Effectiveness and longevity of fuel treatments in coniferous forests across California

Managers' Report: Six Rivers National Forest

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Integrating science, technology and fire management.

Wildland Fire Management RD&A

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Background

Longevity of fuel treatment effectiveness to alter potential fire behavior is a critical question for managers preparing plans for fuel hazard reduction, prescribed burning, fire management, forest thinning, and other land management activities. Results from this study will help to reduce uncertainty associated with plan prioritization and maintenance activities. From 2001 to 2006, permanent plots were established in areas planned for hazardous fuel reduction treatments across 14 National Forests in California. Treatments included prescribed fire and mechanical methods (i.e., thinning of various sizes and intensities followed by a surface fuel treatment). After treatment, plots were re-measured at various intervals up to 10 years post-treatment. Very few empirically based studies exist with data beyond the first couple of years past treatment, and none span the breadth of California's coniferous forests. With the data gathered, this research aimed to meet three main objectives:

Objective 1) *Determine the length of time that fuel treatments are effective at maintaining goals of reduced fire behavior, by*

- *a) measuring effects of treatments on canopy characteristics and surface fuel loads over time, and*
- *b) modeling potential fire behavior with custom fuel models.*

Objective 2) *Quantify the uncertainty associated with the use of standard and custom fuel models.*

Objective 3) *Assess prescribed fire effects on carbon stocks and validate modeled outputs.*

This managers' report is meant to compliment the final report to the Joint Fire Science Program and supply project specific information that is not included in the regional assessment. This report includes a summary of Key Findings and Management Implications from the regional study as well as individual Forest-level information for each plot (i.e., project history, map, navigation directions, plot level findings, and plot protocol). For your use, we included a number of supplementary files with the digital version of this report. Included on the thumb drive are the following also described in Appendix A:

- Final report to the JFSP
- FVS Input database for your Forest for all projects (database file)
- Photo pairs for the plots on your Forest (power point file)
- Plot maps for each project on your Forest (pdf file)
- GIS shapefile with the plots on your Forest

All datasets for the regional project were input into the FFI (Feat/FIREMON Integrated) tool (www.frames.gov/partner-sites/ffi/ffi-home/) for future use and comparisons. Please contact Nicole Vaillant (nvaillant@fs.fed.us) for more information on obtaining the FFI data or other questions.

Key Findings

Objective 1- Determine the length of time that fuel treatments are effective at maintaining goals of reduced fire behavior, by measuring effects of treatments on canopy characteristics and surface fuel loads over time, and modeling potential fire behavior with custom fuel models.

Results have shown initial reductions in surface fuels from fire treatments recover to pre-treatment levels by 10 yr post-treatment. Mechanical treatments continue to have variable effects on surface fuels. With the exception of mechanical treatments in red fir, both treatment types resulted in increased live understory vegetation by 8 yr post-treatment relative to pre-treatment. Mechanical treatment effects on stand structure remains fairly consistent through 8 yr post. Fire-induced delayed mortality contributes to slight decreases in canopy cover and canopy bulk density over time. For both treatment types, overall canopy base height decreases in later years due to in-growth of smaller trees, but it remains higher than pre-treatment. The changes in fuel loads and stand structure are reflected in fire behavior simulations via custom fuel modeling. Surface fire flame lengths were initially reduced as a result of prescribed fire, but by 10 yr post-treatment they exceeded the pre-treatment lengths. Though a low proportion of fire type, initial reductions in potential crown fire returned to pre-treatment levels by 8 yr post-treatment; passive crown fire remained reduced relative to pre-treatment for the duration. Mechanical treatments showed variable and minimal effects on surface fire flame length over time; however the incidence of active crown fire was nearly halved from this treatment for the duration.

Objective 2- Quantify the uncertainty associated with the use of standard and custom fuel models

The Fire and Fuels Extension to the Forest Vegetation Simulator (FFE-FVS) was used to model potential fire behavior for plots treated with prescribed fire to determine the differences in modeled fire behavior using standard and custom fuel models. In general predicted fire behavior from custom versus standard fuel models were similar with mean surface fire flame lengths slightly higher using standard fuel models for all time steps until the 8 yr post-treatment. Similarly, custom fuel models predicted a higher instance of surface fire than standard fuel models with the exception of 8 yr post-treatment.

Objective 3- Assess prescribed fire effects on carbon stocks and validate modeled outputs.

To better understand the impact of prescribed fire on carbon stocks, we estimated aboveground and belowground (roots) carbon stocks using field measurement in FFE-FVS, and simulated wildfire emissions, before treatment and up to 8 yr post-prescribed fire. Prescribed fire treatments reduced total stand carbon by 13%, with the largest reduction in the forest floor (litter and duff) pool and the smallest reduction in the live tree pool. Combined carbon recovery and reduced wildfire emissions allowed the initial carbon source from simulated wildfire emissions and treatment to become a sink by 8 yr post-treatment relative to pre-treatment if both were to burn in a wildfire. In a comparison of field-derived versus FFE-FVS simulated carbon stocks, the total stand, tree, and belowground live carbon pools are highly correlated. However, the variability within the other carbon pools compared was high (up to 212%).

Management Implications

- ✓ Need more long term monitoring.
- ✓ The ability of a fuel treatment to maintain effectiveness in reducing fire behavior and effects depends on the accumulation rates and distribution of fuels, which are used as metrics to judge treatment longevity. Surface and understory fuel loading trends help inform managers' initial treatment and maintenance timelines, priorities, and adaptive management prescriptions.
- ✓ Stand and canopy structure trends help inform both fuel and silviculture integrated objectives and prioritizations.
- ✓ Despite extensive variability between plots, overall trends for treatment-forest combinations exist.
- ✓ Changes to modeled surface fire after prescribed fire treatment included an initial decrease in surface fire flame lengths, then an increase starting around 5 yr post-treatment.
- ✓ Overall, modeled fire behavior in mechanical treatments showed that goals of reduced fire behavior were initially reached, and then began diminishing around 5 to 8 yr post-treatment, with some positive changes still apparent through 8 yr post-treatment.
- ✓ In general, predicted fire behavior from custom versus standard fuel models was similar.
- ✓ Prescribed fire treatments reduced total stand carbon by about 13%, and total stand carbon stocks returned to 97% of pre-treatment levels after 8 yr post-treatment.
- ✓ Although the total stand carbon differences between field-derived and simulated carbon stocks are minimal, the variability within different carbon was great.

Project websites

Please visit our project website in the next few months to year as reports are finalized and publications become available at http://www.fs.fed.us/adaptivemanagement/pub_reports/JFS_vaillant2.shtml.

The final report and many of our presentations and other deliverables will also be available via the Joint Fire Science Program website at http://www.firescience.gov/JFSP_advanced_search_results_detail.cfm?jdbid=%24%26Z%2F8W%20%20%20%0A.

Acknowledgements

We acknowledge funding for this research from the USFS Region 5 Fire Aviation and Management and Joint Fire Sciences program (JFS 09-01-1-01). This project would have never gotten off the ground without the passion and drive of Jo Ann Fites-Kaufman. We thank the countless number of field crew members over the past 12 years, especially T. Decker and K. McCrummen for serving as crew leads during the past four years. Thank you to all the fire and fuels specialists on all the National Forests in California for providing invaluable insight and information about their fuel treatments.

Mad Ridge Fuel Break (Project 45, Mad River District)

Project history

The Mad Ridge fuel break project had six plots set up pre-treatment using three different plot styles (NPS, detailed 2003, and fuels 2003). In 2012 Plots 1 and 2, which were fuels 2003 plots, were changed to detailed 2003 style plots. For details about the protocol used, please see “Appendix B: Sampling Protocol” at the end of the report. Two of the original six plots were not treated and were not continued in this study. Note that plot 2 was originally set up as fuels 2003/chaparral plot, which has extra rebar beyond the ends of the CD transect (0m and 50m); the chaparral sub-plot protocol has since been removed from the study. Plots were sampled prior to treatment (P00), then 1 yr post (P01), 4 or 5 yr-post (P04 or P05), and 7 yr post (P07) (Table 1). Different sampling years occurred because we visited the plots mid-treatment and did not realize that until later.

For analysis at the regional level, plots from all projects were grouped into one of two treatment types (mechanical or prescribed fire) and one of three dominant forest types (yellow pine, red fir, or mixed conifer). All Mad Ridge plots were grouped into the mechanical treatment category and the mixed conifer forest type.

The Mad River RAWS was used for fire weather and fire behavior simulation modeling.

