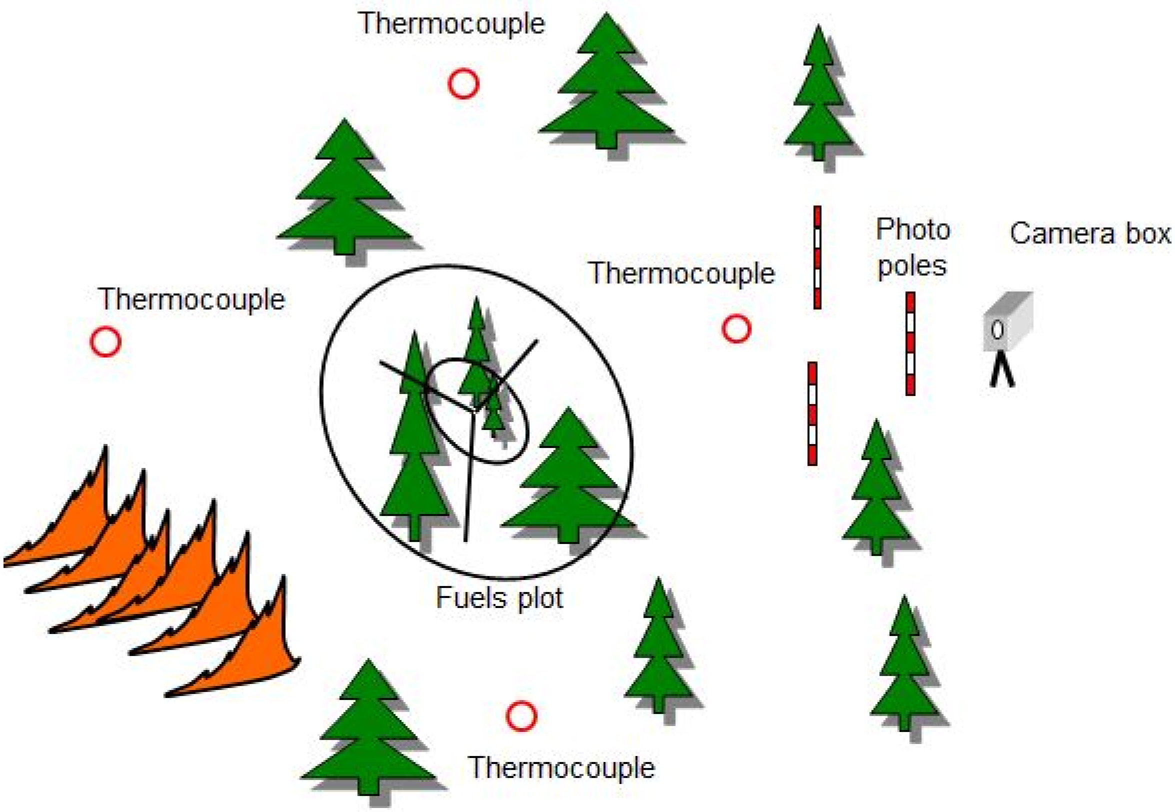
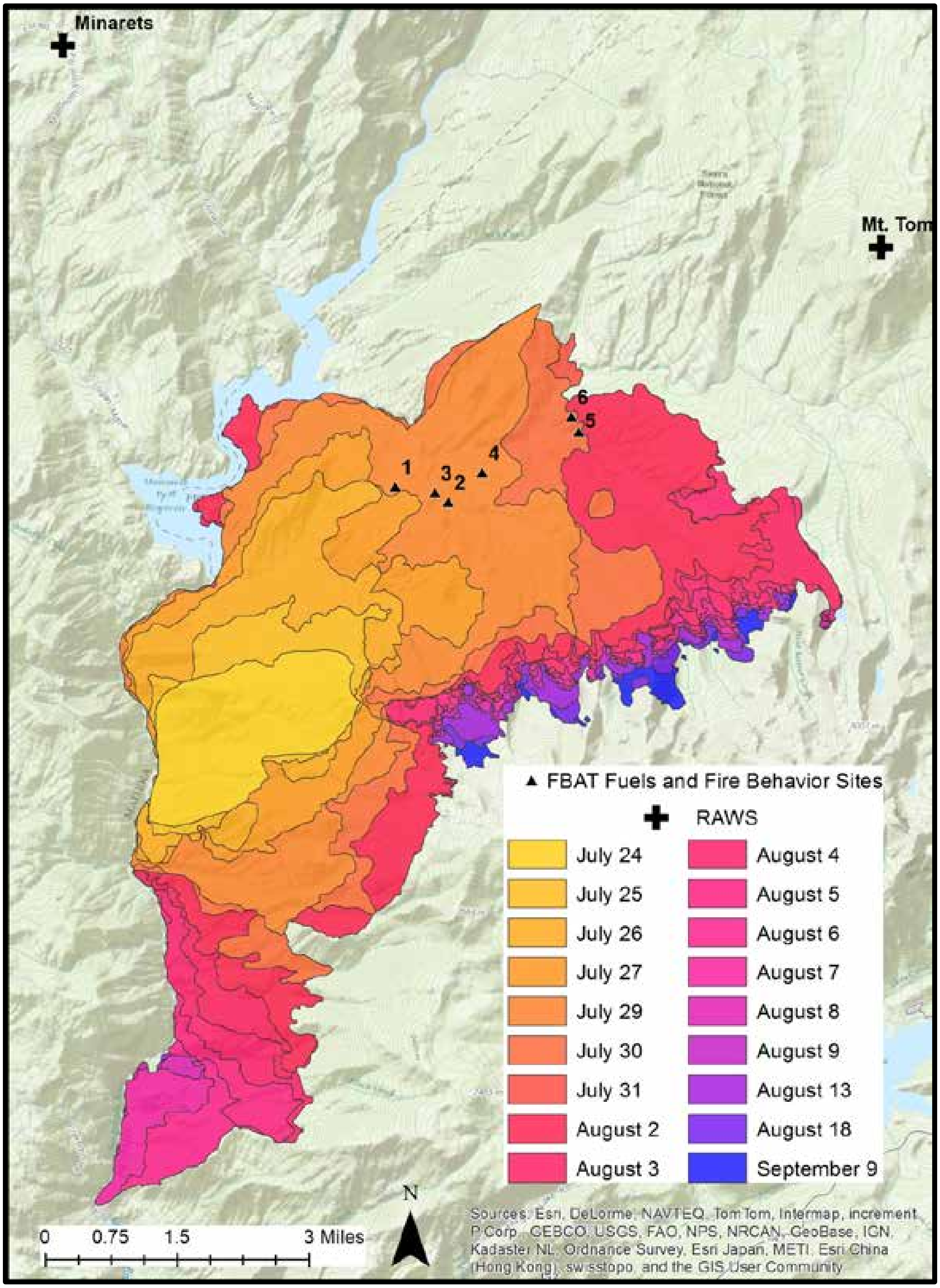


Figure 2: Fire progression, RAWS location, and location of FBAT fuels and fire behavior sites in the Aspen fire. Note the progression date does not always match the date we captured fire behavior due to green islands burning and the time of day of infra-red mapping.



Pre- and Post-Vegetation and Fuel Measurements

Vegetation and fuels were inventoried both before the fire reached each site and then again after the fire.

Figure 3: Example of vegetation and fuel data collection pre- and post-burn at Site 2.

Crown Fuels and Overstory Vegetation Structure

Variable radius sub-plots were used to characterize crown fuels and overstory vegetation structure. A relescope (slope corrected tree prism) was used to create individual plots for both pole (>2.5 to 5.9 inch diameter at breast height (DBH) and overstory (>6 inch DBH) trees. When possible, a prism factor was selected to include between 5 and 10 trees for each classification. Tree species, status (alive or dead), DBH, height, canopy base height, and crown classification (dominant, co-dominant, intermediate or suppressed) was collected for each tree before the fire. Tree height measurements were completed with a laser rangefinder; DBH was measured with a diameter tape.

After the, maximum bole char, scorch, and torch heights and percentages were recorded for each tree. Trees were assumed to be live if any green needles were present. Changes in canopy base height were estimated from the percent scorch (cooked) and torch (consumed) values rather than the maximum heights because of uneven values that were affected by slope and tree alignment with heat. Due to smoke and poor lighting, visibility of a full tree crown was sometimes difficult. If a potentially more accurate assessment of tree survivorship in the plots is desired, we recommend another site visit the following year.

The Forest Vegetation Simulator program (FVS, Crookston and Dixon 2005) and its Fire and Fuels Extension (FFE-FVS, Rebain 2010) was used to calculate canopy bulk density, canopy base height, tree density, and basal area both pre- and post-fire. FVS/FFE-FVS is a stand level growth and yield program used throughout the United States. The Western Sierra variant was used for all calculations.

Understory Vegetation Structure and Loading

Understory vegetation was measured in a one meter wide belt along three 50-foot transects before and after the fire at each site. The fuel and vegetation transects were in view of the video camera (described below in the "Fire Behavior Measurements and Observations" section). Species, average height and percent cover class and density category (based on an ocular estimation) were recorded for all understory shrubs, grasses and herbaceous plants, and seedlings. Biomass of live woody fuels (shrubs and seedlings) and live herbaceous fuels (grasses, herbs, subshrubs) were estimated using coefficients developed for the Behave Fuel Subsystem (Burgan and Rothermel 1984), but calculations were done on a spreadsheet (Scott 2005). See Appendix D for a comparison of two calculations for estimated understory vegetation loading based on FIREMON (Lutes et al. 2006) and Behave Fuel Subsystem.

