Ashland Forest Resiliency Underburn Fire Effects Monitoring Method

Keith Perchemlides, Lyndsey Lascheck, and Kerry Metlen; revised May 2021

Purpose and burn objectives

Prescribed underburns are used to achieve ecological restoration, silvicultural, and fuel management goals as part of the landscape-scale forest stewardship of the Ashland Forest Resiliency (AFR) project, a collaborative partnership of the U.S. Forest Service (USFS), City of Ashland (COA), Lomakatsi Restoration Project (LRP), and The Nature Conservancy (TNC). AFR burns are planned and led by Forest Service staff, with input from all partners, and implemented by mixed crews of USFS, LRP, and Grayback Forestry Inc. personnel. Prescribed burns are intended to meet both fire management and ecological goals by reducing fuel loads and fire risk, and reintroducing beneficial fire for forest restoration while protecting sensitive wildlife habitat. In 2016, those goals were translated into a partnership-approved set of standard AFR prescribed fire and resource objectives, and revised in 2018 (below):

<u>RESOURCE OBJECTIVES</u>

1. Restore forest stands to conditions that promote functional processes that more closely resemble the historical occurrence of more frequent but lower to moderate severity disturbance
2. Protect core public and private values at risk from wildland fire, particularly those associated with:
    a. safeguarding human life,
    b. protecting property,
    c. protecting socio-economic and municipal watershed values,
    d. conservation of late-successional biological and structural diversity
    e. enhancing wildlife habitat
3. Reduce hazardous fuels and obtain conditions that are more resilient to wildland fires
4. Minimize mortality of legacy trees *(large, old trees with complex form, large branches, open structure, wide bark plates, and providing important habitat features and aesthetic value)*

<u>PRESCRIBED FIRE OBJECTIVES</u>

1. Reduce litter and light surface fuels (1 to 100-hr) by 30 - 80%
2. Retain >30% of shrubs and understory trees (< 5" DBH)
3. Limit mortality of intermediate trees (5-12" DBH) to < 40%
4. Retain > 90% dominant/codominant trees (> 12" DBH)
5. Retain >97% of conifers >30” DBH and hardwoods >20” DBH
6. Retain overall effective ground cover for the unit based on soil erosion hazard class:
    - moderate (< 35% gradient), > 60% year-1, > 70% year-2;
    - severe or higher (> 35% gradient), > 70% year-1, > 85% year-2
7. Retain approximately 90% large down logs or snags (>20" diameter)
8. Minimize fire intensity in leave areas, with crown scorch of canopy trees <20%
9. Retain an unburned strip of duff 25’-50’ wide and coarse woody material within 50’ of perennial streams.

Fire effects monitoring overview

AFR fire effects monitoring tracks accomplishment of burn objectives. Plot data are used to quantify and inform the final assessment of whether burn objectives were met. Each objective is linked to a specific monitoring indicator recorded in pre- and post-burn plots, with additional metrics to characterize the unit or inform fire or smoke modeling, and repeat photographs to document fire effects. In addition to monitoring plots, pre- and post-burn unit walk-throughs are used to assess objectives not captured at the plot scale. Pre-treatment plot data are typically collected shortly before the burn (but can be from recent years if conditions have been stable, or collected the day of

the burn if necessary). Post-burn data and photographs are recorded in the fall of the burn-year (for spring/early summer burns) to allow for tree mortality indicators and ground cover conditions to develop.

Plot-based and walk-through data record *what* happened as a result of the burn – fire effects monitoring (FEMO) during the burn documents *how* and *why* it happened. This before-during-after monitoring approach connects fire effects to burn conditions and operations to inform adaptive fire management. FEMO monitoring during the burn records fire weather and fuel condition data, fire behavior, smoke dispersal, ignitions patterns, holding issues, and a timeline of important events and decisions. What is recorded can be adapted for each burn and the FEMO may not make all observations directly (e.g. if other fire staff are available to take weather readings or post as smoke look-out). A key part of the FEMO role is to provide the burn boss with information linking implementation actions and burn outcomes, both in written reports and as direct feedback during burn operations or in after-action review (AAR).