Table 1. Treatment visits completed by year for each of the plots in the project. ~ Indicates that data was not collected for that plot and year.

Plot	2004	2006	2009	2010	2012
1	P00	P01	P04	~	P07
2	P00	P01	P04	~	P07
3	P00	P01	~	P05	~
8	P00	P01	P04	~	P07

Treatment information

Prior treatment: A thinning treatment (presumably conifers) occurred in September of 1965, where Plot 2 is located. Ponderosa pine was then planted in 1967.

During the project treatment: Plots 1, 2, and 8 were thinned and hand piled in August 2004. Plots 1 and 2 hand piles were burned in the fall of 2005. The hand piles in Plot 8 were burned in the spring of 2006 because it was under a smoke Limited Operation Plan for the peregrine falcon. Plot 3 is located in a Tracy's Sanicle Reserve area where no burning is allowed; the thinned material was removed by and burned off-site in 2007. The thinning and removal occurred in the summer of 2006 by the California Conservation Corporation.

Future treatment: None known.

Project location map

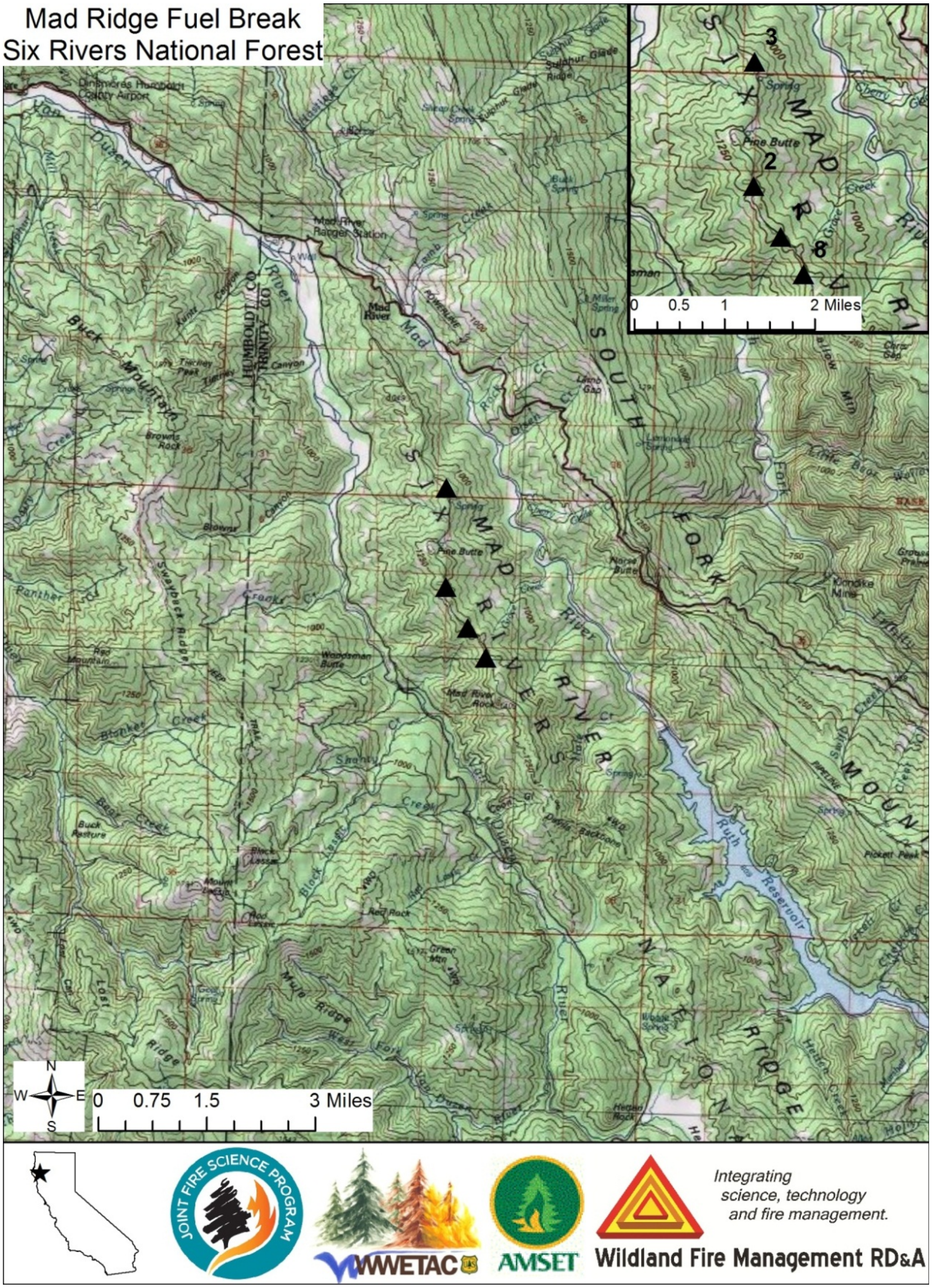


Figure 1. Location map for the Mad Ridge fuel break monitoring plots, showing general location of plots, and inset displaying increased detail of plot locations.

Driving directions/GPS/plot layout

Driving directions

Most plots can be approached from either direction (“a” or “b”) on Mad River Rock Road.

Plot 1- (a) Heading west on Hwy 36, make a left on to Mad River Rock Road and drive for 6.4 miles. Park at the turnout on the right above a slight drainage where the start tree will be on the right (West) side of the road. Or **(b)** take Mad River Rock Road South from Hwy 36 until you reach the “Falcon Gate” (locked entrance to a wildlife preserve area). Turn around and start your odometer here. Drive 0.2-0.3 miles north from the falcon gate. Park at the first turnout on the left as you drove away from the falcon gate. The start tree is on the left (west) side of the road. NOTE: The falcon gate is locked until August.

Plot 2- (a) Heading west on Hwy 36, make a left on to Mad River Rock Road and drive for 5.6 miles. The plot is on the left (east) side of the road. Or **(b)** from plot 1 drive 0.8 miles north on Mad River Rock road until you reach an area with many Douglas-fir snags. The plot will be on the right (east) side of the road on an open South facing aspect with white oaks scattered about above a drainage.

Plot 3- Heading West on Hwy 36, make a left on to Mad River Rock Road and drive to the Oak Campground. Start the odometer at the campground and drive for 1.9 miles South along Mad River Rock Road. Look for the 60 cm Douglas-fir start tree. The plot is downhill from the road to the right (west) side on a slope in a white oak dominant area with some grasses and herbs. There are some large ponderosa pines to the north of the road and one large ponderosa pine to the south of the road.

Plot 8- (a) Heading West on Hwy 36, make a left on to Mad River Rock Road and drive for 6.2 miles. Or **(b)** take Mad River Rock Road South from Hwy 36 until you reach the “Falcon Gate” (locked entrance to a wildlife preserve area). Turn around and start your odometer here. Drive 0.4 miles (north) as you drive away from the falcon gate. The start tree is on the right (east) side. NOTE: The falcon gate is locked until August.

Table 2. Directions (distance and azimuth) for walking from the “start tree” to each plot. The azimuth takes into account the local declination. Distance and azimuth are approximate as they were recorded by crews walking in from the start tree (usually tagged tree near road edge).

Plot	Start tree (DBH and species)	Azimuth °	Distance
1	77 cm Douglas-fir	224	20 m
2	63 cm Douglas-fir	140	40 m
3	60 cm Douglas-fir	162	23 m
8	61 cm black oak (leaning tree with dead fork)	104	35 m

Table 3. GPS coordinates for each plot (decimal degrees, datum NAD 1983, projection NAD_1983_California_Teale_Albers).

Plot	Latitude	Longitude
1	40.387517	-123.485415
2	40.395515	-123.491536
3	40.4155	-123.492311
8	40.486531	-123.486531

Table 4. Plot layout line azimuths (degrees). See Appendix A for plot diagrams. AB and CD are the main transects and F1, F2, F3, and F4 are the fuels transects.

Plot	Plot type	AB	CD	F1	F2	F3	F4
1	Detailed 2003	n/a	153	108	198	n/a	n/a
2	Detailed 2003	n/a	280	54	144	n/a	n/a
3	Fuels 2003	n/a	140	95	185	n/a	n/a
8	NPS	320	320	18	28	180	275

Paired pictures

Below is an example of pictures paired or matched over the time steps the plots were visited. All of the paired pictures are available in the supplied power point file.

