2019 Walker Fire
Plumas National Forest

Fire Behavior Assessment Team (FBAT) Report

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Contrasting effects of the Walker Fire on a plot burned at low severity during a wildfire 12 years prior (left) and a plot with no fire or other treatment recorded in the last century (right).

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Summary

Past wildfire and fuel treatments had a large effect on surface fuel loadings and ladder fuels and fire behavior, fuel consumption, and fire effects were moderated where the Walker Fire burned through an area where the 2007 Wheeler Fire had burned with low severity. The Fire Behavior Assessment Team (FBAT) collected pre-fire data on eight plots, and post-fire data on three of those plots that burned during the Walker Fire. The Walker Fire started on September 4th, 2019, and the last day of appreciable growth was the 15th of September before wetting rain on the morning of the 16th. The fire burned through a wide range of topography, weather, and fuels. Fuels varied greatly across the Walker Fire according to mechanical treatment and fire history, with some areas having seen no fire in the last century and other areas having burned with a range of severity during the 2007 Wheeler Fire (part of the Antelope Complex). FBAT performed plot-based, fuels and vegetation measurements in ponderosa-pine dominated forest, primarily in and around an unburned island near Murdock Crossing on the NE side of the fire (Figure 1). Topography where plots were located was moderate. Plots inventoried included areas that had burned at low severity in the Wheeler Fire, as well as areas outside the Wheeler perimeter with a range of histories ranging from no known treatment or wildfire history to a plot that had received both mechanical treatment and prescribed fire. Substantially lower ground (duff) and surface fuel loadings were inventoried on the recently burned plots compared with where there had been mechanical treatment and/or no record of fire. Ladder fuels were not always reduced by mechanical treatment. Three plots burned in the Walker Fire as a result of burnout operations and, on these plots, fire behavior, fuel consumption, and fire effects were moderated where the 2007 Wheeler Fire caused low-severity effects. In contrast, in a plot with no known history of fire or mechanical treatment, high surface fuel consumption and group torching occurred and first-order fire effects (soil heating, severity ratings, and tree impacts) were elevated.

On the Walker Fire, FBAT integrated a 2-person Terrestrial Laser Scanning (TLS) crew into its operations to support USFS Pacific Southwest Region (Region 5) efforts to improve vegetation, fuels, and carbon mapping and fire emissions prediction for National Forests in California. TLS data were collected on both pre- and post-fire FBAT plots and will be used to develop a high-resolution digital 3D stand maps from which stand characteristics are derived. Stand characteristics, in turn, will be used to calibrate map products derived from pre-existing airborne and satellite-based LiDAR.

During the assignment, FBAT delivered data to the incident meteorologist and fire behavior analyst and provided fire video and an assessment of fuel treatment effects to the public information staff. Additionally, FBAT benefited from drone surveillance by the California Air National Guard and provided feedback on potential future products useful for fire and land management that could be derived from drone imagery. Data from the Walker Fire will be added to the FBAT archive intended to improve fuels and fire management decision support.

Although FBAT's work on the Walker Fire focused on areas burned at low severity during the 2007 Wheeler Fire, the Walker Fire also spread through areas burned at high severity during the Wheeler Fire. The Wheeler Fire made an intense run with dry, hot weather, heavy fuel loadings, and a southwest wind that aligned with the Indian Creek drainage. Vegetation recovery was heavily shrub dominated, resulting in high severity fire effects when the Walker Fire burned the same ground 12 years later. At lower elevations in the Indian Creek drainage outside of the 2007 Wheeler Fire's perimeter, an intense run occurred in heavily forested fuels where there had been no fuel treatments and, again, where southwest winds and the drainage aligned. Re-burning where terrain and prevailing winds align highlights the potential that such areas will become persistently shrub dominated (vegetation-type converted) in the future as climate and fire trends continue. FBAT worked on the 2007 Wheeler Fire and the resulting report provided useful context for the Walker Fire. Plots inventoried by FBAT during the Wheeler Fire were outside of the Walker Fire perimeter and were not revisited. See Appendix F for more discussion.

Introduction

This report summarizes the results of the Fire Behavior Assessment Team's (FBAT's) coordinated, plot-based measurements of fire behavior, vegetation, fuel loading, consumption, and fire effects on the Walker Fire. In addition to the core FBAT measurements, the team supported Terrestrial Laser Scanning (TLS) on the plots as a part of USFS Pacific Southwest (PSW) Region's (Region 5's) initiative to map forest vegetation, fuels, and carbon stocks across California National Forests based on airborne and satellite-based (see GEDI project) LiDAR (Light Detection and Ranging) and other remotely-sensed data. The Walker Fire started on September 4th, 2019, near Genesee and burned about 54,600 acres, primarily in the Plumas National Forest. The days of greatest growth were the 6th and 7th of September (Figure 1). After the two days of rapid growth, firefighting resources, aided by moderate weather, worked quickly towards containment. FBAT installed study plots in ponderosa pine dominated forest on the NE side of the fire both in an island of unburned fuels around Murdock Crossing and outside the outer fire perimeter (Figure 1). Part of the area had been burned with low severity effects during the 2007 Wheeler Fire, providing a contrast with long-unburned fuels both near Murdock Crossing and outside the Walker Fire's perimeter (Figure 2). Burnout operations in the unburned island strengthened containment and helped protect historic structures near Murdock Crossing in the days leading up to and during September 15th when high winds and dry weather caused red-flag conditions. Burnout operations resulted in the burning of plots 4, 5, and 8, before heavy rain during the morning of September 16th ended active spread.

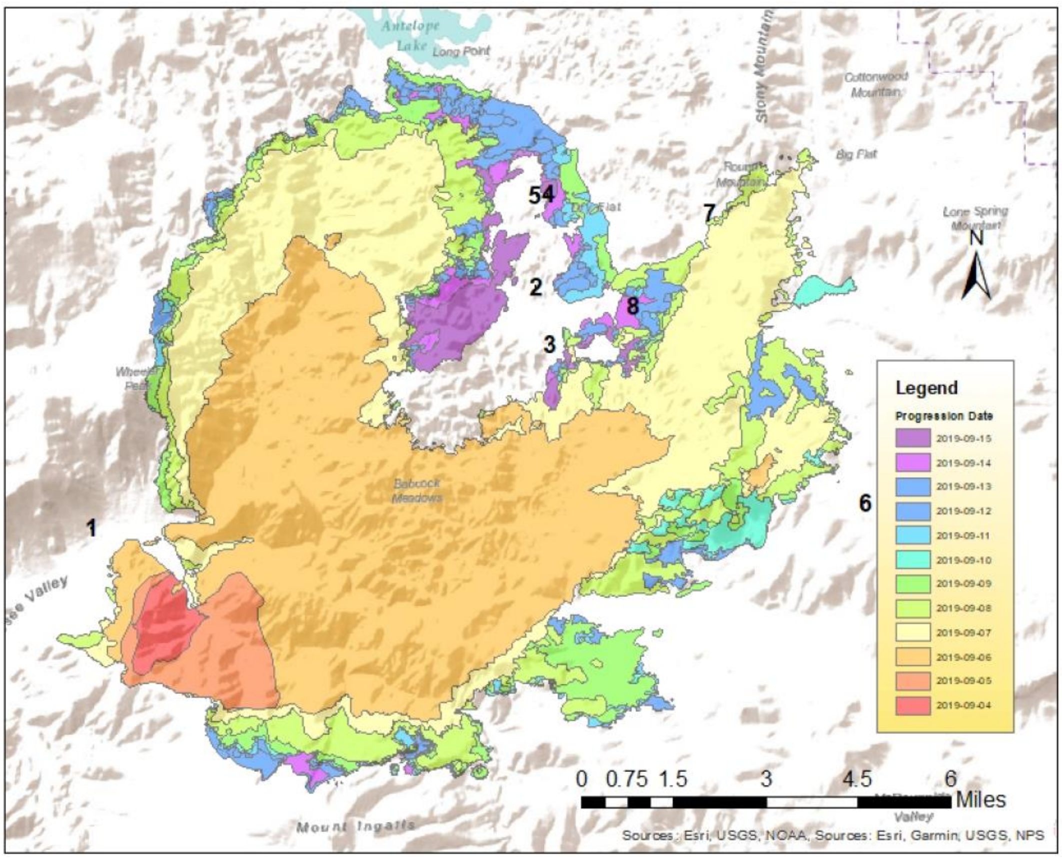

Figure 1. Walker Fire progression map and FBAT plot locations. FBAT inventoried fuels and vegetation and collected TLS datasets on all pre-fire plots. Plots 4, 5, and 8 burned and were re-measured post-fire. For reference, Plot 8 is just east of Murdock Crossing.