Surface and Ground Fuel Loading

Surface and ground fuels were measured along the same three 50-foot transects as the understory vegetation at each site. Surface (litter, 1-hr, 10-hr, 100-hr and 1000-hr time lag fuel classes and fuel height) and ground (duff) fuels were measured using the line intercept method (Brown 1974, Van Wagner 1968). One and 10-hr fuels were tallied from 0 to 6 ft, 100-hr from 0 to 12 ft and 1000-hr from 0 to 50 ft. Maximum fuel height was recorded from 0 to 6 ft, 6 to 12 ft and 12 to 18 ft. Litter and duff depths were measured at 1 and 6 ft. All measurements were taken both pre- and post-fire.

The measurements were used to calculate surface and ground fuel loading with basal area weighted species specific coefficients (van Wagtendonk et al. 1996; 1998) and ultimately percent fuel consumption.

Fuel Moisture Sampling

Prior to the fire, fuel moisture samples are collected from live understory vegetation, low live needles, litter, and 1000-hr fuels. The samples are then dried in an oven for a minimum of 24 hours to determine their moisture content.

Burn Severity

A rapid assessment of burn severity was completed along each transect and for the entire site area to document the effects of fire on the surface and ground (USDI National Park Service 2003). The National Park Service (NPS) uses fire severity ratings from 1 to 5 when evaluating fire severity. In this rating system, 1 represents high fire severity, while 5 represents unburned areas (Appendix B).

Fire Behavior Measurements and Observations

At each site, multiple sensors and a video camera were set up to gather information on fire behavior. The camera is positioned to capture the overall site and to face the direction the fire will likely come from. The sensors include the capability to capture, from any direction of fire spread, the date and time of temperature and heat duration to calculate rate of spread. The sensors are described in more detail below. The video camera is used to determine fire type, flame length, variability and direction of rate of spread and flame duration.

Figure 4: Example of fire behavior equipment set up at the Aspen fire at Site 2 in a mixed conifer dominated area.

Rate of Spread and Temperature

Rate of spread was determined by video analysis and rate of spread sensors (MadgeTech data loggers with a thermocouple attached). The data loggers are buried underground with the thermocouple at the surface of the fuel bed. The thermocouple is able to record temperature up to six days or until thermocouple is damaged by heat. The distance and angle between data loggers were measured to utilize the Simard et al. (1984) method of estimating rate of spread using geometry.

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 was determined from video as well as post-fire effects at each site. For example, sites where there was complete consumption of tree canopy needles indicated tree torching or passive crown fire.

Flame Length and Flaming Duration

Flame length was primarily determined from video footage. If needed, flame length values could be supplemented by tree char height. Flaming duration was based on direct video observation and/or when temperature was measured from sensors l.

Weather

Weather data was downloaded from two permanent Remote Automated Weather Stations (RAWS), Minarets and Mt. Tom (Figure 1) from FAMWEB. RAWS data includes hourly recordings of relative humidity, temperature, wind speed, and wind direction throughout the fire's duration. The energy release component (ERC) values were derived from the gathered data using Fire Family Plus. Incident and local Sierra NF staff provided feedback that the permanent RAWS (Mt. Tom and Minarets) in the fire vicinity were adequate for all readings, *except* that the canyon winds experienced on the fire were not captured well on these RAWS. These two permanent RAWS were used for fire behavior predictions. Two additional portable RAWS were set-up in the canyon itself to get a better idea of the winds influencing the fire, since neither of the permanent RAWS was accurately capturing the diurnal winds that were occurring during/within the fire.

Findings/Results

Fuels and fire behavior data were successfully collected at six sites. The six sites represented different forest/vegetation types (Table 1). Paired photographs of all the sites are available in Appendix A.

Table 1: Description of the six sites.

Site	Forest/Vegetation Type	Slope (%)	Aspect
1	Ponderosa pine plantation	11	NW
2	Sierra mixed conifer in Riparian Conservation Area*	23	NE
3	Manzanita dominated montane shrubland	37	N
4	Sierra mixed conifer adjacent to Riparian Conservation Area*	55	NW
5	Sierra mixed conifer in Riparian Conservation Area*	30	W
6	Sierra mixed conifer	18	S

*sites located near streams in designated Riparian Conservation Areas (pers. comm. Ballard 2014)

Pre- and Post-Vegetation and Fuel Measurements

Overstory Vegetation Structure and Crown Fuels

This FBAT case study is sized to establish some trends based on the site level data collected, but some generalizations are made about the change in canopy characteristics overall. 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). Canopy base height is important because it affects crown fire initiation. Continuity of canopies is more difficult to quantify, but patchiness of the canopy will reduce the spread of fire within the canopy stratum. The data summary listed in Table 2 provides a snapshot of stand characteristics for some areas of Division D (later area was part of Div. F) on the Aspen fire.

Forest treatments that target canopy base height and canopy bulk density can be implemented to reduce the probability of crown fire (Graham et al. 2004). Canopy bulk density varies considerably within the stands summarized above, and reaches a maximum value of 0.35 kg/m^3 at Sites 2 and 5. Thinning to reduce canopy bulk density to less than 0.1 kg/m^3 is generally recommended to minimize crown fire hazard (Agee 1996, Graham et al. 1999), and for the most part, below this point, active crown fire is difficult to achieve (Scott and Reinhardt 2001). Fire is a natural process, or reduction method, for reducing canopy fuels. Tree mortality and canopy fuel changes cannot be determined with certainty until one or more years post-fire due to delayed mortality effects and tree recovery rates.

Tree species within the six sites included: ponderosa pine, sugar pine, white fir, incense cedar, and California black oak. Pre- and post-fire tree metrics are presented in Table 2.

Table 2: Pre- and post-fire overstory vegetation and crown fuel data by site. QMD is the quadratic mean diameter based on tree data collected at the site scale.

Site	Overstory (>6 in DBH) trees/acre		Pole-size (<6 in DBH) trees/acre		QMD (in)		Basal Area (ft²/acre)		Canopy Cover (%)		Canopy Height (ft)		Canopy Base Height (ft)		CBD (kg/m³)	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
1	302	302	207	207	8	8	180	180	65	65	56	56	4	4	0.18	0.18
2	323	21	299	63	11	10	419	44	81	21	76	58	8	89	0.35	0.01
3	5	5	0	0	18	18	9	9	4	4	58	58	18	18	0.01	0.01
4	121	0	194	0	14	0	327	0	73	0	112	0	8	0	0.10	0
5	440	440	123	90	13	14	532	527	82	81	86	86	2	8	0.35	0.35
6	332	332	270	270	9	9	246	246	68	68	80	80	4	4	0.17	0.17

FVS -Stand Visualization System (SVS) graphics based on site level data

Based on field visits and immediate post-fire satellite imagery, sites 1, 3, 5, and 6 only had low to moderate overstory vegetation severity effects, such as modeled by stand graphics in FVS-SVS (figure 5). Sites 2 and 4 had moderate to severe overstory vegetation severity (figure 6). A known deficiency in FVS-FFE modeling is the amount of understory vegetation, which is a fixed amount that the user cannot adjust, and can poorly represent some areas (e.g., site 1). FVS-SVS is not meant for shrub-dominated sites, like site 3. Graphics for each of the six sites are in Appendix B.

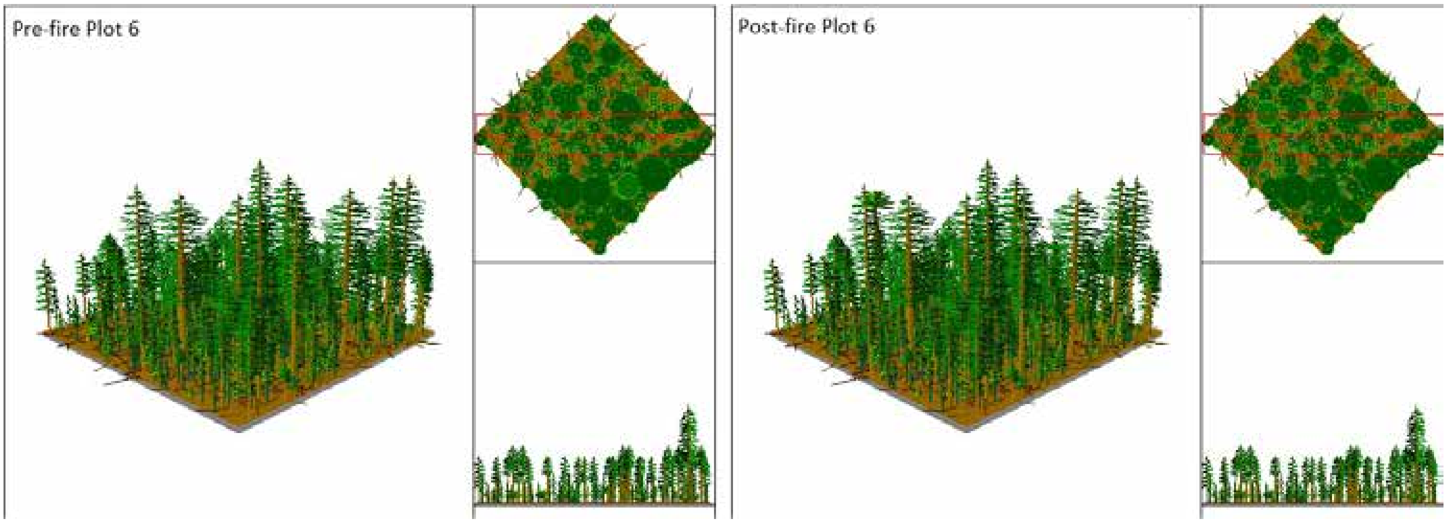


Figure 5. FVS-SVS graphic of site 6 in a Sierra mixed conifer stand, as example of low to moderate overstory vegetation severity.