Monitoring plot method

AFR burn monitoring plots are 0.1 acre, circular (radius = 37.25 feet), and not slope corrected. To capture the range of fuels, topographic settings, stand types, and fire effects, plots are randomly distributed in advance throughout the planned burn unit using GIS tools, with at least one plot per 10 acres and at least 5 plots per unit, or a minimum of 3 plots for small units ($\leq$ 20 acres). Plot locations are GPS-marked and may be moved, added or dropped during monitoring in response to adjustments in the final perimeter or to better represent unit conditions. Pre-burn plot photographs and GPS are used to re-locate plot centers. In data analysis and interpretation, plot data are area-weighted if not proportionally distributed relative to the unit (or sub-unit) acres they represent.

Pre-burn plot data

Table 1 (below) lists and defines the specific burn monitoring plot data, links to prescribed fire objectives, field protocols, and timing before and/or after the burn. Slope, aspect, and canopy closure are recorded to characterize the unit. Fuel model and canopy base height are recorded pre/post burn as indicators of fuel reduction and for fire modeling. To visually document the unit and fire effects, a representative photograph of stand conditions is taken pre-burn, along with a second-low angle photograph of representative surface fuels. For the Ashland watershed, where loose granitic soils and steep slopes create erosion risk, ground cover retention monitoring was developed with the Forest Soil Scientist, measuring effective ground cover (EGC) by line-intercept pre/post burn (objective 6). The percent live cover of understory trees and shrubs (objective 2) are each recorded pre/post burn, adjusted for madrone resprouting. For tree mortality objectives 3 and 4, the percentage of recently dead trees (needles or fine twigs still present) in each relevant size class is recorded pre-burn and used to correctly assign mortality from fire post-burn. During pre-burn monitoring, the unit-scale condition of legacy trees (objective 5) and large down wood or snags (objective 7) are noted. Post-burn unit walk-throughs are used to estimate loss of legacy trees or large down wood, and to assess burn impacts on habitat leave areas (objective 8) or stream buffers (objective 9).

Post-burn plot data

Plots are re-located using GPS and landmarks in the pre-burn photograph. **Table 1** identifies and defines metrics recorded during post-burn monitoring. The stand condition photograph is repeated, and the ground fuels photo repeated if important to illustrate fire effects (optional). The pre-burn ground fuel photograph is used as a reference to visually estimate reduction in surface fuels (objective 1) post-burn. The percent area of each plot burned is also recorded, and canopy closure repeated if there has been substantial crown scorch or torch. Fuel model, canopy base height, and EGC by line-intercept (objective 6) are all repeated. Understory (objective 2) cover is estimated post-burn and the relative difference taken as the reduction in cover. Cover of stump or basal-sprouting madrone is recorded pre

and post burn and used to adjust the reduction in understory cover during summary. For objectives 3,4, and 5, trees in each respective size-class are recorded as fire-killed if ≥90% crown-scorched or torched[1] in fall post-burn monitoring (after ruling out trees recorded as recently dead pre-burn).

Post-burn walk through monitoring follows the same timing as plots, and includes GPS mapping of the final burn perimeter (and as needed, other relevant features such as high-intensity or unburned sub-areas). Traveling to plots and mapping the final unit perimeter provides a consistent and systematic route for pre/post unit walk-through observations. Legacy tree mortality or consumption of large logs and snags can be visually assessed during walk-through if fire effects are mild to moderate, or supplemental sampling can be developed as needed for more intense burns. For example, in 2017 supplemental monitoring was completed in collaboration with Forest Service ecologists to better track and quantify fire impacts to legacy trees (report link). Fire impacts to stream buffers or wildlife leave areas are evaluated post-burn using GPS, field maps, and established indicators of canopy or soil burn severity.

FEMO monitoring during burn operations

Monitoring during the burn is ideally done by a trained fire effects monitor (FEMO). The FEMO tracks fire weather, fuel moisture, smoke and fire behavior as context for understanding fire effects and relative to the prescription ranges in the burn plan. **Table 2** lists and defines the standard set of fire weather and fuel data for AFR FEMO monitoring. At a minimum, fire weather is recorded hourly bracketing the time-span of burn operations and includes air temperature and relative humidity, wind speed and direction, elevation, aspect, cloud (or smoke) cover, canopy cover (shading), and location within the unit. Those data are then used to calculate the percent moisture for fine dead fuel (1-hour fuels) and probability of ignition. If requested by the burn boss or during times of rapid change, more frequent measurements are taken. A fuel moisture probe can be used to sample representative 10, 100, and 1000-hour fuel moisture before and during the burn (optional). Weather and fuel data are best measured inside the unit at locations ahead of the firing crew and soon to be ignited – but not close enough to the fire to compromise operations or safety, or for heat and smoke to bias the readings.