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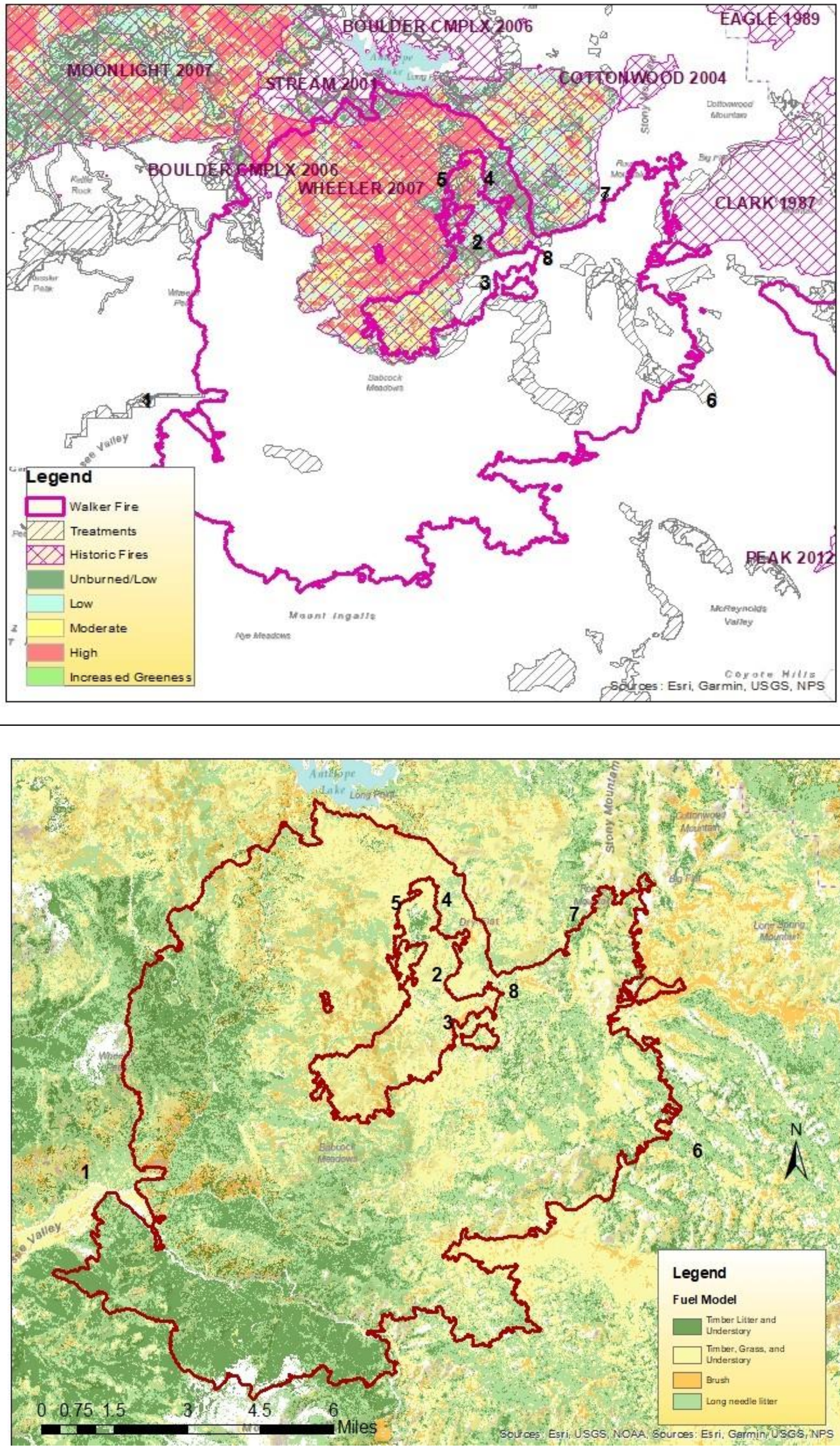

Figure 2. Top panel. Recent wildfire and fuel treatment history on the Walker Fire. Severity of the Wheeler and Moonlight Fires (the Antelope Complex) from the Monitoring Trends in Burn Severity (MTBS) dataset are shown. Fuel treatments (indicated by diagonal lines) from the Forest Service Activity Tracking System (FACTS) database are shown back to 2007. Plots 2, 4, and 5 were installed where the 2007 Wheeler Fire had burned with low severity effects. No other FBAT plots had recorded wildfire history, though bark charring suggests that Plot 7 also burned during the Wheeler Fire. Data sources: MTBS and FACTS.

Bottom panel. The FBAT plots sampled were characterized by Long Needle Litter or Timber, Grass, and Understory fuel types. More heavily forested and shrub-dominated fuels that dominated other areas of the Walker Fire were not surveyed. The Walker Fire perimeter is shown. Data source: LANDFIRE.

Fire weather conditions on the Walker Fire were average to below average relative to the previous 13 years as indicated by the Energy Release Component (ERC, Figure 3). The ERC is an index used to describe potential fire energy release and resistance to suppression. It is strongly related to fuel moisture, declining as fuel moisture increases. The period during which FBAT plots burned was after a minor rain event that presents itself as a dip in the ERC graph on September 10th (Figure 3, circled). After the rain on September 10th, ERC values recovered with warmer, dryer, and windier weather that led to red-flag conditions on the 15th of September. Wetting rain fell on the morning of the 16th leading to the steep decline in ERC (not shown).

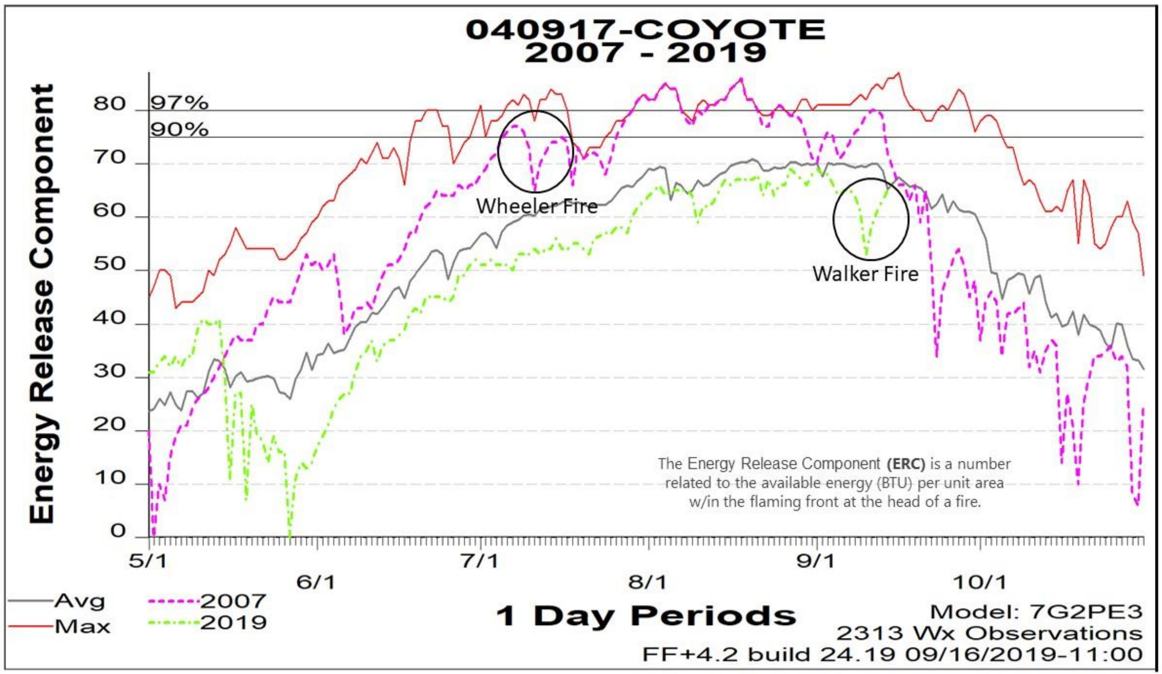

Figure 3. Energy Release Component based on weather from the Coyote Remote Access Weather Station (RAWS) showing the 2007 fire season (Wheeler Fire) and the 2019 season (Walker Fire) through 15 September 2019. The 2019 ERC dropped sharply early on 16 September with wetting rain. FBAT plots burned on September 15th and early on the 16th. Two burned plots were previously burned with low-severity during the Wheeler Fire.

Objectives

FBAT objectives on the Walker Fire were to:

1. Safely maximize the number of plots inventoried both pre- and post-fire.
2. Support the PSW Region's initiative to map vegetation, fuels, and carbon stocks and predict emissions from wildland fires in California National Forests by integrating TLS sampling into FBAT operations.
3. Test new technology that would reduce plot setup times and increase information captured.
4. Continue to build the FBAT data archive to reflect a broad range of fuels, fuel treatments, and climactic conditions in support of fire and land management decision-making.
5. Deliver a report on findings for the benefit of interested land and fire managers and users of the data archive and to facilitate future plot re-measurement.

Measurements and Observations

Pre- and Post-Fire Vegetation and Fuels

Vegetation and fuels were inventoried before the fire reached each plot and repeated post-fire for burned plots 4, 5, & 8. Fire behavior measurements were also made on each burned plot, along with first order fire effects assessments. Plots were monumented with a single rebar at the center of the fuels transects to allow long-term monitoring.