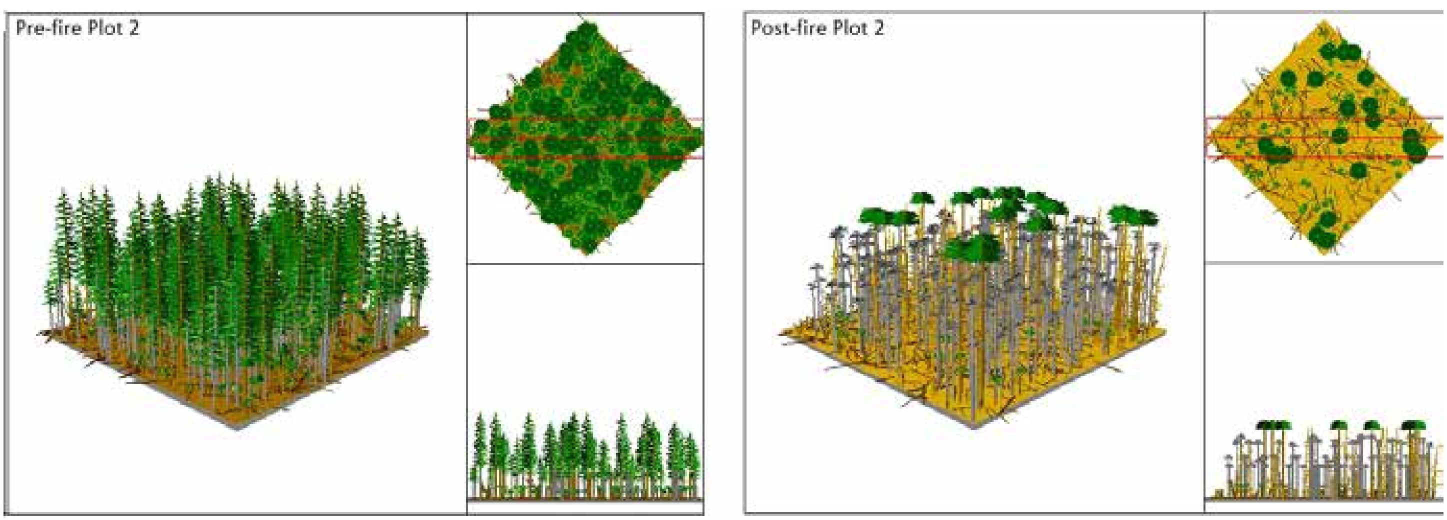


Figure 6. FVS-SVS graphic of site 2 in a Sierra mixed conifer stand in a Riparian Conservation Area, as example of moderate to high overstory vegetation severity.

Fire Effects: Tree Canopy Scorch and Torch

A few days after the fire burned through each site (allow for cooling, safety, and smoldering combustion) additional measurements were gathered (char height, maximum scorch and torch heights, and percentage of the crown scorched and torched) to better assess the fire effects at each site. Percentage values were determined using ocular estimations, and heights were measured with a laser rangefinder. Severity or fire effects can be accessed from the percentage of scorch and torch for each study site (Table 3). The fire had scorched (cooked) portions of most tree canopies, but only torched (consumed) portions of a few tree canopies.

Table 3: Overstory canopy average, minimum and maximum percent scorch and torch at each site.

Site	% Scorch			% Torch		
	Average	Min	Max	Average	Min	Max
1	5	0	20	0	0	0
2	99	90	100	54	0	100
3	<1	0	1	0	0	0
4	100	100	100	45	0	100
5	0	0	0	0	0	0
6	5	0	80	0	0	0

Understory Vegetation Structure and Loading

The understory vegetation was sparse to patchy. Very few grasses or herbaceous species were found at any of the sites (Table 4). Sites 1 and 3 had the highest pre- and post-fire shrub/seedling load (Table 4). Dominant shrubs present at the sites included, manzanita, ceanothus, and chinquapin species. Some shrubs were burned down to stobs (shrub stumps, Table 5). At Sites 1, 2, and 4 the herbaceous and grass understory component was completely consumed by the fire (Table 6). An increase in dead understory vegetation occurred as a result of the fire at site 5. The paired photographs in Appendix A show a sample of the distribution and density of understory flora for each site, as well as illustrate the change post-burn. See Appendix D for a comparison of two different calculations for estimated understory vegetation loading.

Table 4: Pre- and post-fire average understory vegetation loading by site based on Burgan and Rothermel (1984).

Site	Grass/Herb (ton/ac)						Shrub/Seedling (ton/ac)					
	Live pre-fire	Live post-fire	Dead pre-fire	Dead post-fire	Total pre-fire	Total post-fire	Live pre-fire	Live post-fire	Dead pre-fire	Dead post-fire	Total pre-fire	Total post-fire
1	0.0011	0	0.0004	0	0.0014	0	4.454	3.396	1.110	2.164	5.563	5.560
2	0.0002	0	0	0	0.0002	0	0.045	0	0.370	0	0.062	0
3	0.0002	0.0002	0.0001	0.0001	0.0003	0.0002	7.199	6.480	0.801	1.519	7.999	7.999
4*	0.0008	0	0.0001	0	0.0009	0	0.016	0	0	0	0.016	0
5*	0.0003	0.0001	0.0001	0.0002	0.0005	0.0004	0.032	0.004	0.022	0.028	0.055	0.032
6	0.0006	0	0.0003	0	0.0010	0	0.342	0.110	0.039	0.238	0.381	0.347

*Site 5 comparison is just 1 transect of herbs/grasses (vs. 3 transects). Site 4 is just 1 transect (vs. 3 transects).

Table 5: Average height pre-and post-fire for grass/herb and shrubs by site.

Site	Grass/Herb Height (ft)		Shrub/Seedling Height (ft)	
	Pre	Post	Pre	Post
1	0.3	0	4.5	4.3
2	0.2	0	1.9	0
3	0.3	0.2	2.4	2.3
4	0.8	0	3.3	0
5	0.2	0.2	2.1	1.0
6	0.4	0	1.8	1.2

Table 6: Average understory vegetation consumption based on total fuels (table 5) and Burgan and Rothermel (1984).

Site	Consumption (%)	
	Grass/Herb	Shrub
1	<1	<1
2	<1	6
3	<1	<1
4	<1	2
5	<1	2
6	<1	3

Surface and Ground Fuel Loading

The predominant fuels were litter and duff with the exception of Site 2 which had a high 1000-hr fuel load prior to the fire (Table 7). All sites had a 1000-hr fuel size component, even the manzanita dominated site (Site 3). The fuel bed depth ranged from a few inches to up to foot.

Table 7: Average pre-and post-fire fuel loading and fuel bed depth by site.

Site	Fuel Loading (tons/acre)														Fuel Bed Depth (ft)	
	Duff		Litter		1-hr		10-hr		100-hr		1000-hr		Total			
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
1	11.5	2	1.2	0.2	0	0	0	0.1	0.7	0.7	0.2	0.2	13.6	3.2	0.2	0.1
2	26.4	0	10.2	0	0.4	0	0.6	0	1.2	0.3	110.6	2.3	149	2.6	1	0.1
3	10.1	6.7	3	1.8	0.1	0.1	0.1	0.4	1.7	0.3	3.4	2.2	18.4	11.6	0.6	0.3
4	30.3	0	15.8	0	0	0.1	0	0	1.6	0.5	15.4	5.1	63.1	5.8	0.3	0
5	23.1	0	15.5	4.3	0.3	0	0.7	0.2	3.3	0.3	18.5	1.4	44.4	18.5	0.6	0.3
6	37.8	0	10.1	0	0	0	0.7	0.1	0	0	1.6	0	43	0.4	0.2	0.1

Notes: Plot 4 only had two transects pre-fire otherwise all other values are based on an average of three transects.
Fuel loads may be higher after fire because post-fire woody material burned to smaller size classes.
The values presented for total loading per site are an average of three transects and not a sum of the average values listed for each category.

Consumption varied both by fuel category and site (Table 8). Site 3 had the lowest total consumption (37%) and Sites 2 and 5 the highest (98 and 99% respectively). Although it appears as though there was higher consumption in duff than litter for Site 5, this was the average for only where the data captured duff. We captured more litter than duff at this site. Litter and other woody debris do begin to accumulate within a site after the fire burns through, and sometimes before FBAT was able to complete the re-measurements, but post-fire fuels recruitment is not counted during the immediate post-fire site visit. Increases are seen in the 1-hr and 10-hr fuels in Sites 1, 3, and 4, which is sometimes caused by partial consumption of a 100-hr or bigger fuel that post-fire is counted in the 1-hr or 10-hr size class or by slight movement of woody material by slope or other fuels changing structure (e.g., a shrub branch is burnt off and lies across the transect post-fire).

Table 8: Fuel consumption by class and site.