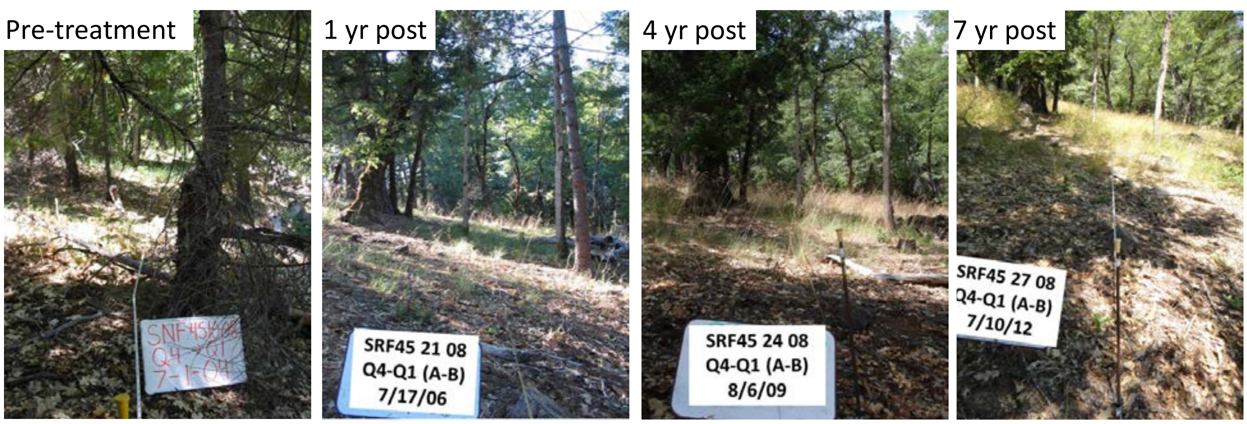


Figure 2. Example paired photos showing changes over the time steps for Plot 8, Q4-Q1 (A-B) from pre-treatment in 2004 through 7 yr post-treatment in 2012.

Plot findings

Below are graphs and data tables of key metrics from the data gathered in the field for each plot and time period within the Mad Ridge fuel break project.

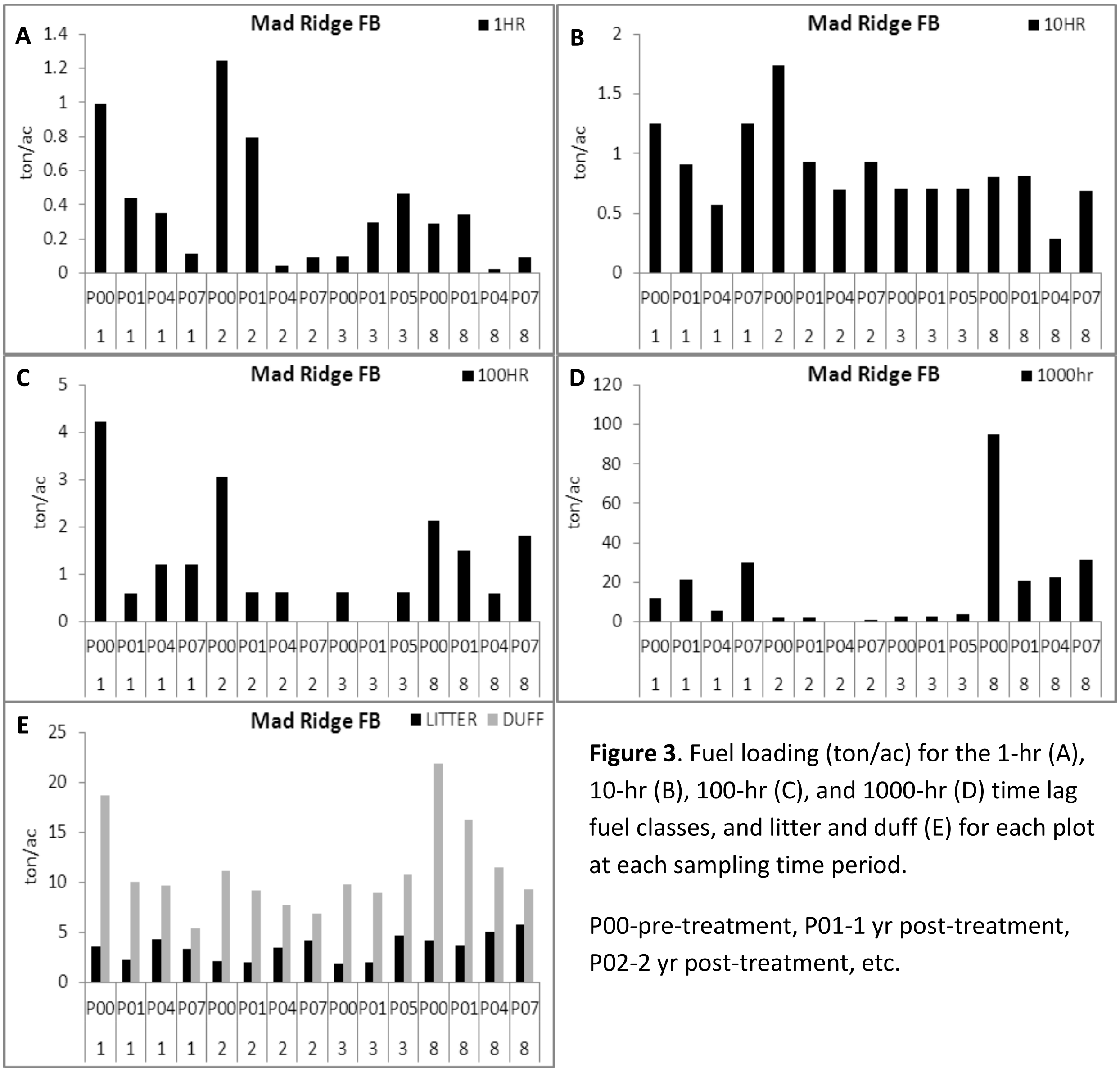


Figure 3. Fuel loading (ton/ac) for the 1-hr (A), 10-hr (B), 100-hr (C), and 1000-hr (D) time lag fuel classes, and litter and duff (E) for each plot at each sampling time period.

P00-pre-treatment, P01-1 yr post-treatment, P02-2 yr post-treatment, etc.

Table 5. Fuel loading (ton/ac) for the 1-hr, 10-hr, 100-hr, and 1000-hr time lag fuel classes, and litter and duff by time period for all the plots in the Mad Ridge fuel break project.

Plot	Time period	1-hr	10-hr	100-hr	1000-hr	Litter	Duff
1	P00	0.99	1.3	4.2	11.7	3.6	18.7
1	P01	0.44	0.9	0.6	21.5	2.3	10.0
1	P04	0.35	0.6	1.2	5.8	4.3	9.7
1	P07	0.11	1.3	1.2	30.0	3.3	5.4
2	P00	1.24	1.7	3.1	1.8	2.1	11.2
2	P01	0.80	0.9	0.6	1.8	2.1	9.2
2	P04	0.04	0.7	0.6	0.0	3.4	7.7
2	P07	0.09	0.9	0.0	0.7	4.2	6.9
3	P00	0.10	0.7	0.6	2.6	1.9	9.8
3	P01	0.29	0.7	0.0	2.6	2.0	8.9
3	P05	0.46	0.7	0.6	3.6	4.7	10.8
8	P00	0.29	0.8	2.1	95.2	4.2	21.9
8	P01	0.34	0.8	1.5	20.5	3.7	16.3
8	P04	0.02	0.3	0.6	22.3	5.1	11.5
8	P07	0.09	0.7	1.8	31.2	5.8	9.4