Overstory Vegetation Structure and Crown Fuels

Variable radius sub-plots were used to characterize crown fuels and overstory vegetation structure. A relascope (slope-correcting tree prism) was used to select both pole (>2.5 to 5.9 in. diameter at breast height, DBH) and overstory (≥6 in. DBH) sized trees. When possible, a basal area prism factor was selected to include approximately 10 trees for each classification. Tree species, status (alive or dead), DBH, height, and canopy base height were 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 fire, minimum and maximum bole char, crown scorch, torch heights, and percentage of scorch and torch were recorded for each tree. Trees were assumed to have survived if any green needles were present. Changes in canopy base height were estimated from maximum branch torch heights with percent of canopy scorched also recorded. Due to smoke and poor lighting, visibility of the full crown can sometimes be difficult.

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

Understory Vegetation Structure and Loading

Understory vegetation was characterized in a 3 ft wide belt along three 50-foot transects before and after the fire. The fuel and vegetation transects were always in view of the video camera (which will be described below in the "Fire Behavior Measurements and Observations" section). Species, average height and percent cover (based on an ocular estimation) were 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) were estimated using coefficients developed for the BEHAVE Fuel Subsystem (Burgan and Rothermel 1984). Calculations were completed by spreadsheet (Scott 2005).

Surface and Ground Fuel Loading

Surface and ground fuels were measured along the same three 50-foot transects used to characterize understory vegetation. Surface fuel loadings (litter, 1-hr, 10-hr, 100-hr and 1000-hr time lag fuel classes and fuel height) 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, 6, and 12 ft. All measurements were taken both pre- and post-fire. These measurements were used to calculate surface and ground fuel loading (fuel/area) with basal area weighted species-specific coefficients (van Wagtendonk *et al.* 1996; 1998). Fuel consumption was the difference between pre- and post-fire measurements.

Terrestrial Laser Scanning

Agencies managing forest lands in California are working to better quantify and map forest vegetation, fuel loading, and carbon stocks and fuel consumption and carbon emissions from wildfires. High resolution 3D maps of forest structure (e.g., crown shapes, ladder fuels, and tree heights) based on TLS samples (Figure 4) will be related to airborne LiDAR data available for National Forests in California to refine maps. The mapping effort is led by the PSW Region's Remote Sensing Lab with TLS sampling led by collaborators at University of

Nevada-Reno. Based on experience with supporting TLS measurements on the 2018 Ferguson Fire, FBAT integrated a TLS sampling team of two red-carded personnel within its operations on the Walker Fire. The TLS crew scanned each plot from multiple perspectives after the core FBAT measurements were collected on pre-fire plots and, for burned plots, before core FBAT measurements were collected post-fire. Time required for scanning ranged from approximately 1.5 to 2.5 hours, increasing with tree density.

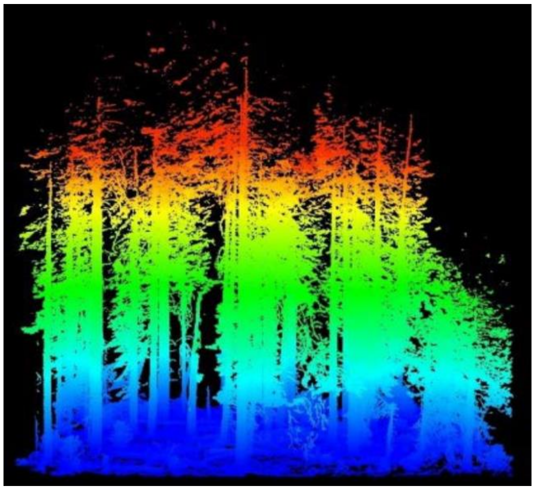

Figure 4. Three-dimensional visualization of a TLS plot dataset with the blue to red color ramp representing increasing height above terrain. Canopy and fuel characteristics will be described from these data.

Fire Behavior

At each plot, thermocouples, an eye-level anemometer, and a video camera were set up to gather information on fire behavior (Appendix A). The thermocouples arrayed across the plot captured date and time of fire arrival. Their location and distance from each other allowed rate of spread to be calculated. An anemometer at eye level recorded wind speeds leading up to the fire. The video camera was used to determine fire type, flame lengths, variability and direction of rate of spread in relation to slope and wind, flame duration, and wind direction. The camera is triggered by fire arrival at thermistors which are connected into a wire circuit that is placed around the plot.

Rate of Spread

Rate of spread was determined both by estimating rate of spread from video analysis (above) and by calculating rate of spread from fire arrival times at thermocouples in known positions. The data loggers that recorded thermocouple temperatures were buried underground with the thermocouple positioned at the surface of the fuel bed. Thermocouples recorded temperatures at two second intervals, allowing a precise measurement of fire arrival. The distances and azimuths among thermocouples were measured and these trigonometrical data and time of fire arrival were used to estimate rate of spread (Simard *et al.* 1984). Rate of spread can be calculated with any combination of three sensors forming a triangle (Figure 5). If more than one triangle of sensors triggered, all rates of spread were calculated, and the range was reported.

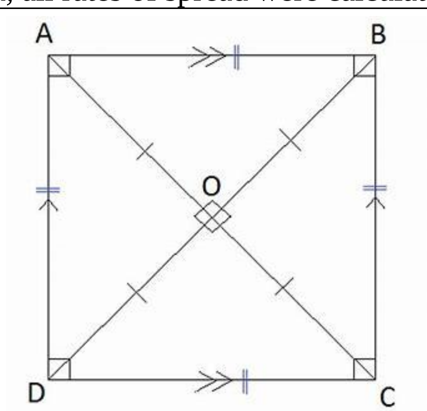

Figure 5. Rate of spread was calculated using geometric triangulation between five heat sensors (ABCD & O) at each plot (Simard *et al*, 1984).. Distances from the central to outer thermocouples is typically about 50 ft.

Fire Type

Fire type was 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 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 and Flaming Duration

Flame length was primarily determined from video footage. The metal poles in the video camera's field of view are marked in 1-foot increments, allowing an approximate flame length to be estimated. Flaming duration was based on direct video observation and can be supplemented by duration of flaming at thermocouples.

Plot Wind Speed

Wind data collected with cup anemometers placed 5 feet above ground at the locations of the camera and give an indication of the wind experienced at each plot as the fire passed through. These data are used in the BEHAVE fire model. The instrument is not fire hardened and is damaged and stops recording when moderate to intense fires arrive at its location. Wind data were recorded at 10 second intervals.

Fire Effects

Burn Severity

A rapid assessment of burn severity was completed along each transect and for the entire plot 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 (highest to lowest) when evaluating fire severity. FBAT uses the same coding matrix (Appendix E) but reverses the scale so that it is more intuitive, with 1 representing unburned areas and 5 representing high fire severity (Appendix E).

Tree impacts

Tree measurements included minimum and maximum char heights and canopy impacts. The combination of minimum and maximum char heights are a better reflection of fireline intensity than maximum char height alone (Inoue 1999). Canopy measurements included scorch (foliage killed but not consumed) and torch (foliage consumed) heights and the percentage of the canopy that was scorched or torched. Percentage scorch and torch values were determined using ocular estimations and heights were measured utilizing an instrument that combines a laser rangefinder and clinometer.

Soil heating

Soil temperature profiles were measured using a prototype device that is easier to use and provides less biased results than existing methods. This device provided measurements of mineral soil temperature at 2, 4, and 6 inch depths below the surface of the mineral soil. In conjunction with soil temperature measurements, forest floor and mineral soil samples were collected before and after fire to assess fire impacts on soil carbon, as well as nutrient cycling and microbial communities. These data are important for understanding changes to soil quality, which influences forest productivity and post-fire recovery of forest ecosystems. Sample analysis will be performed by collaborators at Michigan State University and University of Nevada-Reno.

Findings

Plot characteristics

All eight plots established on the Walker Fire were dominated by ponderosa pine but represented different fuel loadings, stand structures, treatment and wildfire fire histories (Table 1). Pre-fire data were collected at all eight plots and post-fire fuels and fire behavior data were collected at the three plots which burned (plots 4, 5, and 8). Specifically, plots 2, 4, and 5 (and probably plot 7) were burned at low severity in the 2007 Wheeler Fire while plots 1, 3, 6, and 8 were unburned in the Wheeler Fire but had varying treatment histories including prescribed fire for plot 1. Photographic documentation of pre- and post-fire vegetation may be viewed in Appendix C (if plot burned) or D (unburned plots). TLS measurements were made pre- and post-fire on all plots.

Table 1. Site description for eight FBAT plots sampled in the ponderosa pine forest in the vicinity of the 2007 Walker Fire. Latitude and longitude datum is WGS 84. Silvicultural and hazardous fuels treatment history was determined from the FACTS (Forest Service Activity Tracking System) database. Treatments were performed over areas much larger than FBAT plots and, as such, conditions within plots do not always represent average treatment conditions. Wildfire history was determined from perimeters available in the Wildland Fire Decision Support System (WFDSS).