Site	Consumption in tons/acre (%)							Change in Fuel Bed Depth in ft (%)
	Duff	Litter	1-hr	10-hr	100-hr	1000-hr	Total	
1	9.5 (83)	1 (83)	0 (0)	-0.1 (N/A)	0 (0)	0 (0)	10.4 (76)	0.1 (50)
2	26.4 (100)	10.2 (100)	0.4 (100)	0.6 (100)	0.9 (75)	108.3 (98)	146.7 (98)	0.9 (90)
3	3.4 (34)	1.2 (40)	0 (0)	-0.3 (-300)	1.4 (82)	1.2 (35)	6.8 (37)	0.3 (50)
4	30.3 (100)	15.8 (100)	-0.1 (N/A)	0 (0)	1.1 (69)	10.3 (67)	57.3 (91)	0.3 (100)
5	23.1 (100)	11.2 (72)	0.3 (100)	0.5 (71)	3 (91)	17.1 (92)	25.9 (58)	0.3 (50)
6	37.8 (100)	10.1 (100)	0 (0)	0.6 (86)	0 (0)	1.6 (100)	42.6 (99)	0.1 (50)

N/A: Not possible to calculate the percent consumption because fuel loading was zero pre-fire.
- Increase in fuel loading for the given site and metric.

Soil, Substrate, and Vegetation Burn Severity Rating

The National Park Service's severity categories were used to assess post-burn soil/substrate and understory vegetation severity along each transect and for the entire site. Vegetation burn severity is only based on the vegetation that was documented pre-burn. Figures 7 and 8 show the site level estimates. For full descriptions of the categories, please see Appendix B.

Figure 7: Post-fire surface soil (substrate) severity rating by site.

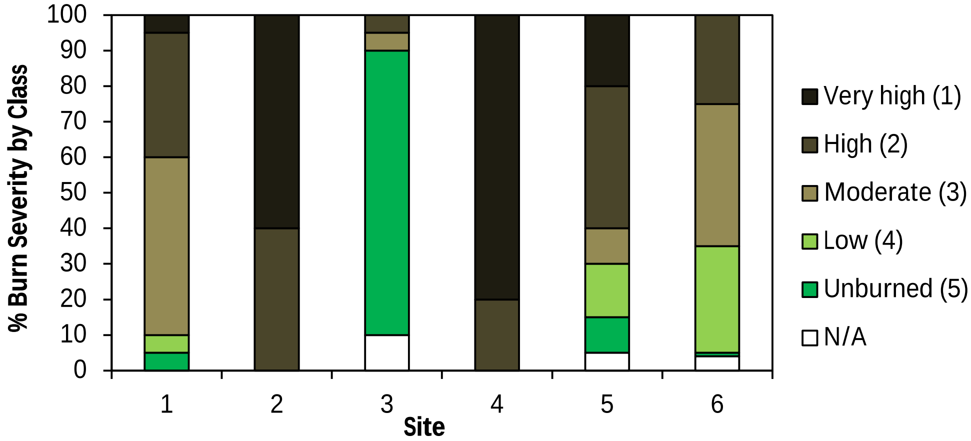
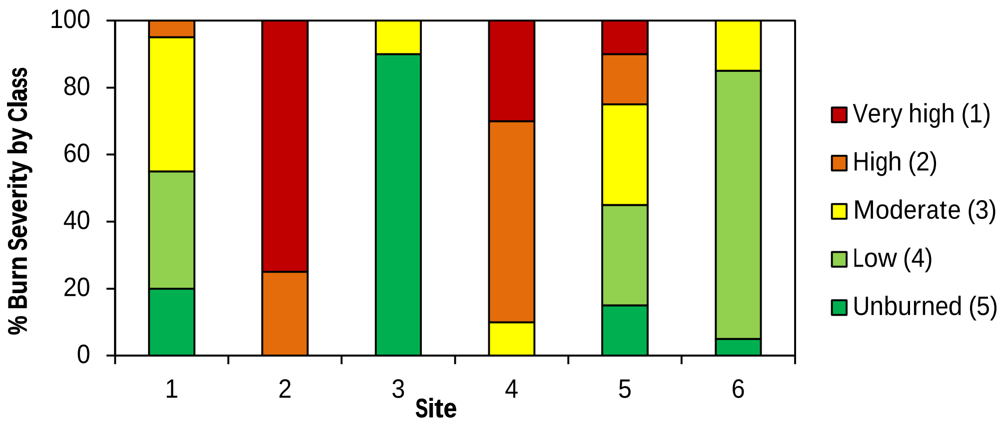


Figure 8: Post-fire understory vegetation severity rating by site.



Fuel Moisture Measurements

Fuel moisture samples were taken on July 28, 2013 at the West Kaiser Campground. Woody material and leaf samples were taken from manzanita, live needles were sampled from white fir and ponderosa pine, and 1000-hr fuels were sampled for ponderosa pine and sugar pine. Fuel moisture values for all samples are listed in Appendix C.

Table 9. Average fuel moisture data from samples collected at the West Kaiser Campground.

Plant Species	Fuel Type	Average Fuel Moisture (%)
Manzanita	woody	45
	leaves	112
White fir	needles	125
Ponderosa pine	needles	124
	1000-hr	13
Sugar pine	1000-hr	10

In addition, a woody fuel probe (the kind used by lumber mills) was used to sample 1000-hr fuels from both ponderosa pine and sugar pine and the moisture ranged from 9 to 11percent. Duff moisture was read by a Campbell duff moisture meter within a mixed conifer stand, and readings ranged from 1 to 3 percent (average of 2 percent).

Fire Behavior Observations and Measurements

The six study sites bordered Stump Springs Road and burned between July 26 and July 30, 2013. Table 10 lists a description of fire behavior observations from onsite videos and includes the fire type, flame length, flame angle, rate of spread and duration of active consumption. All values are determined by watching the video footage using 4-foot reference poles for scale, that have 1-foot gradients in view of the camera. The still shot photos captured from the videos often include the vertical reference poles. Subtle differences were found between the fire behavior measurements between the video camera and the other sensors. See Appendix A for matching pre- and post-fire vegetation pictures.

Footage from two of the FBAT sites with impressive daytime video (sites 2 and 4) were used in the USFS PSW Region video podcast series on ecological restoration released in December 2013: http://www.fs.usda.gov/detail/r5/news-events/audiovisual/?cid=stelprdb5443943

Table 10: Fire behavior data based on the video camera footage.

Site	Fire Type	Flame Length (ft)	Flame Angle (%)	ROS (ch/hr)	Date, Approx. Start of Fire	End of Active Consumption
1	Surface and some torching	1+, 2 to 4 in pockets, ½ tree height	50 to 100%	1 to 2	7/27/13, 17:59	19:20+ left of view consumed
2 (at site)	Surface, group torching and some crowning	2-4, 1 to 1½ tree height	50 to 200%	4 to 6	7/28/13, 18:12	After 19:33, 1000+hr burns entire length
2 (above site)	Surface, group torching and some crowning	5-10, 1 to 1½ tree height	50 to 200%	4 to 6	7/28/13, 17:44	19:06+ foreground consumed
3	No quality video footage available, very patchy burn					
4	Surface and torching, very smoky	1 to 4, occasional 1 tree height	50 to 200%	Too smoky	7/28/13, before 19:17*	After 20:00, past end of video
5	Surface	1 to 2, occasional 2 to 4	variable	<1	7/30/13, 00:04	01:26+ to dark to tell
6	Surface little torching	1 to 4	variable	1	7/30/13, 01:36	02:57+background consumed

* Recovered footage began after fire was established in heavy fuel in front of camera.

Site 1, Ponderosa Pine Plantation
Site 1 was located above the road in a plantation area that had received some maintenance (shrub thinning, potentially). Ponderosa pine was the dominant tree species with other mixed conifer species present at the site. The understory consisted of manzanita and conifer seedlings with minor amounts of herbs and grass. The fire triggered the video camera at 17:59 and captured a low surface fire with primarily a backing orientation, with some isolated shrub torching. Winds appeared calm based on the flagging on the photo reference poles (Figure 9). The second video camera was triggered during darkness and no quality footage was recorded.

Figure 9. Site 1 had a surface fire pass in front of the video camera.

Site 2, Mixed Conifer Stand in Riparian Conservation Area
Site 2 was located east and below the road from Site 1. Dominant trees were white fir, ponderosa pine, and incense cedar. This site had a noticeable component of large (1000-hr) dead and downed fuels as listed in Table 7 above. The video camera inside the site and sensors showed signs of a large heat pulse, resulting in having to send the video camera to a specialist for recovery of the footage. A second video camera was staged near the road looking into the plot (as shown in Figure 4) and triggered at 17:44 capturing passive and active crown fire crossing though the site area. Figure 10 shows the plot area from the road, then from inside the plot from the recovered video which triggered at 18:12, capturing both surface and crown fire (4 ft reference pole at front center).

Figure 10. ***Top photos*-Looking into Site 2 as observed from the video camera positioned on the road above it.**
***Bottom photos* - Looking inside the plot with 4 ft reference pole at front center.**

<u>Site 3, Manzanita dominated shrubland</u>

Site 3 was located above the road and was the only site located in shrublands with a few scattered pines and oaks in the area. The site had a large rock component, discontinuous fuels, and topography was potentially affected by the initial road construction below the site. No quality video footage was captured at this site due to the camera being triggered at a different time than the field of view burning. Post-fire site visit showed a very light, patchy burn had occurred across some of the site area (pictures in Appendix A). Plot 3 data indicated reduced consumption compared to other sites, likely linked to its location and discontinuous fuel beds.