Fire behavior is observed and recorded throughout the unit, especially in areas of active fire, ignitions, or higher intensity. Both typical fire behavior and high-intensity events are documented and compared to the acceptable prescription range. **Table 3** provides a basic checklist and descriptions for fire behavior and smoke observations to record in an AFR FEMO log. At a minimum, fire behavior metrics of flame length (average and maximum) and rate of spread (average) quantify representative fire behavior. Observations are updated when fire behavior, weather conditions, or ignitions change instead of being tied to a set time interval. Peak fire events such as torching, crowning, spotting, or escape, and other descriptive metrics including bole char height, fire type, or flame zone depth are recorded when relevant. The timing, location, and outcome of the test burn(s) are always recorded. Fire behavior records are entered in a unit log linked to notes on burn conditions and operations.

Smoke observations are an important part of AFR burn monitoring given the proximity of the project area to the City of Ashland and sensitive smoke receptor sites. AFR burn plans include acceptable direction(s) of smoke dispersal in the prescription. The approximate height and dispersal direction of the smoke column are recorded when observable. The plume/column type and impacts from heavy smoke (e.g. crew safety, visibility, roads) are noted when relevant. Smoke behavior and time of observation are recorded in the unit log. Ideally, a second observer is posted at a vantage point outside the unit to record smoke, because visibility of the column from within the unit is typically limited.

[1] For future monitoring this could be reasonably adapted down to ≥75% crown-scorch, or more accurately assessed as crown-kill the next growing season. Other easily-observable mortality indicating conditions (e.g. beetle attack, dwarf mistletoe) could also be included in this estimate.

In addition to records on fire behavior and smoke, the FEMO takes notes in a unit log recording the timeline of burn operations, name and affiliation of the burn boss, firing, and holding leads (and trainee(s)), important events, communications and decisions, ignition patterns, holding issues, and status of accomplishing burn objectives. Descriptions of ignition patterns include the type of firing configuration, approximate crew size, line spacing, strip or dot lighting, etc., and are updated when these change. All log notes include the time and approximate location within the unit. Copies of the unit log or notes recorded by the burn boss (or trainee) provide important information on key decisions and events during the burn, and should be incorporated into reporting if available. The burn plan and incident action plan (IAP) are important references. Representative photographs (or video) of fire behavior, smoke, and events during the burn add to the written documentation. Map notes, either sketched in a unit log, on a printed map or mobile device are an important part of burn documentation. Written or mapped notes on unit conditions may also be recorded during pre-burn monitoring and communicated to fire leads if important for informing upcoming burn plans and operations.

If a trained FEMO is not available for during-burn monitoring, weather, fire, and smoke observations taken by a fire crew member, and the burn boss's unit log can suffice to document burn operations and fire behavior.

Appendix 1 – Grid-50 method for densiometer canopy closure:

Canopy closure is measured with a convex-lens spherical densiometer using a defined sub-area of the lens with 12.5 grid cell squares included (Figure 1). In each grid cell, record closure equivalent to quarter-square covered areas. Each cell is scored from 0 – 4, equivalent to 25% cover classes, with a maximum potential score of 50 for each reading. Four directional readings are taken (upslope, downslope, and to each side along contour) and converted to a single percent closure value for the sample point = (sum of canopy hits)/2. When canopy cover is continuous but diffuse with high light infiltration (or sparse and scattered), account for the combined area of the many fine-scale openings (or cover) in each grid cell by giving a score of 1 for each equivalent of a quarter-cell (25%) opening (or cover).

Figure 1. Wedge-shaped portion of densiometer grid used for canopy closure readings (shaded area). There are 12.5 grid cells contained in this area with a total potential score of 50 quarter-cell equivalents. No data are recorded for the un-shaded area.