Plot	Lat.	Lon.	Treatment history	Wildfire history	Slope (%)	Aspect (deg)	Elev. (ft)
1	40° 04.080	-120° 41.823	2009 thin & piling, 2011 pile burn, 2013 understory burn	None recorded	15	160	3851
2	40° 07.314	-120° 33.535	2008 salvage cut borders the plot	Low severity Wheeler Fire	14	80	5758
3	40° 06.489	-120° 33.309	Plot bordered the north side of 2002 precommercial thin	None recorded	8	170	5636
4[1]	40° 08.611	-120° 33.255	1996 commercial & precommercial thin	Low severity Wheeler Fire	7	154	5516
5[1]	40° 08.597	-120° 33.445	1992 cut, 2008 salvage cut, 2009 tree planting	Low severity Wheeler Fire	9	261	5681
6	40° 04.135	-120° 27.579	1986 cut, 1993 precommercial thin, 1998 commercial thin, 2002 precommercial thin, 2005 site prep for planting	None recorded	11	37	6247
7	40° 08.290	-120° 30.289	1975 cut, 1994 commercial & precommercial thin, 2003 precommercial thin	Low severity Wheeler Fire (probably)[2]	3	315	6061
8[1]	40° 06.999	-120° 31.756	No recorded activities	None recorded	7	34	5571

[1]Burned in the Walker Fire; [2]Bole charring in plot 7 is consistent with it having burned in the Wheeler Fire although it is outside the recorded perimeter.

Pre- and Post-Fire Vegetation and Fuels

Overstory Vegetation Structure and Crown Fuels

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 (CBH), or the bottom of the tree canopy, is important because it is an indicator for how likely passive (torching) or active crown fire behavior would be. As stated in Scott and Reinhardt (2001), "Defined in terms of its consequences to crown fire initiation, CBH is the *lowest* height above the ground at which there is sufficient canopy fuel to propagate fire vertically through the canopy." Canopy base height is defined in FVS as the height where the 13-foot running mean canopy bulk density is greater than 30 lbs/acre/ft, or 0.111 kg/m^3. Canopy Bulk Density (CBD) is the mass of canopy fuel available per unit canopy volume (Scott and Reinhardt 2001).

Forest treatments that target canopy base height (CBH) and canopy bulk density (CBD) can be implemented to reduce the probability of crown fire (Graham *et al.* 2004). CBH in plots that burned previously either in the 2007 Wheeler Fire (plots 2, 4, 5, and 7) or in prescribed fire (plot 1) averaged 25 ft (range 18-40 ft) while CBH's in other plots (untreated and mechanically treated) averaged 17 ft (range 1-30 ft) indicating the potential utility of low severity fire as a treatment in preventing future canopy fires. Mechanically treated plots that had not experienced recent fire can vary substantially in CBH depending on specifics of the treatment with mechanically treated (yet unburned) plots 6 and 3 having CBH's from 1 to 30 ft, respectively (Table 2).

Table 2. Canopy characteristics for plots inventoried on the Walker Fire. Canopy height and cover are estimated directly from plot data. Canopy height is the average across all overstory trees in the sample. QMD, tree density, basal area, canopy base height, and canopy bulk density are FVS outputs based on plot data.

Site	Overstory[1] density (trees/acre)	Pole[2] density (trees/acre)	QMD (in)	Basal Area (ft²/acre)	Canopy Cover (%)	Canopy Height (ft)	Canopy Base Height (ft)	Canopy Bulk Density (kg/m³)
1	79	96	9	76	46	57	18	0.03
2	98	0	16	144	62	68	23	0.07
3	89	0	16	125	31	76	30	0.05
4[3]	85	0	19	160	23	77	24	0.05
5[3]	197	0	14	199	46	66	19	0.08
6	62	**407**	8	164	38	90	**1**	0.08
7	86	0	20	179	31	89	40	0.04
8[3]	415	**576**	9	468	62	71	**6**	0.27

[1]≥6 in DBH; [2]<6 in DBH; [3]Burned in the Walker Fire.

Thinning to reduce canopy bulk density to less than 0.10 kg/m^3 is generally recommended to minimize crown fire hazard (Agee 1996, Graham *et al*. 1999); below this point, active crown fire is unlikely (Scott and Reinhardt 2001). Only plot 8, the plot with no wildfire or treatment history, had a canopy bulk density above the 0.10 kg/m^3 threshold (Table 2). Plot 8 also had relatively high canopy foliage loadings (Table 3). It should be noted that plot 8 was located in a clump of uneven-aged trees and represented the upper end of tree density across the surrounding stand that was characterized by patchy tree distribution. The head fire across plot 8 resulted in a group torching event while the low-intensity fire across plots 4 and 5, which had higher canopy base heights, had no discernable impacts on the canopy. Biomass is presented in Table 3 for later comparison with TLS-derived estimates of forest carbon stocks.

Table 3. Canopy biomass predictions pre-Walker Fire based on tree sampling and the Forest Vegetation Simulator (FVS) analysis. No snags were present on any plot.

Plot	Biomass (tons/acre)				
	Snag	Foliage	Live (<3 in)	Live (≥3 in)	Total
1	0	2	8	25	36
2	0	3	13	47	64
3	0	2	13	42	58
4[1]	0	4	19	57	79
5[1]	0	5	19	58	82
6	0	6	23	67	96
7	0	3	20	70	92
8[1]	0	**15**	46	142	203

[1]Burned in the Walker Fire.

Surface, Ground, and Understory Vegetation Fuel Loading

The three plots located inside the 2007 Wheeler Fire perimeter (plots 2, 4, and 5 and probably plot 7) had the lowest total ground, surface, and understory fuel loads (Table 4). The two plots with the highest total fuel loadings (plots 6 and 8) had either no recorded history of fire (both plots) or no mechanical treatment in 14 years. Except for plots burned in the 2007 Wheeler Fire, duff was the predominant fuel. Duff loadings were particularly high in plots 6 and 8. Shrubs were abundant on plot 6, but live understory fuels were otherwise of secondary importance. A partial species list for grasses, forbs, shrubs, and trees in the understory is provided in Appendix C.

Table 4. Surface fuels and fuel bed depths for plots inventoried on the Walker Fire. Note the high total ground and surface fuel load in the two plots (6 and 8) with no evidence of recent fire. Over 88% of this is accounted for by the duff and litter.

Plot	Mean Fuel Loading (tons/acre)									Fuel Bed Depth (in)
	Duff	Litter	1-hr	10-hr	100-hr	1000-hr	Forb & Grass	Shrub & Seedling	Total	
1	9.2	1.8	0.04	0.41	0.37	3.82	0.008	0.002	14.4	10.67
2	6.1	2.3	0.19	0.77	1.70	0	0.001	0.353	7.7	23.17
3	10.3	3.2	0.15	0.56	0.73	0.27	0.001	0.047	15.0	8.33
4	2.5	3.2	0.09	0.14	0	0	0.054	0.194	6.1	5.17
5	1.1	2.2	0.04	0.49	0.37	3.82	0.01	0.144	6.8	9.67
6	**26.0**	**6.0**	0.07	0.70	1.11	0	0.027	2.273	**36.2**	8.50
7	3.4	2.2	0.02	0.14	0	0.27	<0.001[1]	0.028	5.8	5.33
8	**20.3**	**2.1**	0.09	0.63	0	0	<0.001[1]	0.005	**23.1**	8.00

[1]Trace amount.

Fire Behavior

Narrative

The narratives below describe fuels and fire spread through the plots. For general plot locations, see Figures 1 and 2. Overall, plot 8 had a higher fuel load and more extreme fire behavior than plots 4 and 5 (Table 5). The least severe fire occurred on plot 5 as a major storm approached on the morning of 16 September. Rain extinguished the fire as it was spreading through the plot. Weather was windy and dry (red flag conditions) during daylight on 15 September when plots 4 and 8 burned. All plots were in ponderosa-pine dominated stands.

Table 5. Fire type, flame lengths, and rates of spread (ROS) for FBAT plots burned on the Walker Fire. For rate of spread, a flame front moving at 1 chain/hour is roughly one foot/minute. Sensor failure in the case of plot 8 and a partially burned plot 5 prevented ROS estimation from sensors.

Plot	Fire Type	Flame Length (ft)	Flame Angle* (%)	ROS (ch/hr) Camera	ROS (ch/hr) Sensors	Date & Approximate Arrival Time	End of Active Consumption
4	Backing surface fire	1-2	75	0.9	1.5 – 2	9/15/2019 1430 PDT, arrived at NE corner of plot	9/15/2019 1555 PDT, moved through SW corner
5	Plot partially burned, creeping surface fire extinguished by rain	0.5	N/A	<1	N/A	9/16/2019 0749 PDT, arrived at NE corner of plot	Wetting rain extinguished flaming after approx. 1/3 of the plot had burned
8	Surface fire both creeping and running with isolated torching	0.5 - 15	N/A	4 - 5	N/A	9/14/2019 1500 PDT, arrived at NW corner of plot	Flaming front exited plot at approx. 1530, duff consumption continued for several hours

<u>*Plot 4*</u>

Plot 4 is located west of USFS Rd 26N07, south of Rd 27N02Y and north of Rd 27N41. Evidence of a low severity burn during the 2007 Wheeler Fire was present as well as past thinning (Table 1). Fuel loading was generally low and there was little understory vegetation (Table 4). The plot camera recorded backing fire through the plot with flame lengths around 1 ft, occasional wind shifts created short periods of flanking/head fire with flame lengths 2 - 3 ft (Table 5). Sensors placed at known locations within and around the plot recorded rates of spread between 1.5 – 2 ch/hr. Surface fuels were generally consumed in the slow-moving fire (Tables 6 and 7). Bole scorch resulted from flame "eddying" around trees as the fire backed into the wind (Table 8). During the time plot 4 burned, the Coyote RAWS reported temperature 73° F, relative humidity (RH) 14% and 10hr fuel moisture 4%. Pierce RAWS reported winds from the southwest at 18 mph with gusts to 33 mph.