<u>Site 4, Mixed Conifer Stand</u>

Site 4 was the only site located a short distance to the North from Stump Springs Road, along the 7S05G spur road. It was in a steep area of mixed conifer above a large drainage with ponderosa pine, incense cedar, white fir, black oak and a minor sugar pine component. Like plot 2, this video camera went sent to specialist for recovery of the footage. About half of the footage was recovered and showed active surface fire underway at 19:17 and fire behavior ranging from torching to crown fire with a strong upslope wind (Figure 11).

Figure 11. From recovered video footage active surfacing and torching fire behavior for Site 4.

Site 5 and 6, Mixed Conifer Stands

These sites are located below the Stump Springs Road nearby each other. Site 5 is dominated by white fir and located in a Riparian Conservation Area, and site 6 is dominated by ponderosa pine with smaller amounts of incense cedar and sugar pine. Both sites burned shortly after midnight with low intensity surface fires (Figures 12 and 13).

Figures 12 and 13. Site 5 on the left and Site 6 on the right.

Data Collected from Temperature Sensors

Rate of spread and temperature data were gathered using fire resistant data loggers, or sensors, at each site (Table 11, Figure 14). Sites 1 and 6 had three sensors function well in a grid of four sensors, which is the minimum to calculate rate of spread across the site. Sites 2, 4, and 5 had two of four sensors work, which give us date and time of temperature ranges, but we are unable to calculate the exact rate of spread captured by the grid of sensors. Site 3 sensors were not burned or captured marginal data; it was a patchy burn area among a manzanita dominated area with poor fuel connectivity.

Figure 14: Thermocouple temperature graph for portion of temperatures measured at Site 1.

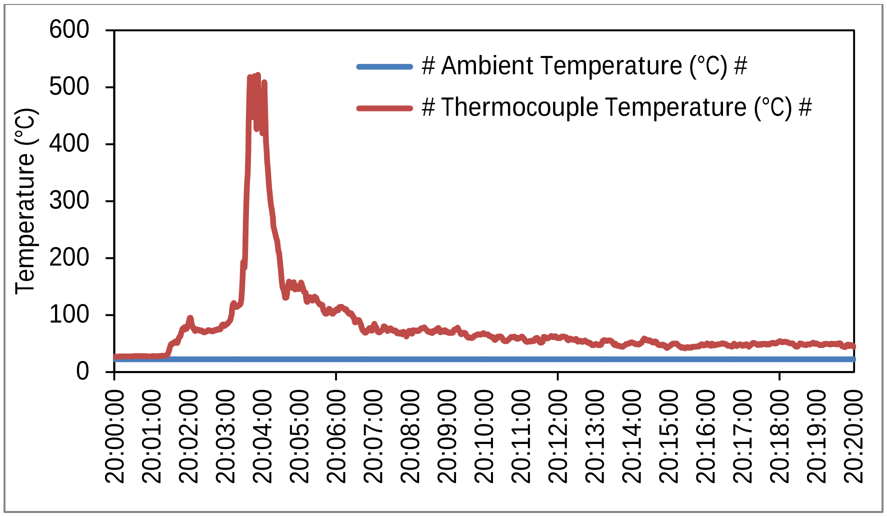


Table 11: Rate of spread (ROS), max temperature, and duration of heat from the temperature sensors.

Site	Date, Time fire detected by a sensor	ROS (ch/hr)*	Maximum Temperature (°C)	Heat Duration Range Above 80 °C (minutes)
1	7/27/13, 17:31	0.70	521	3 - 25
2	7/28/13, 17:55	Equipment failure for 2 sensors	1072	46 - 79
3	Patchy burn area; no quality data was collected			
4	7/28/13, 20:29	Equipment failure for 2 sensors	435	4 - 25
5	7/30/13, 08:45	Equipment failure for 2 sensors	668	< 1 - 3
6	7/30/13, 00:18	0.68	1080	2 - 143

*Sites 1 & 6 had three sensors work; Sites 2, 4, & 5 had two sensors work; Site 3 sensors were not burned.

Weather Observations

Daily Energy Release Component (ERC), wind speed, temperature and relative humidity from the permanent Minarets and Mt. Tom RAWS (see map in Figure 1) and SNF01 portable RAWS are shown in Figure 15 for the duration of the fire and in Figure 16 for the days the sites burned. The SNF01 portable RAWS was located at Lookout point off the 7S27 road. The portable RAWS was not included in the ERC graphic due to the short duration of the dataset at Lookout point.

Figure 15: ERC, wind speed, temperature, and relative humidity for the duration of the fire (July 22-Sept 9).

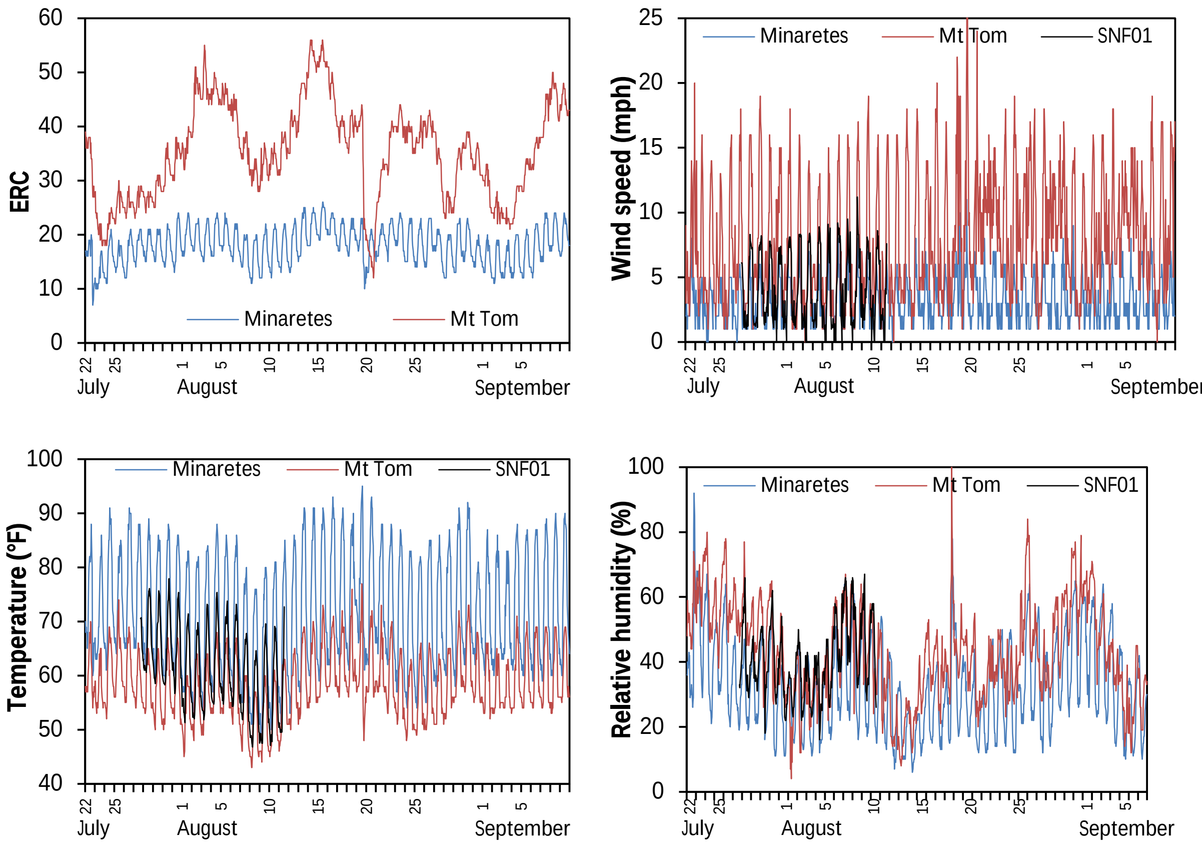
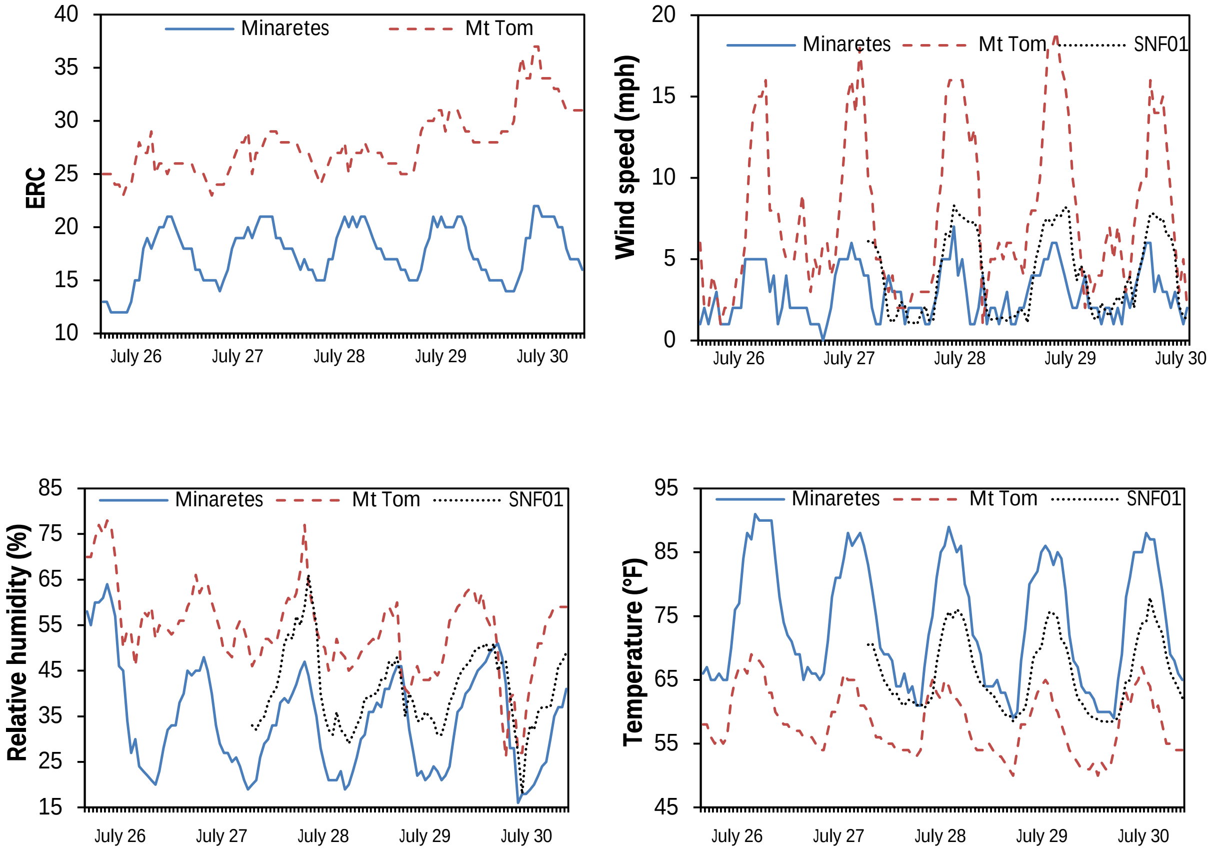