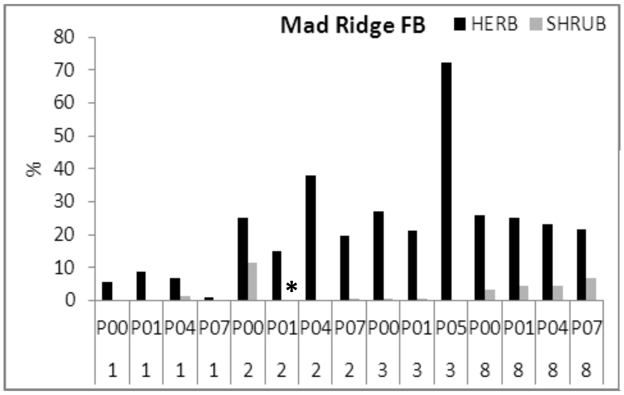
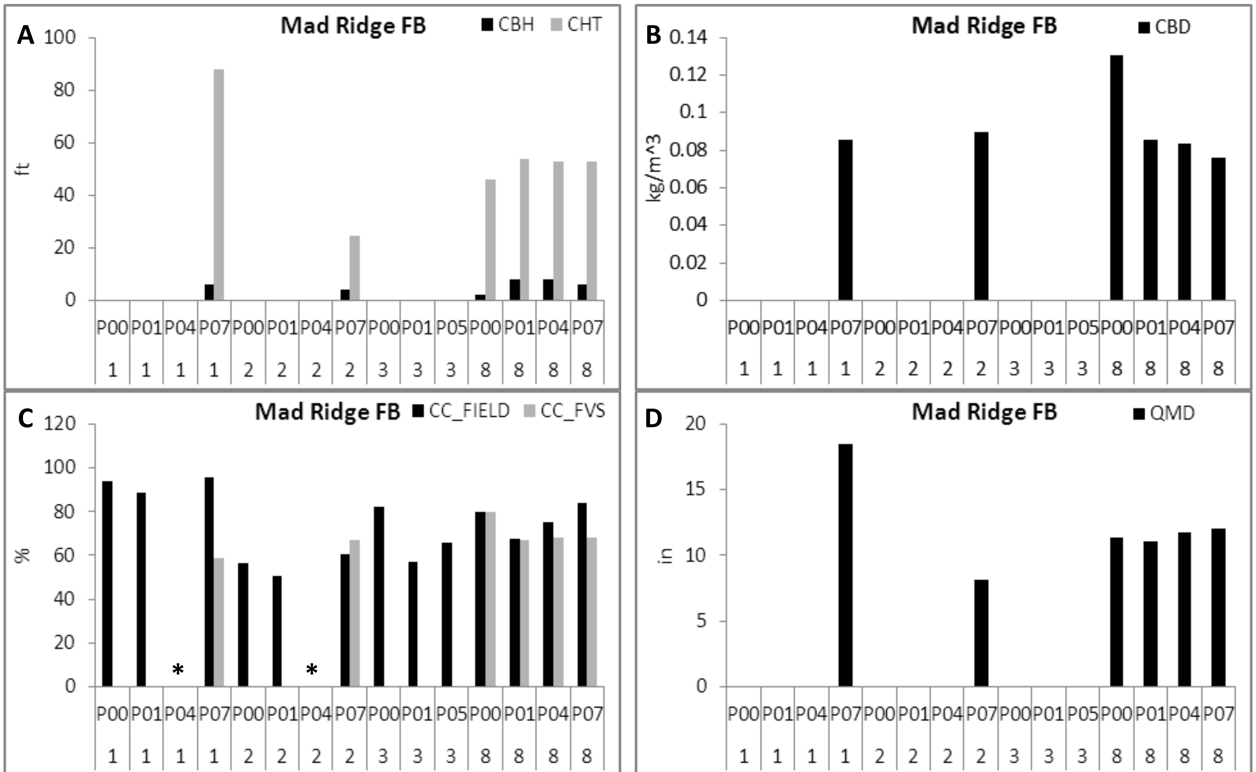


Figure 4. Average herbaceous plant and shrub cover for each plot at each sampling time period.

*Indicates the data was not collected, not a zero value (see Table 6).

Table 6. Understory vegetation cover by time period for all the plots in the Mad Ridge fuel break project. * Indicates the data was not collected for the given plot and time period.

Plot	Time period	Herbaceous cover (%)	Shrub cover (%)
1	P00	6	0
1	P01	9	0
1	P04	7	1
1	P07	1	0
2	P00	25	12
2	P01	15	*
2	P04	38	0
2	P07	20	0
3	P00	27	0
3	P01	21	1
3	P05	72	0
8	P00	26	3
8	P01	25	5
8	P04	23	4
8	P07	22	7



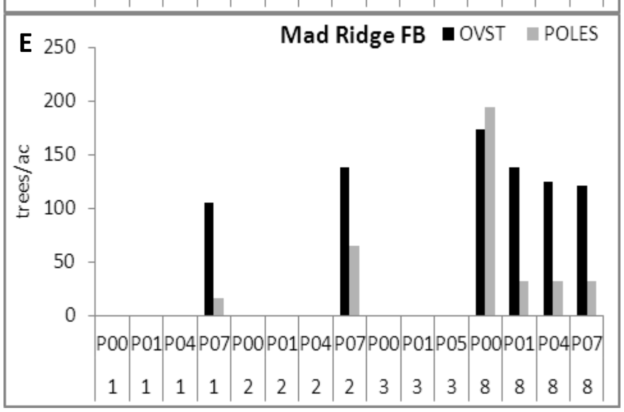


Figure 5. Canopy height and canopy base height (A), canopy bulk density (B), canopy cover from field data and FVS (C), quadratic mean diameter (D), and overstory and pole-sized tree density (E) for each plot at each sampling time period.

With the exception of those indicated with a * zero values indicate tree data was not collected because of the type of plot installed, not a lack of trees (see Table 7).

Table 7. Canopy characteristics by time period for all the plots in the Mad Ridge fuel break project.
* Indicates the data was not collected for the given plot and time period.

Plot	Time period	Canopy cover (%) - field	Canopy cover (%) - FVS	Canopy height (ft)	Canopy base height (ft)	Canopy bulk density (kg/m^3)	Quadratic mean diameter (in)	Overstory (trees/ac)	Pole-sized (trees/ac)
1	P00	94	*	*	*	*	*	*	*
1	P01	89	*	*	*	*	*	*	*
1	P04	*	*	*	*	*	*	*	*
1	P07	96	59	88.1	6.0	0.086	18.5	105	16
2	P00	56	*	*	*	*	*	*	*
2	P01	50	*	*	*	*	*	*	*
2	P04	*	*	*	*	*	*	*	*
2	P07	61	67	24.5	4.0	0.090	8.1	138	65
3	P00	82	*	*	*	*	*	*	*
3	P01	57	*	*	*	*	*	*	*
3	P05	66	*	*	*	*	*	*	*
8	P00	80	80	45.8	2.0	0.131	11.4	174	194
8	P01	67	67	53.9	8.0	0.086	11.0	138	32
8	P04	75	68	52.9	8.0	0.084	11.7	125	32
8	P07	84	68	52.8	6.0	0.076	12.0	121	32

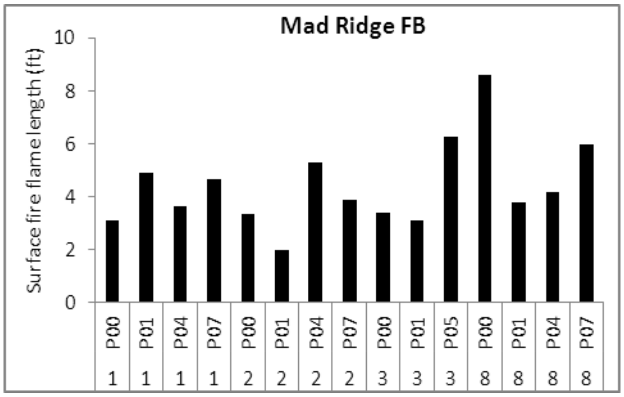


Figure 6. Surface fire flame length from custom fuel models using NEXUS for each plot at each sampling time period under 90th percentile fire weather conditions.

Table 8. Surface fire flame length (modeled in NEXUS with custom fuel models) and type of fire for 90th percentile fire weather conditions for all the plots in the Mad Ridge fuel break. * Indicates the tree data was not collected and fire type was not modeled.

Plot	Time period	Surface fire flame length (ft)	Type of fire
1	P00	3.11	*
1	P01	4.90	*
1	P04	3.64	*
1	P07	4.65	Surface
2	P00	3.33	*
2	P01	1.98	*
2	P04	5.30	*
2	P07	3.88	Passive crown
3	P00	3.38	*
3	P01	3.07	*
3	P05	6.27	*
8	P00	8.61	Passive crown
8	P01	3.77	Surface
8	P04	4.18	Passive crown
8	P07	5.97	Passive crown

Salyer Hawkins (Project 46, Lower Trinity District)

Project history

The Salyer Hawkins project had three plots set up pre-treatment using detailed 2003 plot styles. For details about the protocol used, please see “Appendix B: Sampling Protocol” at the end of the report. Plots 2 and 3 were treated and continued in this study.

For analysis at the regional level, plots from all projects were grouped into one of two treatment types (mechanical or prescribed fire) and one of three dominant forest types (yellow pine, red fir, or mixed conifer). For this project, plots were grouped into the mechanical treatment type and mixed conifer forest type. Plots were sampled prior to treatment (P00), then 1 yr post (P01), 2 yr post (P02), 5 yr post (P05), and 8 yr post (P08) (Table 9).