Plot 5
Plot 5 is located north of USFS Rd 26N41 west of its intersection with Rd 26N07 between Frazier Cabin and Murdock Crossing (Figure 1). Evidence points to a previous low severity burn during the Wheeler Fire (Table 1). Fire reached plot 5 in the morning just before wetting rain on 9/16; precipitation halted fire spread about 1/3 of the way through the plot. The plot camera recorded creeping and backing fire entering the plot from the NE with flame lengths less than 0.5 ft prior to the rain (Table 5). Because the fire did not cross the entire plot, rate of spread could not be determined from the sensors. During the time Plot 5 burned, the Coyote RAWS reported temperature 52° F, RH 68%, and 10hr fuel moistures 6%. Pierce RAWS reported winds from the west-northwest at 4 mph with gusts to 10 mph.

Plot 8
Plot 8 is located just north of USFS Rd 26N15 near Murdock Crossing (Figure 1). This plot had greater fuel loading when compared to the other burned plots (Table 3) and no record of fire or fuels treatment (Table 1). Past logging was evident by old stumps with advanced rotting/decay. Backing fire flame length was 1 – 2 ft with wind shifts and heat pulses resulting in flame lengths of 4 – 6 ft along with some torching (Table 5). Backing/flanking fire burned into the plot from the northwest. Surface fire predominated, with occasional single tree and group torching. Surface fuels were mostly consumed (Tables 6 and 7). Char and scorch heights on trees was dependent on proximity to group torching (Table 8). Low duff moisture contents and high duff loadings supported sustained duff smoldering on plot 8. Drone imagery from plot 8 approximately 2.5 hours after ignition illustrate the sustained heating from duff consumption (Figure 6). During the time plot 8 burned, the Coyote RAWS reported temperature 82°, RH 11%, and 10hr fuel moistures 4%. Pierce RAWS reported winds from the west-southwest at 11 mph with gusts to 26 mph. Because of equipment failures with the primary plot camera and thermocouple loggers, fire behavior was on plot 8 was estimated from time-lapsed imagery, using a backup camera installed in an opening near the plot.

Figure 6. Infrared radiation from duff consumption imaged by a California Air National Guard drone on plot 8 at 19:29 PDT - about 2.5 hours after the flaming front spread through the plot. The crosshairs near the center of the image are close to plot center. Cool areas are dark while hot areas (e.g., duff and log consumption) are bright.

Fuel Consumption
Consumption was by far highest on plot 8 (Table 6), which had no recent history of treatment or recorded wildfire (Table 1). The high pre-fire fuel loads allowed more total tons/acre to be consumed (Table 6). The fire also consumed a large percentage of the existing fuel for most fuel classes (Table 7). Duff consumption in plot 8 is probably artificially low given that depths were measured before rainfall when remaining duff (particularly the upper layer of less consolidated material known as the fermentation layer) was charred and underlying ash was not blown away, compacted, or washed into the soil.

In contrast to plot 8, plots 4 and 5 had a history of low severity understory burning during the Wheeler Fire (Table 1), low pre-fire fuel loadings (Table 4), and exhibited minimal total fuel consumption (Table 6). Much of the fresh litter, 1-hour fuels, forb and grasses present were still consumed in plot 4's backing surface fire. The percentages of duff, litter, and woody fuels consumed on plot 5 are low given that there was consumption only on one transect while consumption is calculated for the entire plot.

Table 6. Duff and surface fuel consumption (tons/acre). Only one transect was burned on plot 5 resulting in low plot-level consumption.

Plot	Mean Fuel Consumption (tons/acre)								
	Duff	Litter	1-hr	10-hr	100-hr	1000-hr	Forb & Grass	Shrub & Seedling	Total
4	0	2.61	0.09	0	-0.003	0	0.05	0.127	2.9
5	0.35	0.25	0.01	0.21	0	1.07	0.01	0.002	1.9
8	10.37	2.06	0.09	0.63	0	0	0	0.001	13.2

Table 7. Duff and surface fuel consumption (%).

Plot	Mean Fuel Consumption (%)							
	Duff	Litter	1-hr	10-hr	100-hr	1000-hr	Forb & Grass	Shrub & Seedling
4	0	82	100	0	N/A	N/A	100	53
5	33	11	25	43	0	44	100	1
8	51	100	100	100	N/A	N/A	100	20

Given an average of 27% torch on trees in plot 8 (Table 8), an estimate of canopy fuel consumption is 27% of 15 tons/acre of green needle loading (Table 3) or 4 tons/acre. As such, canopy fuel consumption was about 30% of ground and surface fuel consumption on plot 8. There were no visible impacts on the canopies in burned plots 4 and 5 and, thus, no consumption above the relatively small amount of consumed ground and surface fuels.

Fire Effects

We collected post-fire measurements one to two days after fire in each burned plot, allowing for combustion to complete. Measurements included: soil heating, NPS severity ratings (soil & understory, Appendix D), char height, maximum and percentage crown scorch (foliage brown), and torch heights (foliage consumed). These metrics combined give an overall picture of the extent of fire impacts.

In plot 4, the backing surface fire (Table 6) had low to moderate severity effects in the soil and understory (Figure 7 and Table 8). Bole charring occurred up to 4 feet and was difficult to assess because of the substantial amount of char remaining from the 2007 Wheeler Fire. There was no measurable scorching or torching on any of the overstory trees (Table 8, Figure 8).

In plot 5, the creeping fire (Table 6) was suppressed by rain after burning only 1/3 of the plot. Soil and substrate severity ratings were negligible (Table 8, Figures 7 and 8).

In plot 8, the surface fire and high levels of duff consumption resulted in moderate to high severity ratings for the substrate and understory effects (Tables 6 and 8, Figure 7). Much of the canopy was either scorched or torched (Figure 8), with average torch height of 33 ft (Table 8).

Table 8. Walker Fire average bole char height, percent scorch and torch, and substrate and vegetation severity ratings. Substrate and severity ratings range from 1 (no fire) to 5 (extreme, see Appendix D). Scorch and torch

heights are not reported because much of the canopy impacts were the result of a group torching event that impacted the sides of the canopies of adjacent trees. Thus, scorch and torch heights are not meaningful.

Plot	Bole char (ft.)		Scorch (%)	Torch (%)	Severity	
	Min	Max			Substrate	Vegetation
4	0	4	0	0	2.1	3.0
5	0	0	0	0	1.1	1.3
8	7	29	63	27	3.4	3.2

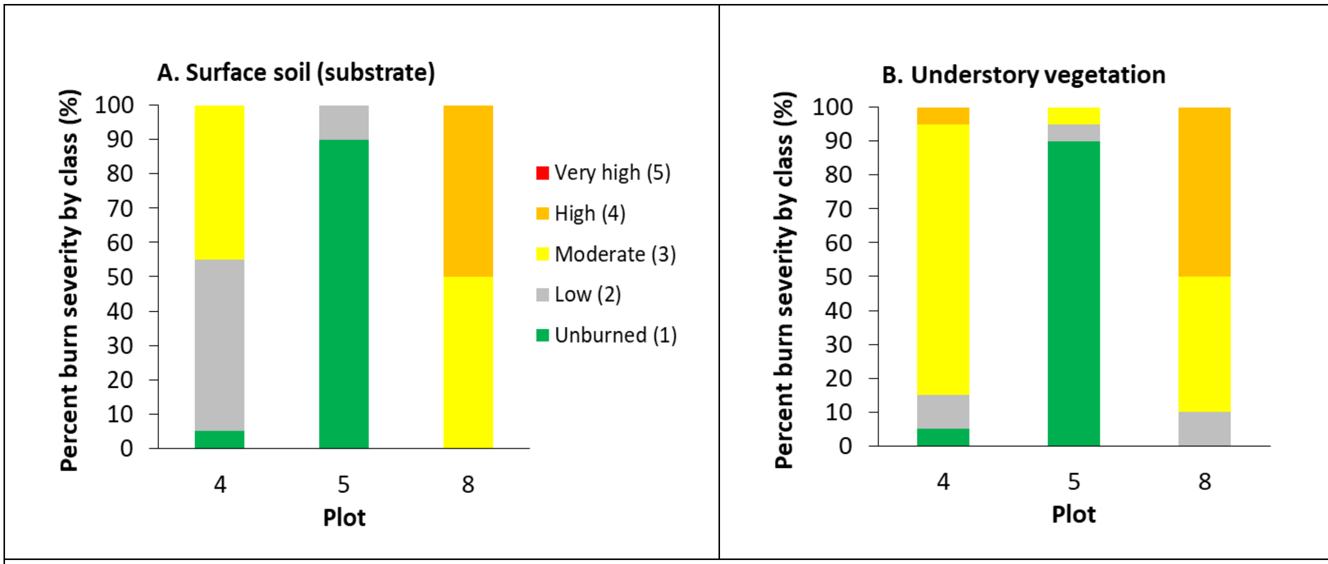

Figure 7. Soil and understory vegetation severity on burned plots.