Figure 16: ERC, wind speed, temperature, and relative humidity for the days the sites burned.



Summary and Accomplishments

The following summary is for Division F only, in the vicinity of Stump Springs Road, when FBAT was on the incident (July 26 to Aug. 4, 2013).

Our objectives were to:

- Characterize fire behavior and quantify fuels over a variety of fuel conditions. Key considerations were which sites could be measured safely given access and current fire conditions. Obtain data in fuel treatment areas and adjacent untreated areas, as possible, which will be burned by the fire.
- Obtain crown fire footage, if possible, as a role FBAT serves in the Crown Fire Synthesis Project (http://www.fs.fed.us/wwetac/projects/alexander.html). See upcoming FBAT highlights in Fire Management Today Special Issue 73(4).
- Gather and measure representative vegetation and fuel samples to calculate moisture content to support incident staff and future emissions and fire behavior modeling.
- Assess fire severity and effects at the study sites based on immediate post-fire measurements.
- Cross-train and work with the Calaveras Wildland Fire Module doing field measurements on the fire.
- Produce a summary report based on preliminary analysis for fire managers and the Sierra National Forest.

Six sites were successfully measured and burned over in the Aspen fire, nearby Stump Springs Road in Division F from July 26 to August 4, 2013. Numerous vegetation mixed-severity areas are found within the fire perimeter, as well as some areas where crown fire occurred. FBAT study sites were able to capture a range of fire severity areas, including some higher intensity and severity conditions, while the team imbedded in the organization of the incident management team and met safety guidelines.

We met the above objectives, and communicate results through the distribution of this report and its input data. We were unable to capture data in fuel treatment areas due to lack of spatial data, long duration since treatment, and/or access. A variety of vegetation areas were measured instead, including a plantation site and three sites inside and adjacent to Riparian Conservation Areas. Fuel moisture samples were gathered and measured in one operational area on Division F in the vicinity of the West Kaiser Campground and were given to the fire behavior and smoke emissions staff, as well as estimated fuel loadings/consumption. This report presents multiple metrics to compare fuel and fire behavior between the sites and illustrates some of the variable fire behavior and vegetation found in the Aspen fire area affected by surface and crown fire spread. Sierra NF staff said the collection of quantitative data on real-time fire behavior in various fuel models and topography can be used in future environmental planning documents, in addition to other literature. The Sierra NF is currently one of three Forests in the USFS PSW Region considered Early Adopters for revising their Forest Plans following the 2012 Planning Rule. This information about the Aspen fire will provide insight for this planning effort.

This information is shared with managers to evaluate the Aspen fire in meeting current or future Land and Resource Management Plan's desired conditions (e.g., condition class) or other comparisons. The information is valuable when shared with: firefighters to improve situational awareness; managers to improve predictions for fire planning; and scientists for improving smoke and fire behavior modeling. A BAER study was conducted of the soil burn severity; see that report for further details. This report will be distributed to Aspen fire incident personnel, the Sierra National Forest, and USFS Fire and Air Quality Management.

Lessons Learned

Successful cross-training with module

1. We increased our skill set between the Calaveras Wildland Fire Module (WFM) and FBAT members. We continued to meet our 100 percent safety goal. We will continue to improve our proficiency with setting up additional sensors and post-fire data processing.

Immediate and current data sharing

2. Immediate data sharing with the incident Air Quality/Emissions staff, BAER team, and READ group occurred. This report and detailed site data is shared with the Sierra NF silviculture and natural resource staff; additional data details are available upon request.

Equipment

3. We overheated two video cameras and their footage in the process of capturing torching and crown fire behavior. We had a large ratio of temperature sensor failures too; this needs improvement. FBAT/WFM field crew needs to have more attention to the location of the video cameras or sensors near any heat sources (e.g., logs and snags) as possible.

4. We did not capture site specific wind measurements and consistent ambient air temperature (not affected by direct flames) as part of our normal protocol, partly due to our extra focus on cross-training the remaining field and operational protocol with the Module. However, wind direction and general wind speed trends (using a modified Beaufort scale) can be obtained from video footage taken facing the flagging (serves as a "wind vein") tied to the video reference pole. Needle freeze can indicate the direction the fire burned through the site and also gives an indication of wind direction.

Improvements Needed

5. We desire a stronger understanding (with all collaborators and co-workers) about FBAT objectives on data collection on wildfires, the purposes and uses of the data, and future linkages. Sharing reports like this, reviewing the links between field data efforts and data analysis or modeling steps, and feedback from the Sierra National Forest and other interested groups will improve everyone's understanding. Aspen fire data is added to the growing wildfire dataset gathered by FBAT to address regional and national goals, and other research efforts. For example, see the USFS PSW Region's "Restore" video podcast series (episode 13) on *Fire Behavior and Ecological Restoration* released in December 2013 that uses footage from the Aspen fire videos: http://www.fs.usda.gov/detail/r5/news-events/audiovisual/?cid=stelprdb5443943

6. Study site placement is a multi-faceted decision, starting with safety decision criteria and strives to maximize data success rates. FBAT focused on conifer dominated sites, except site 3 that is manzanita dominated. FBAT strives to set up sites inside and adjacent to fuel treatments. Post-fire GIS analyses found some treated areas (FACTS) were in the vicinity of the FBAT sites, and some areas were co-located where more than 15 years had passed since treatment. FBAT had three sites inside and above designated Riparian Conservation Areas, one plantation site, and one manzanita dominated shrubland which adds information to those often poorly-represented data categories for fire behavior and effects.

7. FBAT desires to incorporate nearby site emissions monitors and weather stations that would not be subject to nearby fire or heat impingement. FBAT will continue to work with cooperators to brainstorm feasibility. The information from the Aspen fire, or from the entire growing FBAT wildfire dataset, can help the modeling arena as we work to tailor field methods and data analysis to increase usefulness. For example, last year FBAT combined efforts with the PSW Research Station and others to compare FBAT fire consumption data in CA to FOFEM modeling; the manuscript passed the review stage and is due to be released soon.

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Personal Communications

During or after the Aspen fire in 2013-2014:

Carolyn Ballard and Denise Tolmie, Sierra National Forest
Frankie Romero and Jim Menakis, USFS Washington Office, Fire and Aviation Management
Jo Ann Fites-Kaufman, USFS PSW Regional Office

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Appendix A: Paired Photographs from Pre- and Post-Vegetation and Fuel Sites