The Hoopa RAWS was used for fire weather and fire behavior simulation modeling.

Table 9. Treatment visits completed by year for each of the plots in the project.

Plot	2004	2005	2006	2009	2012
2	P00	P01	P02	P05	P08
3	P00	P01	P02	P05	P08

Treatment information

Prior treatment: No treatment in the last 10 years prior to the 2004 plot installations.

During the project treatment: Two treatment types occurred within the unit. A 200-foot buffer adjacent to private land was a mixture of mechanical and prescribed fire and the interior of the unit was only underburned. Hand piles were created from thinning large brush and small trees in August of 2004 for plots 2 and 3. The hand piles in plot 2 were burned on 1/25/2006 and thepiles in plot 3 were burned during the fall/winter of 2008/2009 (sometime between November and January).

Future treatment: The plots will be part of the Waterman East Integrated Vegetation Management Project, which is in the planning phase, and may start implementation in fiscal year 2014 or 2015.

Project location map

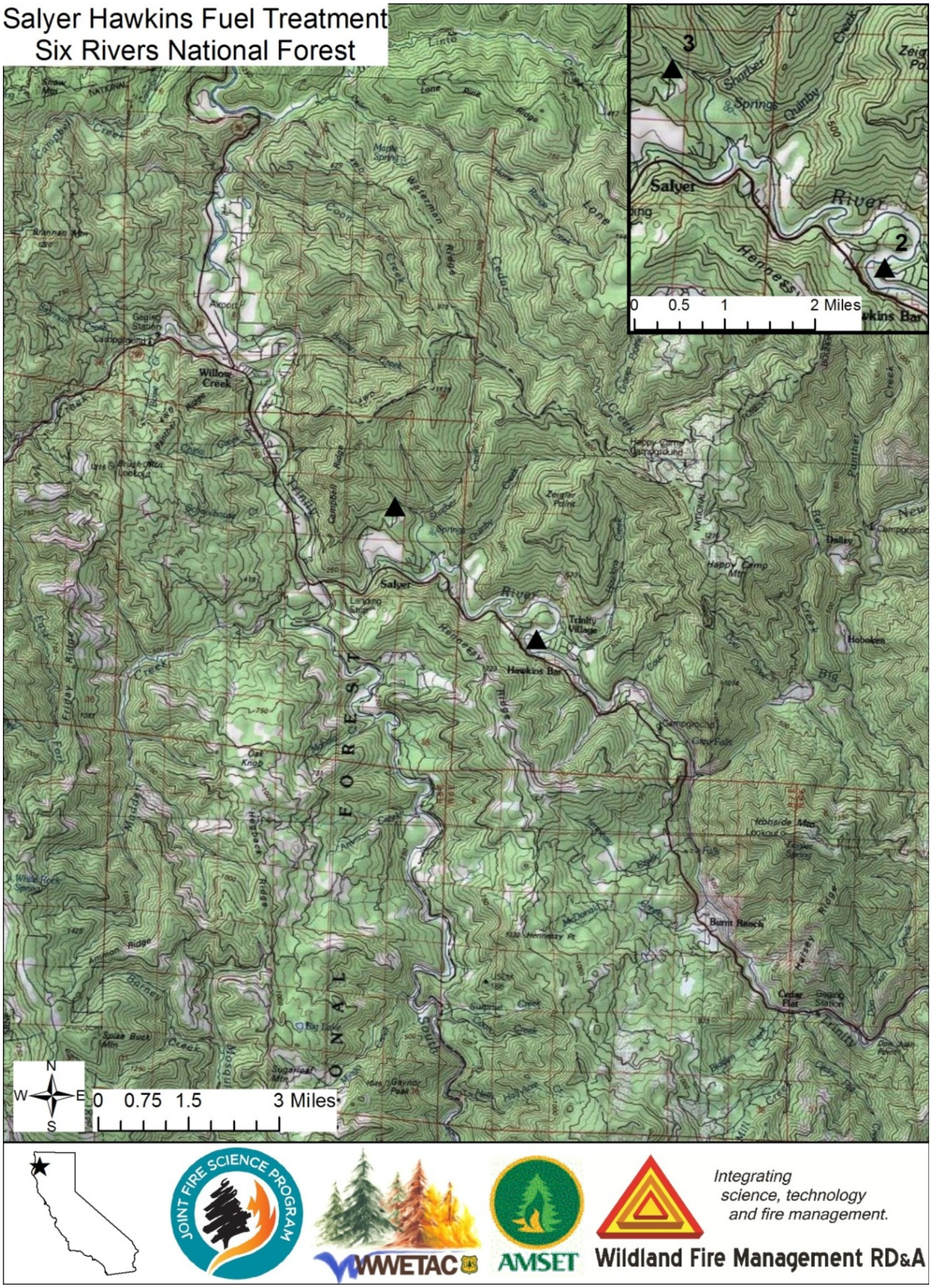


Figure 7. Location map for the Salyer Hawkins fuel treatment plots, showing general location of plots, and inset displaying increased detail of plot locations.

Driving directions/GPS/plot layout

Driving directions

Plot 2- From Salyer go left off Hwy 299 after the Hawkins Bar store and gas station. Take the road that goes to Denny off Hwy 299. Cross the river and turn left at Hawkins Bar Road (0.9 mi). Stay to the left and take Trinity Court toward the fire station. Park where the rock wall ends across from the fire station. Walk to the power line right off of Trinity Court #1 driveway. Go right along the power line row about +/- 75 m there is the start tree, a 32 cm DBH power line pole (or 3 wire telephone pole) with a placard/tag on it.

Plot 3- On Hwy 299 across from Salyer store and drive on Salyer Loop Rd. (a.k.a. Campbell Ridge Rd). Go north across the river, and at stop sign head left on Salyer Loop/Campbell Ridge Rd at 1.7 miles go straight uphill, do not turn at Campbell Ridge Rd., go another 0.2 miles and park by the white fence on the left. Plot is near three houses/yards. Start tree is lower profile, and is 3 m uphill of the driveway that is 10 m past the 2nd telephone pole (or 39 m past the first telephone pole at the top of the hill past the white fence).

Table 10. Directions (distance and azimuth) for walking from the" start tree" to each plot. The azimuth takes into account the local declination. Distance and azimuth are approximate as they were recorded by crews walking in from the start tree (usually tagged tree near road edge).

Plot	Start tree (DBH and species)	Azimuth °	Distance
2	32 cm power line pole	18	30 m
3	44 cm Douglas-fir	42	20 m

Table 11. GPS coordinates for each plot (decimal degrees, datum NAD 1983, projection NAD_1983_California_Teale_Albers).

Plot	Latitude	Longitude
2	40.877176	-123.531946
3	40.907867	-123.578498

Table 12. Plot layout line azimuths (degrees). See Appendix A for plot diagrams. Where CD is the main transect and F1 and F2 are the fuels transects.