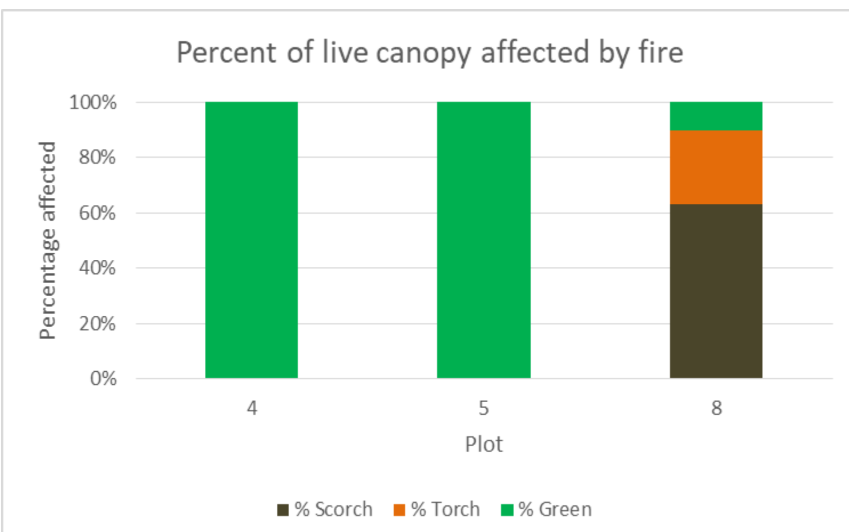

Figure 8. Percentage of the canopy on burned plots that was scorched or torched during the Walker Fire.

Soil heating reflected contrasting duff loadings and consumption on plots 4 and 8. On plot 4, duff consumption was absent to minor and mineral soils experienced a minor but detectable increase in temperature at 2 and 4 in. depths. In contrast, soils below deep duff that consumed on plot 8 experienced high levels of soil heating over a long duration (Figure 9a). In general, temperatures above 140° F cause immediately lethal effects on (non-dormant) plant tissues and microbes. This temperature threshold was reached at our deepest temperature sensor (6 inches depth) in plot 8, whereas the temperature did not reach the lethal threshold even at 2 inches depth in plot 4. As expected, soil temperature rise caused by solar radiation (see plot 4) and fire are dampened as depth below the duff increases.

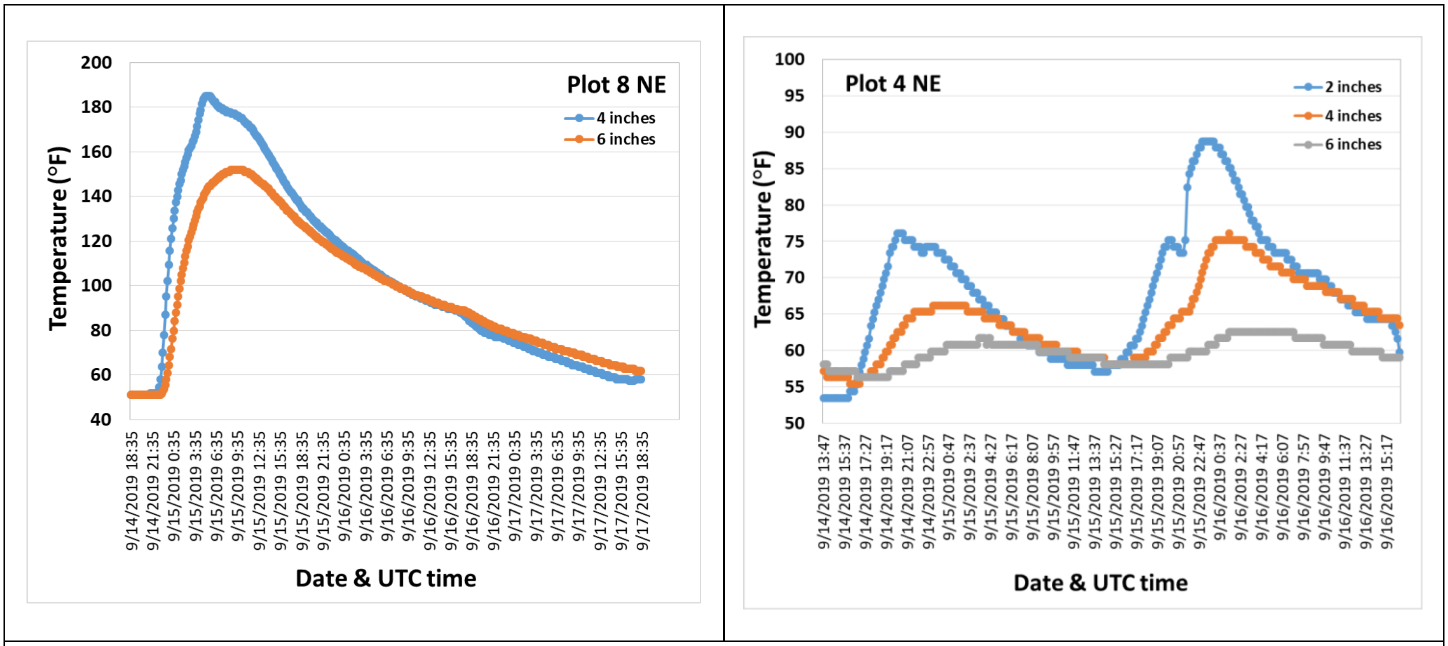

Figure 9. Soil temperature profiles from burned plots 4 and 8 at two, four, or six inches below the duff. Plot 4 (right panel) shows the daily cycle of soil heating one day prior to burning as well as the additional rise in temperatures due to the fire on the second day. Plot 8 (left panel) shows extensive and prolonged soil heating, with soil still cooling on the second day after the flame front had burned through the plot.

Conclusions

FBAT results from the Walker Fire add to a consistent narrative about the effectiveness of low-severity understory-burning in reducing fuel loads and moderating subsequent fire behavior and effects in open ponderosa pine stands. FBAT collected data on pre-fire fuels and vegetation on eight plots during the Walker Fire and active fire behavior, fuel consumption, and fire effects on three of those plots that burned. In addition to the standard FBAT plot measurements, TLS data were collected pre- and post-fire in support of the PSW Region's ongoing efforts to map forest vegetation, fuels, and carbon stocks and wildland fire emissions across California National Forests. Low severity effects of the 2007 Wheeler Fire in ponderosa pine on mild terrain were particularly effective at reducing fuels and moderating fire behavior and effects during the Walker Fire. In contrast, two plots in areas with no recorded fire history (prescribed or wildfire) had high surface and ground fuel loads as well as high densities of ladder fuels that, in the one such plot that burned, resulted in deep duff consumption, extensive soil heating, group torching behavior, and high levels of tree injury and expected tree mortality.

FBAT met objectives on the Walker Fire to the extent that we safely inventoried as many pre- and post-fire plots as possible. We had limited success positioning plots so that they would burn because of successful suppression, moderate weather, and wetting rain on the 16th of September that all reduced fire growth after early runs. Success in getting plots burned generally increases the earlier FBAT arrives on a fire. TLS measurements were successfully accomplished on all pre- and post-fire plots. We tested new equipment that promise to reduce plot setup time and increase information return. New cameras were easy to use, reduced plot setup time, and triggered successfully except in one instance. The trigger failure was a problem that we will be able to solve easily. Soil temperature measurement devices were easy to use and provided good information but were difficult to install in hard soils, a problem that we can now work to fix. Data will be added to the FBAT archive and will be useful in any future study of fuel treatment impacts on fuels, fire behavior, and fire effects. This report will help guide use of the archive.

Rapid fire growth and severe effects occurred on the Walker Fire where there was alignment of prevailing winds and drainages and spread through shrub-dominated fuels resulting from the 2007 Wheeler Fire. The risk of severe effects because of untreated fuels and positive feedbacks among fires is expected to continue into the future given current fire and climate trends. A discussion of the Walker Fire in the context of the 2007 Wheeler Fire is provided in Appendix F. FBAT worked on both fires.