Plot 1 Transect 2, 0-50 Pre

Plot 1 Transect 2, 0-50 Post

Plot 1 Transect 2, 50-0 Pre

Plot 1 Transect 2, 50-0 Post


Plot 2 Transect 1, 0-50 Pre


Plot 2 Transect 1, 0-50 Post

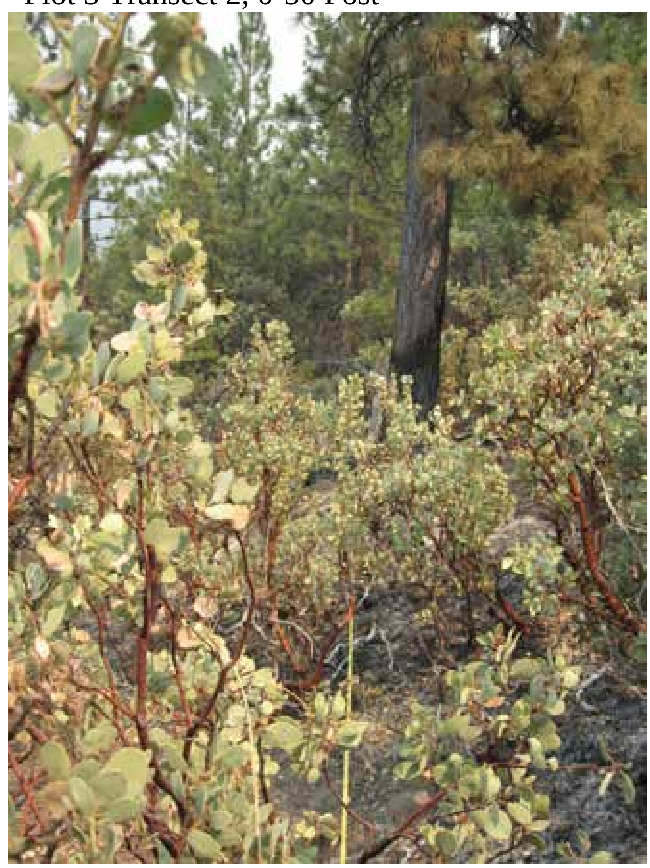

Plot 2 Transect 2, 50-0 Pre


Plot 2 Transect 2, 50-0 Post


Plot 3 Transect 2, 0-50 Pre


Plot 3 Transect 2, 0-50 Post


Plot 3 Transect 3, 50-0 Pre


Plot 3 Transect 3, 50-0 Post

Plot 4 Transect 1, 50-0 Pre

Plot 4 Transect 1, 50-0 Post

Plot 4 Transect 2, 0-50 Pre

Plot 4 Transect 2, 0-50 Post


Plot 5 Transect 1, 0-50 Pre


Plot 5 Transect 1, 0-50 Post


Plot 5 Transect 2, 0-50 Pre


Plot 5 Transect 2, 0-50 Post

Plot 6 Transect 3, 0-50 Pre

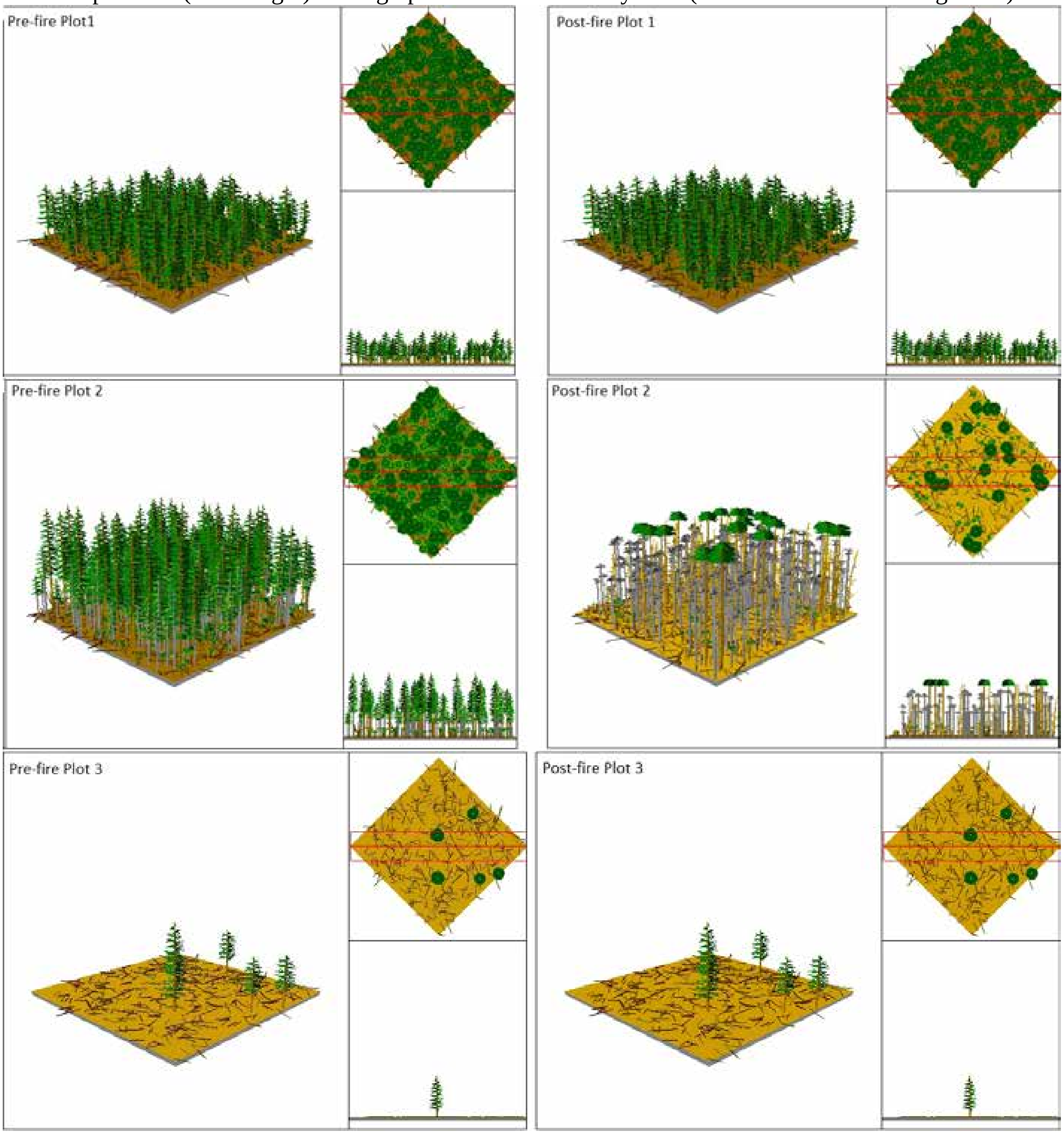
Plot 6 Transect 3, 0-50 Post

Plot 6 Transect 3, 50-0 Pre

Plot 6 Transect 3, 50-0 Post

Appendix B: FVS-SVS Graphics

Pre- and post-fire (left to right) stand graphics based on 6 study sites (sites 1 to 6 in descending order)



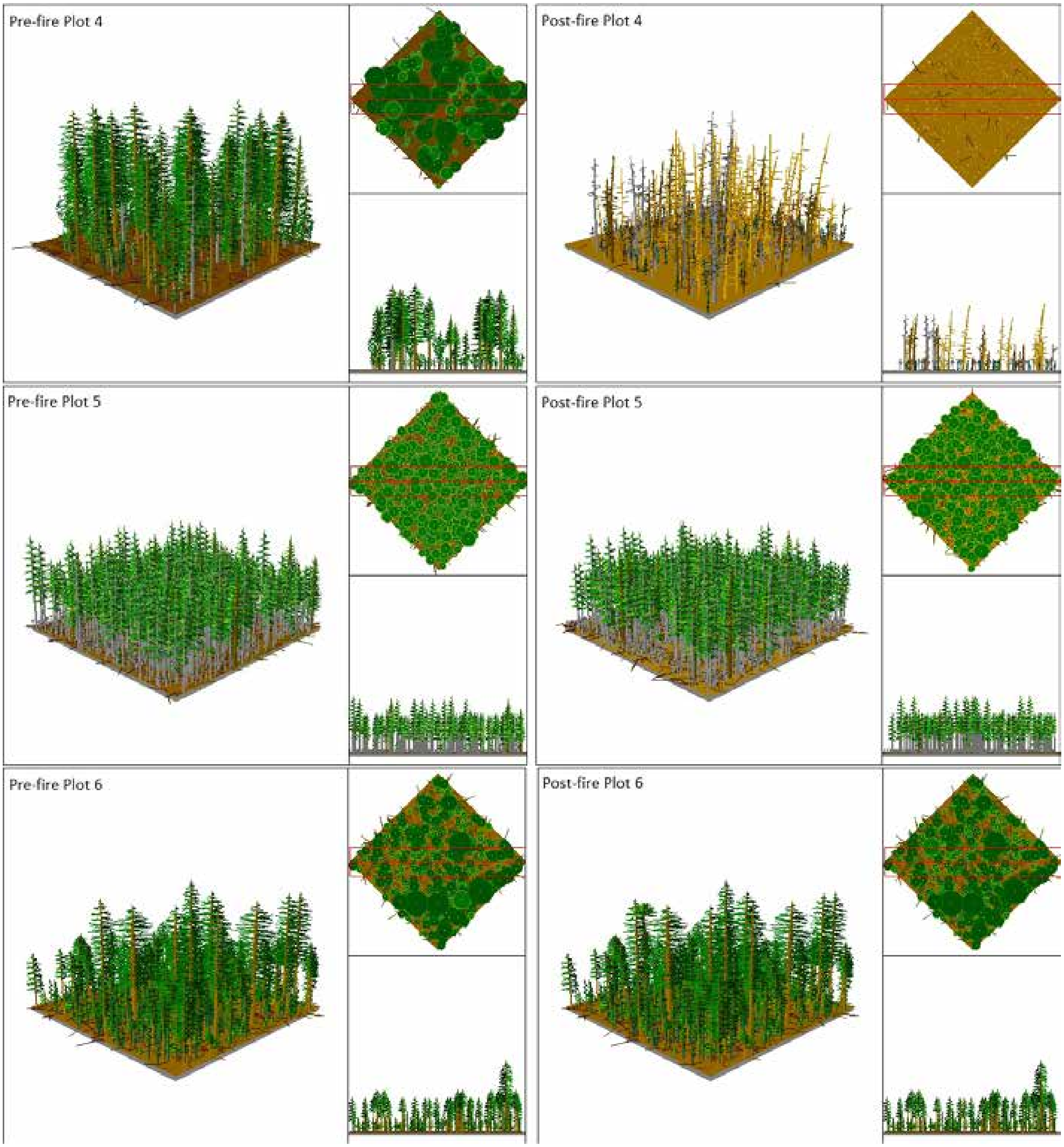


Figure B1. Pre- and post-fire stand visualizations from stand data at sites 1 to 6 in descending order.