Plot	Plot type	CD	F1	F2
2	Detailed 2003	178	133	223
3	Detailed 2003	63	18	109

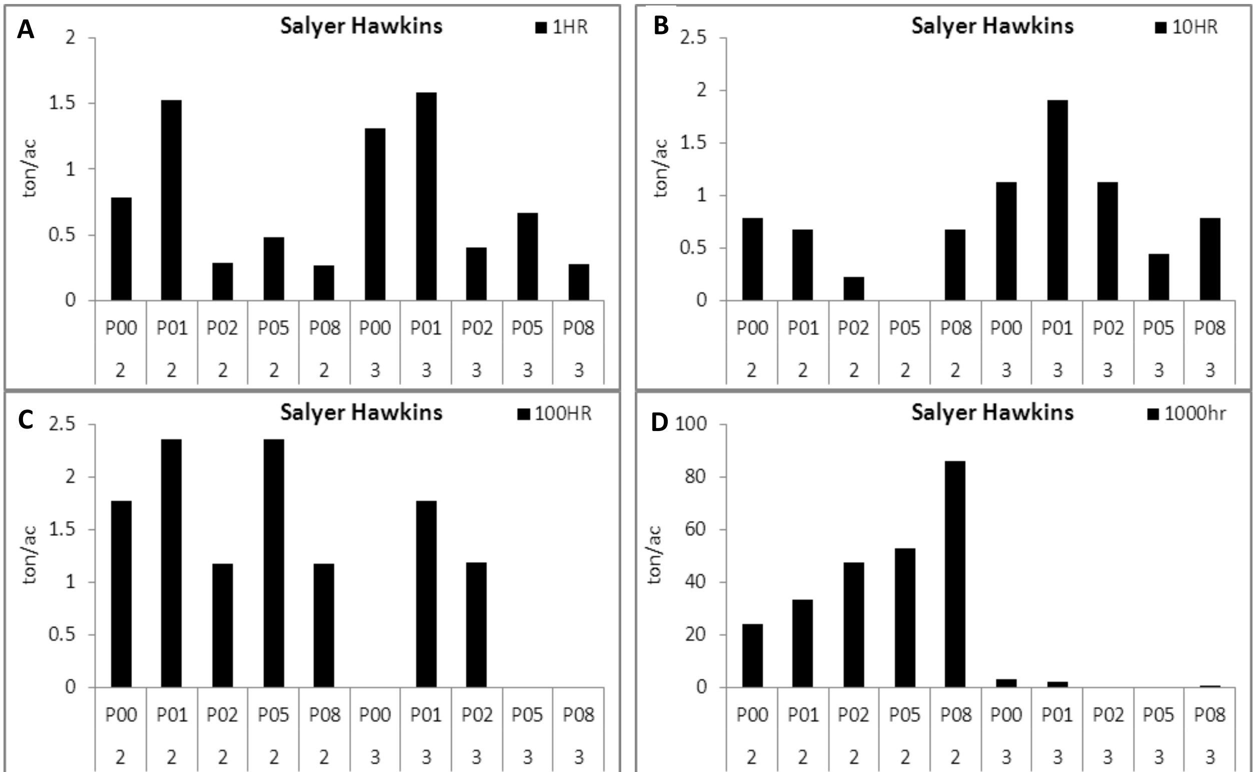
Paired pictures

Below is an example of pictures paired or matched over the time steps the plots were visited. All of the paired pictures are available in the supplied power point file.

Figure 8. Example paired photos showing changes over the time steps for plot 3 on the CD or main transect line from pre-treatment in 2004 through 8 yr post-treatment in 2012.

Plot findings

Below are graphs and data tables of key metrics from the data gathered in the field for each plot and time period within the project.



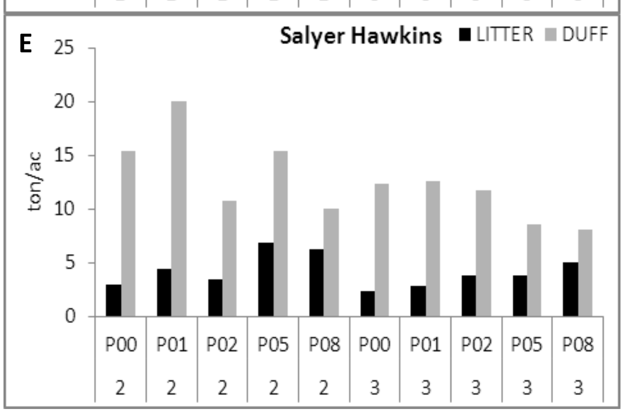


Figure 9. Fuel loading (ton/ac) for the 1-hr (A), 10-hr (B), 100-hr (C), and 1000-hr (D) time lag fuel classes, and litter and duff (E) for each plot at each sampling time period.

P00-pre-treatment, P01-1 yr post-treatment, P02-2 yr post-treatment, etc.

Table 13. Fuel loading (ton/ac) for the 1-hr, 10-hr, 100-hr, and 1000-hr time lag fuel classes, and litter and duff for by time period for all the plots in the Salyer Hawkins fuel treatment project.

Plot	Time period	1-hr	10-hr	100-hr	1000-hr	Litter	Duff
2	P00	0.79	0.8	1.8	24.1	2.9	15.5
2	P01	1.52	0.7	2.4	33.5	4.5	20.1
2	P02	0.29	0.2	1.2	47.5	3.5	10.8
2	P05	0.49	0.0	2.4	52.8	6.8	15.5
2	P08	0.27	0.7	1.2	86.0	6.2	10.1
3	P00	1.31	1.1	0.0	3.1	2.4	12.4
3	P01	1.59	1.9	1.8	2.3	2.8	12.6
3	P02	0.40	1.1	1.2	0.0	3.8	11.7
3	P05	0.67	0.4	0.0	0.0	3.8	8.6
3	P08	0.28	0.8	0.0	0.9	5.0	8.1

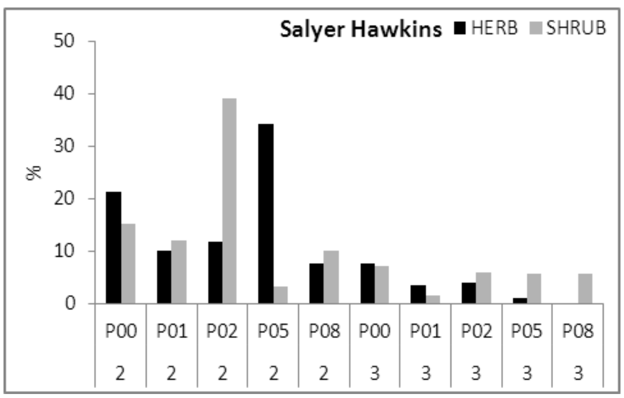


Figure 10. Average herbaceous plant and shrub cover for each plot at each sampling time period.

Table 14. Understory vegetation cover by time period for all the plots in the Salyer Hawkins fuel treatment project.

Plot	Time period	Herbaceous cover (%)	Shrub cover (%)
2	P00	21	15
2	P01	10	12
2	P02	12	39
2	P05	34	3
2	P08	8	10
3	P00	8	7
3	P01	4	2
3	P02	4	6
3	P05	1	6
3	P08	0	6

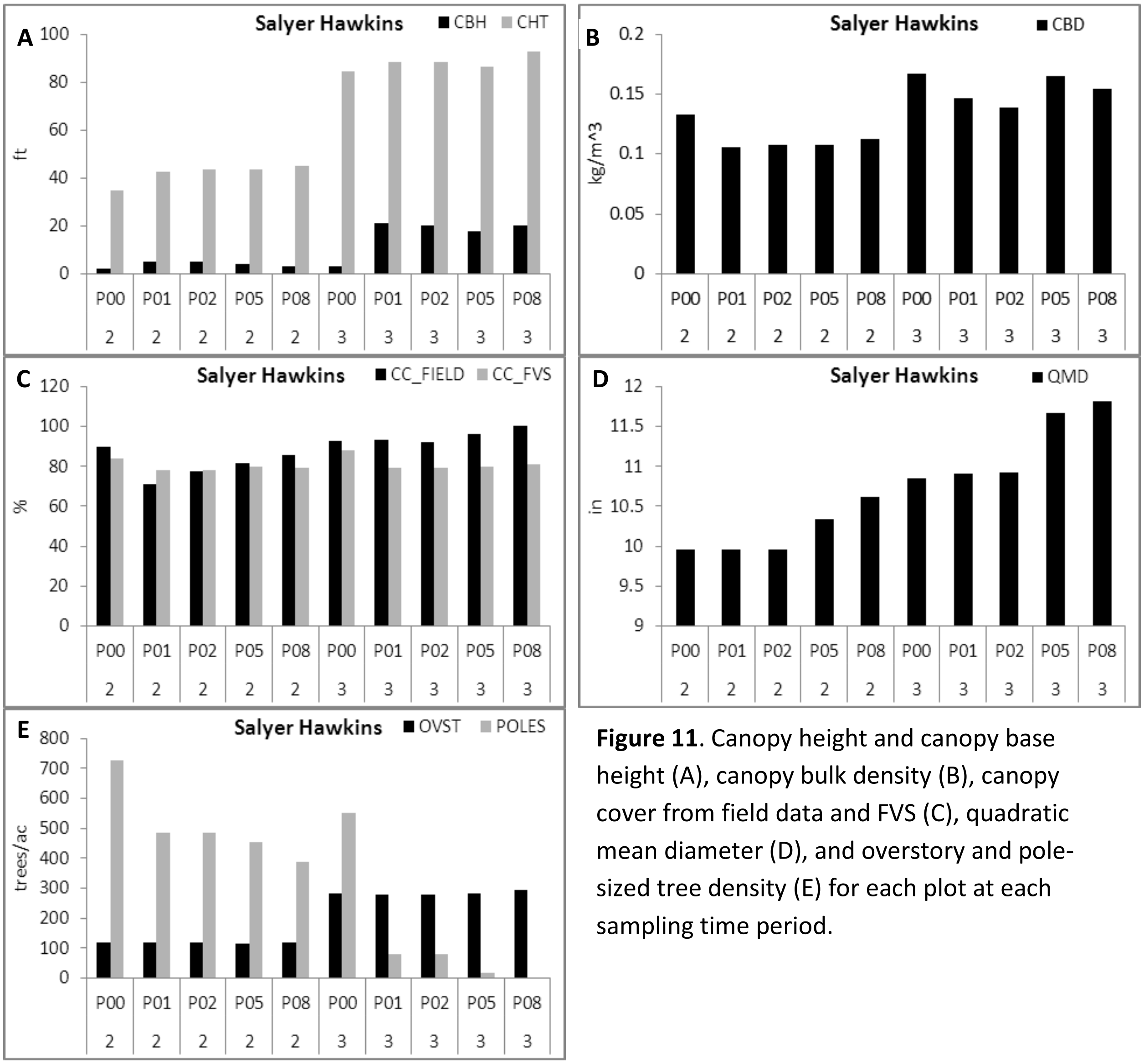


Figure 11. Canopy height and canopy base height (A), canopy bulk density (B), canopy cover from field data and FVS (C), quadratic mean diameter (D), and overstory and pole-sized tree density (E) for each plot at each sampling time period.