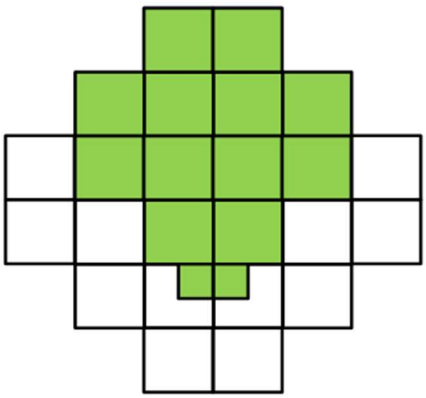

Table 1. Summary of plot-based and walk-through fire effects monitoring metrics, with summary on field protocol and timing of observations. For cover estimates in 0.1-acre plots, a square measuring 6 ½ feet on each side is equivalent to 1% of the plot area.

Data field	*Definition and notes*	*Timing*	*Purpose*
PlotID	Unique plot identifier assigned in GIS = "UnitID" + sequential number.	pre	Link to GPS GIS plot locations
Date	Monitoring dates. Post-burn done same year as the fire, at end of growing season, ideally after main litter fall but before the start of substantial fall rains ~ Sept - Oct.	pre/ post	
PhotoID	Photo identifier. Photo taken eye level from plot center out, representative of stand and fuels, include landmarks near and far to aid repeat photo post-burn, bring pre-burn printed images for post repeat.	pre/ post	Visual record of unit condition and fire effects
PhotoAzm	Compass bearing in degrees (azimuth), plot center to center of photo.	pre	Aids repeat photo
GrndPhotoID	Photo identifier. Pre-burn representative ground fuels and understory, taken from plot edge to plot center, low horizon. May repeat post-burn, optional.	pre/ post	Use to estimate fuel reduction, Objective 1, record of fire effects
Slope%	Clinometer, % slope, average above and below plot if variable.	pre	Describes unit, informs Objective 6
Aspect	Compass bearing directly downslope, in degrees (+/- 5)	pre	Describes unit, informs fine fuel moisture and POI tables
Closure%	Densiometer in four directions, up, down, side slopes, using grid-V with 50 quarter cells per direction, keep running tally of canopy hits and divide by 2 for % closure.	pre/ post	Describes unit, records fire effects on canopy cover, if any
EGC%	Effective ground cover. Line intercept tally of all surface cover with gaps < 0.1 ft, except exposed soil, along two 25 ft transect from 10 ft to 35 ft from plot center, oriented to bearing of aspect + 45 degrees. Total distance covered along both transects in decimal feet x 2 = % EGC (100 - total gaps x2 = %EGC)	pre/ post	Objective 6, direct measure of EGC
SBfuel	Fuel model from Scott and Burgan (2005) photo series using TNC local fuel model guide - best fit model selected based on what fuels/vegetation will carry the fire or significantly affect fire behavior, relative loading, and anticipated flame lengths, rate of spread.	pre/ post	Describes unit fuel loading, indicator of fuel/fire behavior reduction from burning, used for fire or smoke modeling
CBH(ft)	Height (nearest foot) from ground to continuous (< 6' gap) ladder fuels to canopy (not isolated trees), 0.1 if to ground, "0" if no canopy	pre/ post	Indicator of ladder fuel reduction, fire modeling input
AreaBurned%	Percent of total plot area with visible char or consumption from burn, post-burn only.	post	Describes fire implementation and post-burn unit conditions
1-100hr%Red	Percent reduction in litter and light surface fuels (1 – 100-hour ground fuels = litter/grass and sticks up to 3" diameter) recorded post-burn only, use pre-burn ground fuels photo as a visual reference.	post	Objective 1, direct measure of surface fuel reduction
UstorCvr	Percent cover of all live/green understory shrubs (>12" height) and trees (<5" dbh), recorded as the actual absolute cover not occupied area. This measure includes all ARME but can be adjusted with resprout cover metric below - ARMEre. Excludes groundcover woody species and tree seedlings.	pre/ post	Objective 2, direct measure of understory reduction
ARMEre	Percent cover of all live/green madrone stump or basal sprouts (>12" height and <5" dbh) used to adjust UstorCvr, actual cover not occupied area. This is cover of pre-burn thinning resprouting or post-burn basal resprouting to subtract from understory cover total (not additional).	pre/ post	Objective 2, additional metric added for 2018 monitoring
IntMort	Percent of intermediate trees (5-12" dbh) that are recent dead or fire killed, pre-burn data discerns mortality from causes other than fire. Recorded as percent = dead in plot/total in plot x 100.	pre/ post	Objective 3, direct measure of intermediate tree mortality
OvrMort	Percent of (co)dominant trees (>12" dbh) that are recent dead or fire killed, pre-burn data discerns mortality from causes other than fire. Recorded as percent = dead in plot/total in plot x 100.	pre/ post	Objective 4, direct measure of overstory mortality/survival
	Walk-through assessment metrics:		
LegMort	Percent of legacy trees in unit killed by burn, walk-through (or separate sampling), not plot based, may need to assess again in year-2. Legacy trees are large, old (> 150 yrs) trees with complex form, wide bark plates, and provide important habitat features and structure.	pre/ post	Objective 5, direct measure
LDWloss	Percent consumption of large diameter wildlife logs and snags (>20" diam), walk-through, not plot-based.	post	Objective 7, direct assessment
LeaveSevr	Apparent fire severity in leave areas, reference CBI scale, walk-through, not plot-based.	post	Objective 8, direct assessment
StrBuffer	Where applicable, percent of length of perennial streams in unit retaining unburned buffer of duff 25'-50' wide and retaining coarse woody material within 50' of stream channel.	post	Objective 9, direct measure