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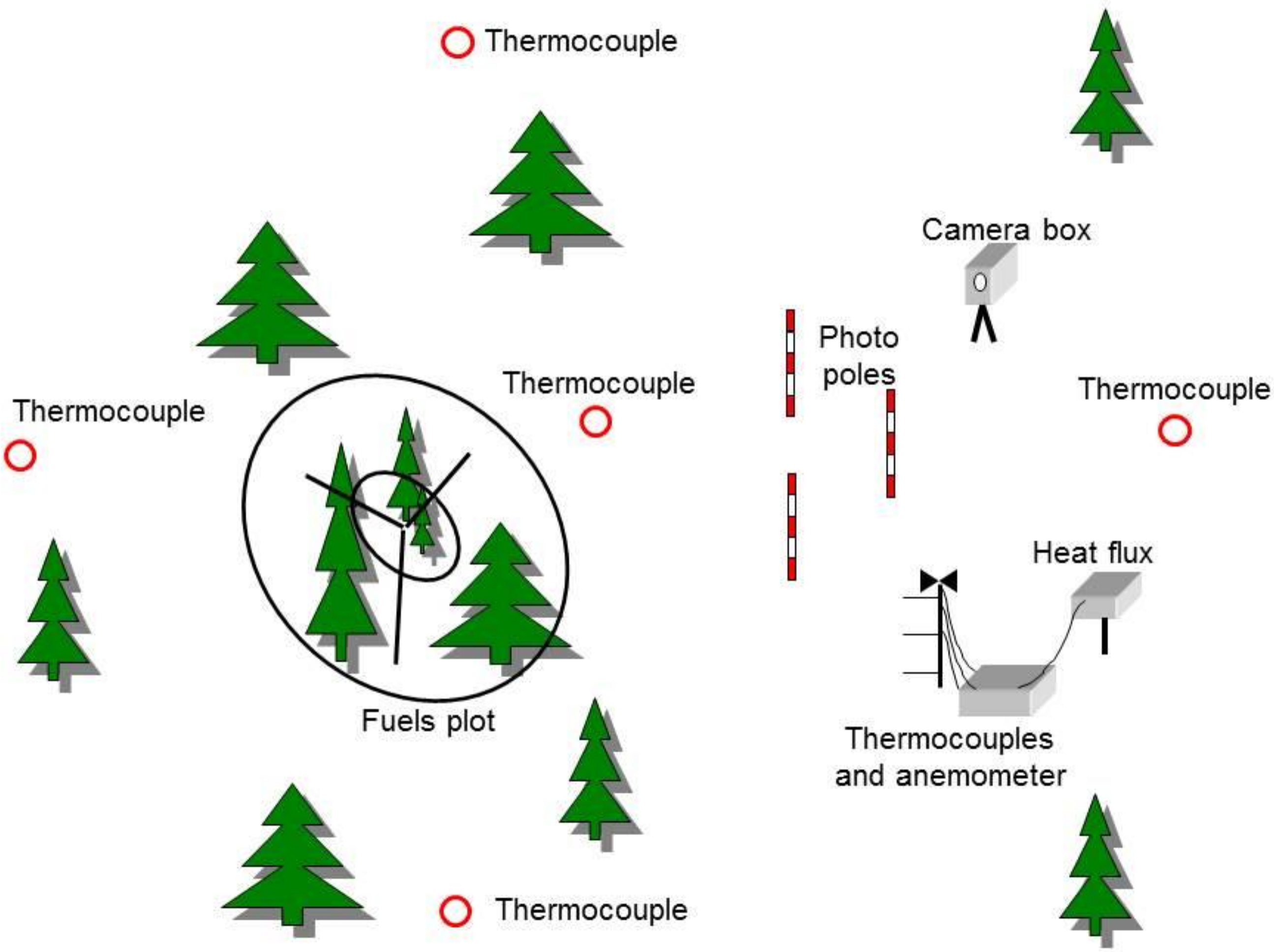
Appendices
A. FBAT Plot Layout
FBAT selects study sites to represent a variety of fire behavior and vegetation/fuel conditions. Plot selection priorities are also based on safe access to areas that would most likely be burned over within the timeframe that FBAT would be at the incident. Within each plot both fuels and fire behavior data are collected. A graphic of a typical plot set up is shown below (Figure 1). Plot layout changes based on terrain, fuels, and additional objectives (Terrestrial Laser Scanning, soil sampling, etc.). No Fire Behavior Package (heat flux) was used on the Walker Fire.



B. Plot Species List

Grass, forb, shrub, and tree species presence along understory fuel transects in plots sampled on the Walker Fire. Trees include individuals present as seedlings and saplings. Presence is indicated by a “1”. Total number of species by lifeform is provided at the end of each lifeform’s section of the table. Unknown species are not included. Species lists for plots 1-3 and 8 are not complete while lists for plots 4-7 are close to complete. Species abbreviations are composed of the first two letters of the genus and specific epithet.

	Plot							
Lifeform and Species	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Grasses								
Agoseris spp.				1				
ANRO		1						
Astragalus spp.				1				
Bromus spp.							1	
BRTE	1			1	1		1	
Carex spp.				1	1		1	
Festuca spp.							1	
Phlox spp.		1						1
Pterospora spp.		1						
Poa spp.		1	1	1	1		1	
PRTE							1	
SIHY		1	1	1	1	1	1	
Stipa spp.		1		1	1			
VUMI				1	1			
Number of species	**N/A**	**N/A**	**N/A**	**8**	**6**	**1**	**7**	**N/A**
Forbs								
Achillea spp.			1					
ACMI					1			
Agoseris spp.				1	1	1	1	
ANRO				1				
Antennaria spp.							1	
APEN						1		
Asteraceae			1					
Astragalus spp.	1			1			1	
Castelija spp.						1		
CEVI					1			
Cirsium spp.			1		1			
COGR	1		1	1	1		1	
COPA				1	1	1	1	
Cryptantha spp.			1				1	
EPMA					1			
EPMI			1	1	1	1	1	
Fragaria spp.	1		1					
FUGR				1	1			
Gallium spp.	1					1		
Hieracium spp.					1	1		
Lathyrus spp.							1	
Lupinus spp.			1	1			1	
Osmorhiza spp.						1		
Penstemon spp.					1	1		
PHGR				1	1		1	
PNGR							1	

PODO							1	

Lifeform and Species	Plot							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Forbs, continued								
Scuttelaria spp.							1	
Senecio spp.					1		1	
Stellalroa spp.						1		
Sumariaceae spp.							1	
TAOF			1					
Number of species	**N/A**	**N/A**	**N/A**	**9**	**13**	**10**	**15**	**N/A**
Shrubs								
ARPA					1	1		
ARTR								1
BAWY		1	1	1	1	1		1
CEPR		1	1	1	1	1	1	
CEVE					1	1		
CHVI			1	1			1	
PSME					1			
PUTR		1	1	1	1		1	1
QUCH	1							
Symphoricarpos spp.						1		
Number of species	**N/A**	**3**	**4**	**4**	**6**	**5**	**3**	**3**
Trees								
ABCO						1		
PICO		1	1					
PIPO	1			1	1	1	1	
Prunus sp.						1		
QUKE	1							
Number of species	**2**	**1**	**1**	**1**	**1**	**3**	**1**	**0**

C. Burned Plots: Paired Pre- and Post-Fire Photographs

See next page.


Plot 4 Transect 1, 50-0 Pre

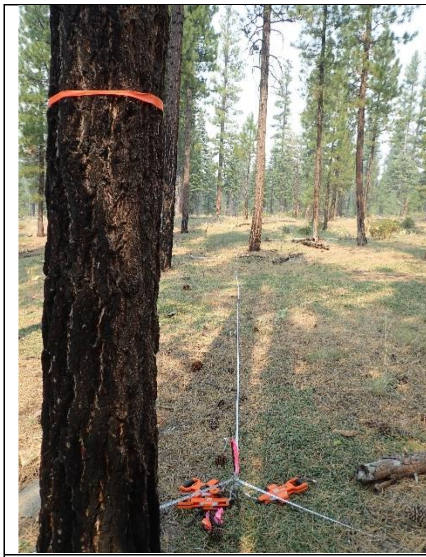

Plot 4 Transect 1, 50-0 Post


Plot 4 Transect 2, 50-0 Pre


Plot 4 Transect 2, 50-0 Post


Plot 4 Transect 3, 50-0 Pre


Plot 4 Transect 3, 50-0 Post



Plot 5 Transect 1, 50-0 Pre

Plot 5 Transect 1, 50-0 Post

Plot 5 Transect 2, 50-0 Pre

Plot 5 Transect 2, 50-0 Post

Plot 5 Transect 3, 50-0 Pre

Plot 5 Transect 3, 50-0 Post

	
Plot 8 Transect 1, 50-0 Pre	Plot 8 Transect 1, 50-0 Post

	
Plot 8 Transect 2, 50-0 Pre	Plot 8 Transect 2, 50-0 Post

	
Plot 8 Transect 3, 50-0 Pre	Plot 8 Transect 3, 50-0 Post

D. Photographs of Unburned Plots

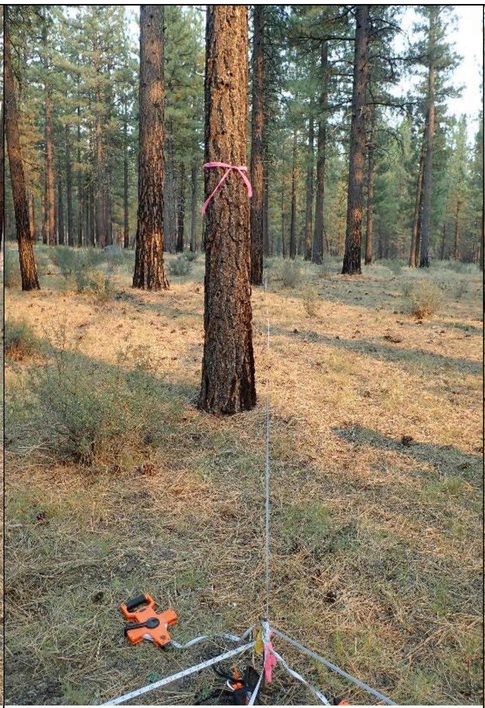
See next page.