Table15. Canopy characteristics by time period for all the plots in the Salyer Hawkins fuel treatment project.

Plot	Time period	Canopy cover (%) - field	Canopy cover (%) - FVS	Canopy height (ft)	Canopy base height (ft)	Canopy bulk density (kg/m^3)	Quadratic mean diameter (in)	Overstory (trees/ac)	Pole-sized (trees/ac)
2	P00	90	84	34.9	2.0	0.133	10.0	117	728
2	P01	71	78	42.8	5.0	0.106	10.0	117	486
2	P02	78	78	43.5	5.0	0.108	10.0	117	486
2	P05	81	80	43.7	4.0	0.108	10.3	113	453
2	P08	86	79	45.1	3.0	0.113	10.6	117	388
3	P00	93	88	84.6	3.0	0.167	10.9	283	550
3	P01	93	79	88.2	21.0	0.147	10.9	279	81
3	P02	92	79	88.2	20.0	0.139	10.9	279	81
3	P05	96	80	86.7	18.0	0.165	11.7	283	16
3	P08	100	81	92.9	20.0	0.155	11.8	295	0

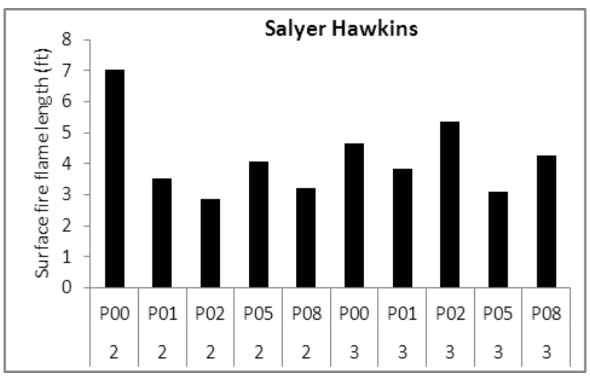


Figure 12. Surface fire flame length from custom fuel models using NEXUS for each plot at each sampling time period under 90th percentile fire weather conditions.

Table 16. Surface fire flame length (modeled in NEXUS with custom fuel models) and type of fire for 90th percentile fire weather conditions for all the plots in the Salyer Hawkins fuel treatment project.

Plot	Time period	Surface fire flame length (ft)	Type of fire
2	P00	7.04	Active crown
2	P01	3.52	Passive crown
2	P02	2.86	Passive crown
2	P05	4.06	Passive crown
2	P08	3.23	Passive crown
3	P00	4.65	Active crown
3	P01	3.83	Conditional crown
3	P02	5.37	Conditional crown
3	P05	3.10	Conditional crown
3	P08	4.25	Conditional crown

Appendix A: Description of Supplied Files

For your use we included a number of supplementary files with the digital version of this report (see the supplied thumb drive).

Final report to the JFSP

We included a digital version of the Final Report we submitted to the Joint Fire Science Program for the entire regional assessment.

FVS input database

For each Forest we included an FVS-ready database with all the plots from all the projects (*.mdb). The database includes two different StandInit and TreeInit tables depending on the plot types within the Forest; separate StandInit and TreeInit tables were created for the "detailed" plots and the "fuels" plots. We did this so one would not assume there was tree data available for all plots when it might not have been sampled. The fuel loading data was collected on all plots and is included by size class in both StandInit tables. For the detailed plots, the tree data collected is within the TreeInit table. For the fuels plots, a "dummy" tree list (a single white fir seedling) was created so the plots can be run through FVS, but caution should be used with these because of the lack of real tree data. If data was missing it is represented as a blank in the data tables.

Photo pairs

Most of the photos taken for each plot is included in the supplied Power Point file (*.pptx). Photos were taken along the main transect line(s) and fuel lines each time the plot was visited.

Plot maps

In addition to the imbedded maps in this report, we have supplied PDF versions of the project maps.

GIS shapefile

We supplied a GIS file with all the plots for the Forest.

Appendix B: Sampling Protocol

Data collection protocol (inclusive of all plot layouts)

Plot information naming example

1. Forest name: *"Tahoe NF"*
2. Forest ICS code: *"TNF"*
3. Project name: "Jaybird"
4. Project number: pre-determined for tracking purposes
5. Status: P00=pre-treatment, P01=1st year post, P02=2nd year post, etc.
6. Plot number: *"1"*
7. Surveyors: *"last name, first initial"*
8. Date: *"5/8/09"*
9. Notes: general notes about the area, treatment, anything that stands out

Shrub transect(s) (50 m)

Collect shrub information (for any shrubs that intersect the transect tape) along the length of the transect(s): transect, species, status (live/dead), shrub range in decimeters (dm, distance along transect, i.e. 0.6-0.9 m=3 dm), average height (cm).

Herbs (1x1 m quadrats)

Collect herbaceous species information for all plants rooted in the quadrat. Record the transect, frame, life form (fern, forb, grass, vine, other, unknown), status (live/dead), average height (cm), species (if you know it), and cover class (1=0-5%; 2= 6-25%; 3= 26-50%; 4=51-75%; 5=76-95%; 6=96-100%). Also please take general botany notes for the plot, such as species observed in the plot overall but not captured in the quadrats, and general observations about how much of the plot has weeds or herbaceous plant dominance.

Seedlings (<2.5 cm DBH)

Tally seedlings by species code, status (live/dead), and height class (15=1-15 cm; 30=16-30 cm; 60=31-60 cm; 100=61-100 cm; 200=101-200 cm; 300=201-300 cm, etc.).

Pole-sized trees (>2.5 to <15 cm DBH, and > 4.5 ft (1.37 m) tall)

Live poles: tag #, species, DBH (cm), status (live/dead), partial crown height (m), total tree height (m), canopy class (D=dominant, CD=codominant, I=intermediate, S=suppressed).

Dead poles: tag#, species, DBH (cm), status (live/dead), total tree height (m), decay class (1 newly dead thru 5 long dead).

Overstory trees (>15 cm DBH and > 4.5 ft (1.37 m) tall)

Live trees: tag #, species, DBH (cm), status (live/dead), partial crown height (m), total tree height (m), canopy class (D, CD, I, S).

Dead trees: tag#, species, DBH (cm), status (live/dead), total tree height (m), decay class (1 newly dead thru 5 long dead).

Canopy cover

Collect and record canopy cover, using the moosehorn (canopy sight tube) along the main transects (AB and/or CD) every 1m, starting at 1m and ending at 50m. The moosehorn should be held at the meter mark on the tape, standing on the side of the shrub transect opposite to the side where the herb quadrats are being place. Count the number of hits or intersections, out of 25, where canopy overlaps the grid intersections.

Fuel loading

Each planar fuel transect is 50 ft in length and information is gathered to characterize surface and ground fuels and fuel bed depth.

Surface fuels (1, 10, 100, 1000-hr)

Record the project, plot, transect and tallies for small fuel classes (1, 10, 100-hr), and take notes on the **dominant trees or shrub species** contributing to the fuel load for each transect.

Tally: 1-hr (>0.25") from 0-6 ft, 10-hr (0.25-<1") from 0-6 ft, 100-hr (1-<3") from 0-12 ft.

Record the species, diameter (cm), and status (rotten/sound) for each 1000-hr (> 3') from 0-50 ft.