Appendix C: Fuel Moistures from West Kaiser Campground

Fuel moisture samples were taken on July 28, 2013 at the West Kaiser Campground. Both woody material and leaf samples were taken from manzanita, live needles were sampled from white fir and ponderosa pine, and 1000-hr fuels were sampled for ponderosa pine and sugar pine. All samples were weighed after sampling then again after drying for at least 24 hours.

Table C1. Fuel moisture data from samples collected at the West Kaiser Campground.

Plant Species	Fuel Type	Fuel Moisture (%)	Average Fuel Moisture (%)
Manzanita	woody	26	45
		65	
	leaves	104	112
		118	
		113	
White fir	needles	123	125
		128	
		124	
Ponderosa pine	needles	119	124
		134	
		118	
	1000-hr	11	13
		9	
		14	
		15	
		16	
Sugar pine	1000-hr	13	10
		14	
		2	

Appendix D: Understory Vegetation Loading Comparison

The FBAT program has traditionally used the Burgan and Rothermel (1984) methods adapted by Scott (2005) to estimate and calculate live understory fuel loading (i.e., grass, herbs, shrubs, seedlings), as presented in the body of the report (Tables 4 and 6). Fire Effects Monitoring and Inventory Protocol (FIREMON, Lutes et al. 2006) is an accepted protocol by the fire and fuels community, so we did a quick comparison of the formulas and values using the 6 FBAT sites at the Aspen fire (Tables AD1 and AD2, below). Note all plots had three understory vegetation transects, except site 4; but sometimes a transect had no herb/grass or shrub/seedling components.

Table AD1: Pre- and post-fire understory vegetation fuel loading by site based on FIREMON.

Site	Grass/Herb (ton/ac)						Shrub/Seedling (ton/ac)					
	Pre-Fire			Post-Fire			Pre-Fire			Post-Fire		
	Live	Dead	Total	Live	Dead	Total	Live	Dead	Total	Live	Dead	Total
1	0.0105	0	0.0105	0	0	0	2.22	0.55	2.77	1.69	1.07	2.76
2	0.0015	0	0.0015	0	0	0	0.07	0.03	0.1	0	0	0
3	<0.0001	0.0009	0.0009	<0.0001	0.0006	0.0006	3.54	0.4	3.94	3.18	0.76	3.94
4	0.0082	0.0007	0.0089	0	0	0	0.15	0.01	0.16	0	0	0
5	0.0012	0.0004	0.0016	0.0004	0.0008	0.0012	0.22	0.19	0.41	0.03	0.25	0.28
6	0.006	0.0035	0.0095	0.0001	0.0009	0.001	0.72	0.05	0.77	0.14	0.3	0.44

Table AD2: Understory vegetation consumption by site based on FIREMON.

Site	Consumption (%)	
	Grass/Herb	Shrub
1	100	0
2	100	100
3	33	0
4	100	100
5	25	32
6	89	43

In general for the Aspen fire, the grass, herbaceous and shrub components in these plots were very minimal. Plots with more live fuel loading would be a better test case. Because the grass and herbaceous component were often minimal amounts, field data was often estimated to be less than or equal to 1 percent cover for each species for 4 of 6 sites. The calculated bulk densities are highly dependent on the user-assigned vegetation type and vegetation density values chosen. When a user chooses lower vegetation types and densities, then usually very light bulk densities are calculated; this transitions to heavier bulk densities when heavier vegetation types and densities are chosen.

Note that inherent differences between the bulk density values used in Burgan and Rothermel and FIREMON equations for calculating live understory fuels drive differences in outputs. The bulk densities used in Burgan and Rothermel and FIREMON equations have different ranges. The bulk densities used in the Burgan and Rothermel equation can range from 0.80 to 1.44 for grasses and herbaceous plants and 0.18 to 14.71 kg/meter-cubed for shrubs, whereas the bulk densities in the FIREMON equations are 0.8 and 1.8 kg/meter-cubed for herbs and shrubs, respectively. The bulk densities for the Burgan and Rothermel equation are chosen based on a look up table of type and density. The lower combinations of type and density values yield lower Burgan and Rothermel total fuel loadings than the FIREMON equations, and the higher values for type and density yield fuels loading yield higher amounts than FIREMON values. Note these relationships generally hold true when plant percent cover and height are both 1 (sensitivity analysis), and change only slightly with percent cover and height greater than 1.

Our comparison shows that overall, the FIREMON estimates were higher for herb/grasses and mixed for shrub/seedlings, probably due to lower vegetation and density types observed and chosen for the calculations (Tables AD3 and AD4, below). A notable exception is the shrub/seedling loading differences for sites 1 (plantation with manzanita understory) and site 3 (manzanita shrubland with minimal overstory trees) that have a range or difference of 2 to 4 tons/acre. Unfortunately, this comparison shows two different estimates of fuels with no clear indication of which is more accurate, but it does show the possible range of conditions depending on calculation methods. Further investigation is needed between these calculations to find which is more representative of understory vegetation loading in Sierra mixed conifer and other ecosystems, such as by literature comparison, conversations with specialists, and conducting destructive sampling and measuring actual amounts.

Table AD3. Comparison of herb and grass loading by Burgan and Rothermel to FIREMON.

Site	Status	B & R Total Load (ton/ac)	FIREMON Total Load (ton/ac)	Difference
1	pre	0.0014	0.0143	0.0129
	post	0.0000	0.0000	0.0000
2	pre	0.0002	0.0015	0.0014
	post	0.0000	0.0000	0.0000
3	pre	0.0003	0.0033	0.0029
	post	0.0002	0.0024	0.0021
4*	pre	0.0009	0.0089	0.0080
	post	0.0000	0.0000	0.0000
5*	pre	0.0005	0.0046	0.0042
	post	0.0004	0.0036	0.0032
6	pre	0.0010	0.0095	0.0086
	post	0.0000	0.0002	0.0002

*comparison is just 1 transect of herbs/grasses

Table AD4. Comparison of shrub and seedling loading by Burgan and Rothermel to FIREMON.

Site	Status	B & R Total Load (t/ac)	FIREMON Total Load (ton/ac)	Difference (tons/acre)
1	pre	5.56	2.76	2.80
	post	5.56	2.76	2.80
2	pre	0.06	0.10	-0.04
	post	0.00	0.00	0.00
3	pre	8.00	3.94	4.06
	post	8.00	3.94	4.06
4*	pre	0.02	0.16	-0.14
	post	0.00	0.00	0.00
5	pre	0.05	0.00	0.05
	post	0.03	0.28	-0.25
6	pre	0.38	0.77	-0.39
	post	0.35	0.44	-0.09

*comparison is just 1 transect of shrubs/seedlings

Appendix E: Burn severity coding matrix from the National Park Service

Table 12. Burn severity coding matrix from the National Park Service (USDI 2003).

Code	Forests		Shrublands	
	Substrate	Vegetation	Substrate	Vegetation
Unburned (5)	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
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	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 after burn; 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
Moderately Burned (2)	litter mostly to entirely consumed, leaving course, 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 course, 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 (0.25-0.50 inch in diameter) still present; 40-80% of the shrub canopy is commonly consumed.
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 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 0.5 in diameter
Not Applicable (0)	inorganic pre-burn	none present pre-burn	inorganic pre-burn	none present pre-burn

Appendix F: About the Fire Behavior Assessment Team (FBAT)

The Fire Behavior Assessment Team (FBAT) operates under the management of the Adaptive Management Services Enterprise Team (AMSET) of the USFS. We specialize in measuring fire behavior and fuels on active wildland and prescribed fires. We utilize fire behavior sensors and fire-resistant video cameras to measure direction and variation in rate of spread, fire type (e.g. surface, passive or active crown fire behavior), onsite weather, and couple this with measurements of fire effects, topography, and fuel loading and moisture. We measure changes in fuel loads from fire consumption and can compare the effectiveness of past fuel treatments or fires in terms of fire behavior and effects. We are prepared to process and report some data while on the incident, which makes the information immediately applicable for verifying LTAN or FBAN fire behavior prediction assumptions. In addition, the video and data are useful for conveying specific information to the public, line officers and others. We can also collect and analyze data to meet longer term management needs, such as calibrating fire behavior modeling assumptions for fire management plans, unit resource management plans, or project plans.

We are a team of fireline qualified technical specialists and experienced fire overhead. The overhead personnel include a minimum of crew boss qualification, and more often one or more division supervisor qualified firefighters. The team can vary in size, depending upon availability and needs of order, from 5 to 12 persons. We have extensive experience in fire behavior measurements during wildland and prescribed fires. We have worked safely and effectively with over 17 incident management teams. We are comprised of a few AMSET FBAT core members and other on-call firefighters from the USFS and other agencies. We are available to train other interested and motivated firefighters while on fire incidences, as time allows.

We can be ordered from ROSS, where we are set up as "Fire Behavior Assessment Team", and are in the CA Mobilization Guide (near the BAER Teams). We can be name requested, and we'll request additional personal to join our team, like a Wildland Fire Module, based on the Module's availability. Please contact us directly by phone to notify us that you are placing an order, which will speed up the process. You can reach Carol Ewell at 530-559-0070 (cell) or via the Stanislaus NF dispatch (209-532-3671 x212). Or you can reach Alicia Reiner at 530-559-4860 (cell). We may be available if you call dispatch and we are already assigned to a fire. We can work more than one fire simultaneously and may be ready for remobilization. Our web page is below and has links to most of our Incident Summary Reports.

Website: http://www.fs.fed.us./adaptivemanagement/projects/FBAT/FBAT.shtml