Table 2. Fire weather and fuels data definitions for metrics recorded at regular time interval on FEMO form.

DATE	date of observations, day of burn
TIME (24 HOUR)	time of observation by 24-hour clock - typically observations made hourly or every 30 minutes
LOCATION	location of observations relative to unit, aspect, landmarks, ignitions
ELEVATION (FEET)	approximate elevation at location from map contour, GPS unit, or Kestrel
SLOPE (<30% or >30%)	approximate percent slope at location, at minimum record if > / < 30% for fuel moisture tables
ASPECT	general aspect at location as cardinal direction, at minimum N, E, S, W for fuel moisture tables
SHADING (<50% or >50%)	ground surface shading at location from canopy cover, at minimum record > / < 50% shading
DRY BULB TEMP (°F)	air temperature from dry bulb on sling psychrometer
WET BULB TEMP (°F)	corresponding temperature from wet bulb on sling psychrometer
RELATIVE HUMIDITY (%)	calculated RH% based on elevation, wet bulb and dry bulb temperatures using tables (or other tool)
CLOUD COVER (%)	approximate percent cloud (or smoke) cover overhead, note in comments if includes smoke cover
WIND SPEED / GUSTS (MPH)	average eye-level wind speed and maximum (gusts) at location from anemometer
WIND DIRECTION	typical direction of wind at location as cardinal direction - comment if shifting, up/down slope, etc.
1-HOUR FUEL MOISTURE (%)	calculated percent moisture of 1-hour fuels from Fine Dead Fuel Moisture tables - based on dry bulb temperature and RH, then adjusted by season, slope, aspect, time, and if above/below/level with fire
PROBABILITY OF IGNITION (%)	calculated probability of ignition for 1-hour fuels from table (or other tool) - based on dry bulb temperature, if exposed or shaded at location, and the current 1-hour fuel moisture
COMMENTS	important additional or explanatory information on weather readings or calculated fuel metrics

Table 3. Checklist and description of important fire behavior and smoke observations to record in FEMO log.

TIME (24 HOUR)	time of observation by 24-hour clock - timing as relevant to capture typical behavior and updated at relevant changes in behavior, ignitions, fuels, topography, etc., not at regular time interval
LOCATION	location of observations relative to unit, aspect, landmarks, ignitions
FLAME LENGTH AVG. (FEET)	visually estimated average/typical length from flame base to tip in feet
FLAME LENGTH MAX. (FEET)	optional - where relevant visually estimated average/typical length from flame base to tip in feet
RATE OF SPREAD (FEET/MIN)	average/typical rate of fire spread in feet per minute – feet per minute is closely equivalent to chains per hour for field estimation
TOPOGRAPHY	where relevant to fire behavior, record the slope, aspect, landform at observation location
FUEL TYPE	if relevant to fire behavior and different from the typical fuel type(s) of the unit
TORCHING/CROWNING	if observed, record location and describe for fire ascending into canopy
SPOTTING/ESCAPE	if observed, record location and distance of spotting, extent and control of slop-over
SMOKE COLUMN HEIGHT (FEET)	estimated height of smoke column rise before dispersing, or if smoke not rising/dispersing
SMOKE DIRECTION	direction of main smoke dispersal in cardinal directions and relative to prescription