Ground fuels (litter/duff/chips)

Measure and record litter and duff depth (thickness) measurements to the nearest 1 cm (measure thickness of each layer, not depth from surface). Starting at 1 foot, take 10 readings, one every 5 ft on each transect: (1 ft, 5 ft, 10 ft… 45 ft). Duff begins where the litter layer organic materials have begun to decompose, and duff ends where the composition is greater than 50% mineral soil. If a sampling spot lands exactly on a log, rock, or other obstruction, take the reading immediately adjacent to the obstruction. If you hit bare soil, your reading will be 0.

If there was mastication/chipping completed, record the depth of the chipped materials as well.

Fuel bed depth

Measure and record the height of the **tallest** downed and dead woody fuel for ten 5 ft collection point intervals (0-5 ft, 5-10 ft, 10-15 ft, up to 45-50 ft) along the planar transect. Measure from the **base of the litter layer to the top of the fuel particle**; measure to the nearest whole cm. If you do not have any dead and downed fuels, your measure will be based on the maximum litter depth in that interval.

Photos

Avoid people and gear in the photos. Line up with the photos supplied from previous plot visits to the best of your ability. Use a photo board to document the photo location within the photos, matching the plot naming protocol example above. **Always take the photos in a portrait orientation (up and down) with the transect tape in the bottom middle of the image**. Photos were only taken from 0 to 50 ft for each fuels transect (labeled F1, F2, etc.), from C to D (and A to B if applicable) for the shrub transect, and one general picture of the plot (this one will not have an old photo to match).

National Park Service (NPS) plot specifics

Shrub transects (50 m)

Collect the shrub data along Q4→Q1 (transect AB) and Q3→Q2 (transect CD) transects according to the current protocol.

Herb quadrats

Looking from 0 m to 50 m on the Q4→Q1 transect, place the herb frame on the right hand side of the line from 9-10 m, 19-20 m, 29-30 m, 39-40 m and 49-50 m. Record this as transect AB. These are frames 1, 2, 3, 4, and 5, respectively.

Looking from 0 m to 50 m on the Q3→Q2 transect, place the herb frame on the left hand side of the line from 9-10 m, 19-20 m, 29-30 m, 39-40 m and 49-50 m. Record this as transect CD. These are frames 1, 2, 3, 4, and 5, respectively.

Seedlings

This should take place in a 50 square meter area between the 25 m and 30 m rebars in quadrant Q1. See the diagram.

Pole-sized trees

Pole-sized trees are measured in the entire area of quadrant Q1. See the diagram.

Overstory trees

Overstory trees are measured in the whole plot area and are numbered in order starting in quadrant Q1 and ending in quadrant Q4. See the diagram.

Canopy cover

Along the Q4→Q1 (transect AB) and Q3→Q2 (transect CD) transects collect the moosehorn intersections every meter starting at 1 m and ending at 50 m.

Fuel loading

The four fuels lines start along the P transect at point 1A, 2A, 3A, and 4A. Each line was given a different random bearing and is 50ft long, the end point rebar are marked as 1B, 2B, 3B, and 4B.

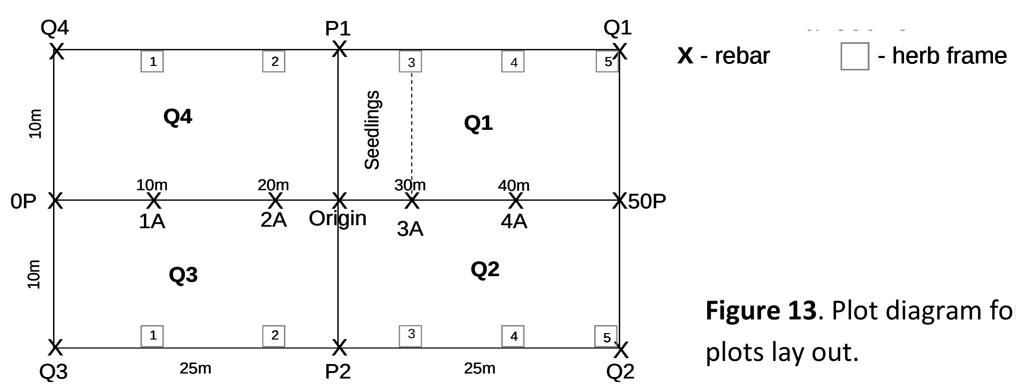


Figure 13. Plot diagram for the NPS plots lay out.

2003 detailed plot specifics

Shrub transects (50 m)

There is one transect (CD) for these plots. It **should** be contour to the slope.

Herb quadrats

There are five quadrats for these plots. They are located from 9-10 m, 19-20 m, 29-30 m, 39-40 m, and 49-50 m along the uphill side of CD transect.

Seedlings

This is a circular plot starting at the pole/seedling origin rebar (at 33.92 m on transect CD) extending out and around 3.99 m in all directions.

Pole-sized trees

This is a circular plot starting at the pole/seedling origin rebar (at 33.92 m on transect CD) extending out and around 8.92 m in all directions.

Overstory trees

This is a circular plot starting from the origin (at 25 m on transect CD) extending out and around 17.85 m in all directions.

Canopy cover

A total of 50 canopy cover readings will be measured. They will start at 1 m and continue every meter until the end of the transect CD (50 m).

Fuel loading

There are two 50 ft fuel transects for this layout. They both start at 7.15 m along the CD transect and have a rebar labeled “F1/F2 0ft”. F1 extends uphill at a 45º angle toward the center of the plot, F2 extends downhill at a 45º angle toward the center of the plot.

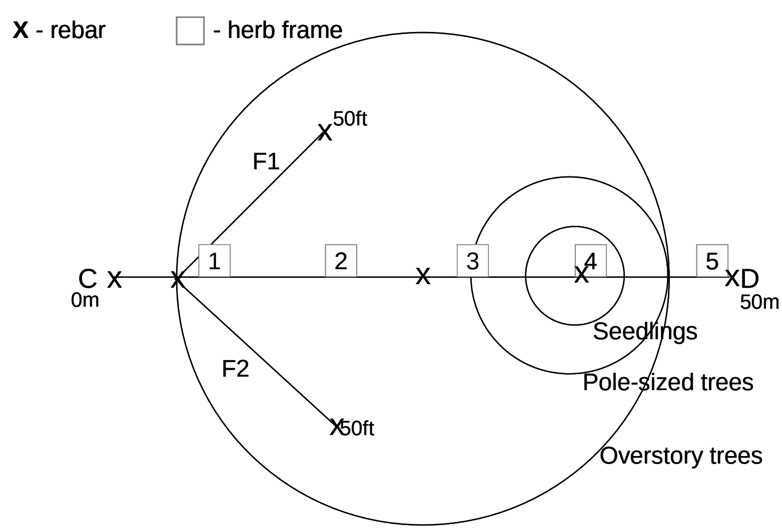


Figure 14. Plot layout diagram for the detailed plots installed from 2003 to 2006.

2003 fuels plot specifics

Starting in 2012 tree data was collected on Fuels '03 plots that were visited. You need to establish the pole/overstory and seedling rebar and tag all pole & overstory trees and gather data on all size classes!

Shrub transect

There is one transect (CD) for these plots. It **should** be contour to the slope.

Herb quadrats

There are 5 quadrats for these plots. They are located from 9-10 m, 19-20 m, 29-30 m, 39-40 m, and 49-50 m along the uphill side of CD transect.

Canopy cover

A total of 50 canopy cover readings will be measured. They will start at 1 m and continue every meter until the end of the transect CD (50 m).

Fuel loading

There are two 50 ft fuel transects for this layout. They both start at 7.15 m along the CD transect and have a rebar labeled "F1/F2 0 ft". F1 extends uphill at a 45º angle toward the center of the plot, F2 extends downhill at a 45º angle toward the center of the plot.

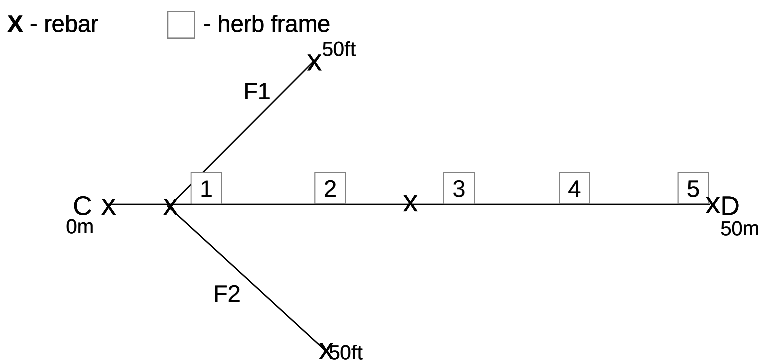


Figure 15. Plot layout diagram for the fuels plots installed from 2003 to 2006.