		
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 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

E. NPS Burn Severity Coding Matrix

Table E1. Burn severity coding matrix from the National Park Service (USDI 2003).

Code	Forests		Shrublands	
	Substrate	**Vegetation**	**Substrate**	**Vegetation**
Unburned (1)	not burned	not burned	not burned	not burned
Scorched (2)	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 (4)	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 (5)	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

F. What the Walker & Wheeler Fires Suggest About the Future

The Energy Release Component (ERC, Figure F1) is an index used to describe potential fire energy and is shown for the Walker and 2007 Wheeler Fires based on data from the Coyote Remote Access Weather Station (RAWS). On Sept 6th, the Walker Fire made a large run up Indian Creek drainage. The ERCs before and during the Walker Fire were below average and were likely not the only factor contributing to the run. The alignment of 32 mph southwest winds with the Indian Creek drainage, as well as relatively continuous and densely forested fuels lower in the drainage, likely allowed the fire to gain its initial momentum. As the fire burned further up the drainage on the 6th and 7th, it encountered continuous shrub fuels and high loadings of coarse woody debris that resulted from the Wheeler Fire. The dip in ERC on September 10th was due to a rainfall event which increased the relative humidity and fuel moistures. Although the ERC's did climb again after the rainfall event, suppression resources were able to take advantage of the decreased fire behavior to largely contain and maintain control of the fire through another bout of higher ERC's and red flag winds on September 15th.

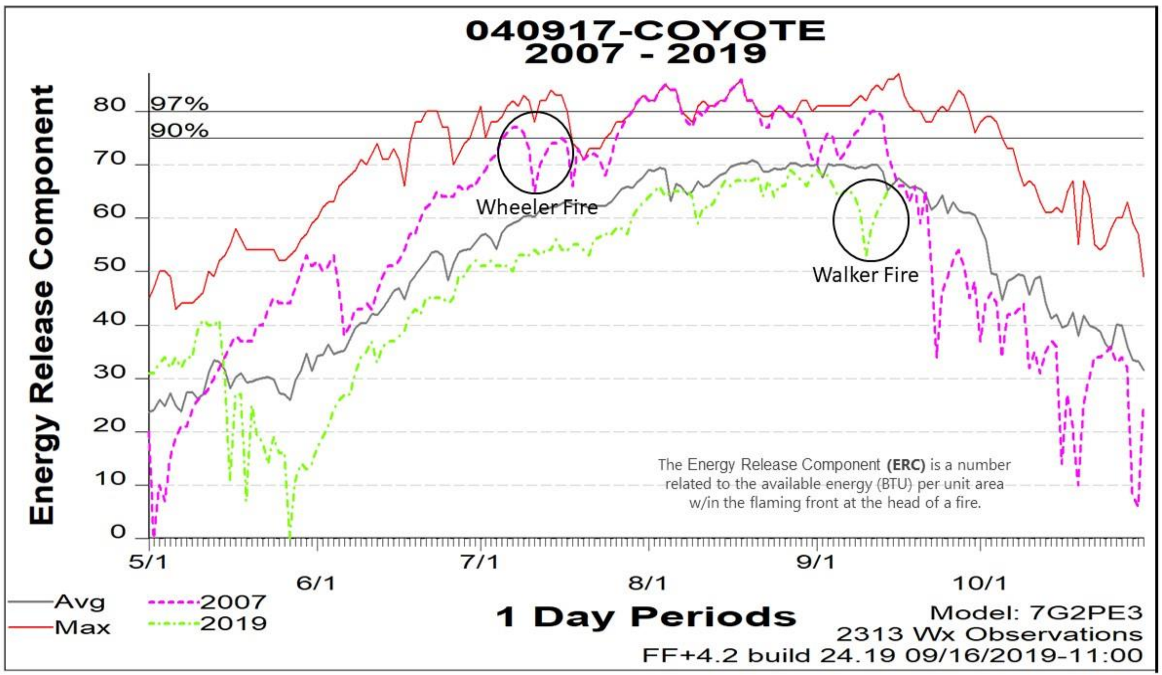


Figure D1. ERC plot showing the 2007 fire season (Wheeler Fire) and the 2019 season (Walker Fire) through 15 September. The 2019 ERC dropped quickly on 16 September with wetting rain.

Twelve years ago, the ERC's were above the 90th percentile in early July when the 2007 Wheeler Fire made a large run up Indian Creek drainage and developed a pyro cumulus column which then collapsed, driving the Wheeler Fire N, S and E on July 7th, 2007. Prior to this date, the area had not had a fire in over 100 years. Many stands were dense, with abundant surface and ladder fuels. The long-unburned surface and ladder fuel loadings provided enough fuels for fire to ignite canopy fuels. Densely packed trees crowns in untreated stands had enough canopy fuel loadings to readily carry canopy fire. This contributed to intense and highly severe fire behavior during the large run on July 7th. Vegetation was almost completely consumed and most trees in dense stands were killed, resulting in the area being dominated by shrubs in 2019. Fuel hazard, fire behavior, and effects were reduced in treated areas (Antelope Fire FBAT Report).

Lessons pertaining to historic fuels, forest and fire management leading up to the Wheeler and Walker Fires, and the interaction between these two fires, give us insight into how to manage fuels and what we might see repeated in future fires. The previously heavy fuels and dense forest in the SW-NE oriented Indian Creek drainage burned very intensely in a single day's run and resulted in high severity effects and shrub dominated fuels a decade after the Wheeler Fire. The continuous shrub fuels carried fire well in the Walker Fire, where moderately dry and warm weather set up with prevailing SW winds. Fires in continuous fuels aligned with wind and terrain can be difficult to control until either winds subside or the fire burns past the aligned drainage. It is possible this SW Indian Creek drainage will be prone to large, intense fire when fire weather and SW winds align again in the future, creating a vegetation type conversion where fire is too frequent and intense in brush fuels to allow establishment of trees.

Outside the brush-dominated drainage, the Walker Fire progression slowed when it encountered areas burned with lower severity in 2007 Wheeler northeast of Babcock Peak. Where these areas did burn again, they burned with low intensity and severity (see Table 8, Figures 7 and 8). It was in these areas and in contrasting areas outside the Wheeler Fire's footprint that FBAT focused its sampling effort on the Walker Fire.

G. The Fire Behavior Assessment Team

The Fire Behavior Assessment Team (FBAT) supports the USFS strategic goal of increasing treated acres through information delivery to land and fire managers and by its support for applied science on wildfires and prescribed fires. FBAT specializes in coordinated measurements on active wildfires and prescribed fires. Standard fuel and vegetation sampling methods are used pre-fire; fire behavior characterization is done with fire-resistant sensors and 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 energy transfer; and post-fire assessments are based on standard fuel consumption and fire effects sampling methods. Information is delivered to incident teams and affected land management units and data are archived in the USFS Research Data Archive to support development of fire behavior and fire effects decision tools; foster better understanding of wildland fire dynamics across the range of forest conditions and weather; and support training, safety, education, and outreach. FBAT is guided by an advisory group and receives financial and other support from the USFS Enterprise Program, National Forest System, Fire & Aviation Management, and Research & Development.

FBAT continues to build a dataset of coordinated fuels, fire behavior, and fire effects measurements. FBAT data have been used in refereed studies assessing modeled fuel consumption and emissions (Lydersen and others 2014) and black carbon sequestration (Miesel and others 2018). FBAT prepares reports on individual fires for host units summarizing fuels, fire behavior, and fire effects and provides case studies on fuel treatment effectiveness. FBAT active-fire video has supported training, education and public relations activities. On request, FBAT delivers fuels, fire weather, and fire behavior information daily to Incident Management Teams during assignments. Core FBAT measurements are sometimes used to support add-on projects including, currently, support for the USFS Pacific Southwest Region's (Region 5's) efforts to map vegetation, fuels, and carbon stocks and emissions from wildland fires.

FBAT has worked safely and effectively on over 25 wildfire incidents. Teams are composed of fireline-qualified technical specialists and experienced fire overhead. The operations lead is, at minimum, crew boss qualified, and more often, division supervisor or taskforce lead qualified. The science lead coordinates measurement activities on an assignment. The team can vary in size from 5-10 members, depending upon availability and needs. Most team members are USFS employees while other federal agencies and AD firefighters are also represented. FBAT can be ordered through ROSS through name-requests. For information and ordering, please contact Matthew Dickinson (FBAT Lead, 614-556-2271 [cell] or matthew.b.dickinson@usda.gov) or Carol Ewell (FBAT Assistant Lead, 530-559-0070 [cell], carol.ewell@usda.gov, or via the Stanislaus NF dispatch [209-532-3671 x212]).