# FUELS REPORT FOR THE BEATOOTH FRONT STORM DAMAGE CLEAN-UP AND FUELS REDUCTION PROJECT

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Custer National Forest
Northern Region

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## Analysis Area

Proposed activities fall into three separate drainages on lands administered by the US Forest Service, Custer National Forest (CNF). Drainages include Main Fork of Rock creek, Fishtail creek and Little Rocky creek. Activities to reduce natural fuel loading are proposed on 612 acres within these three drainages. Effects to fuels and potential fire behavior considered within this report will be assessed on 377 acres in the Fishtail and Little Rocky creek drainages, and 235 acres in the Main Fork of Rock creek drainage. Probability of acres burned will be assessed for drainage areas. Much of the area in the three drainages, outside of project units is located on steep slopes with very few roads, for access. Also, much of the area surrounding the project units in the three drainages lies within Wilderness and Roadless areas, further limiting treatment opportunities.

## Regulatory Framework

### Forest Plan Direction

The Custer National Forest Management Plan dictates that management of the Custer National Forest insures a safe environment for public use, as well as for resource management activities (USDA Forest Service, 1986). Guidance in the in the CNF Fire Management Plan (USDA Forest Service, 2008) states:

- Make firefighter and public safety the highest priority of every fire management activity.
- Reduce wildland fire hazard in and near high value public and private land.

Framework within the CNF Fire management plan dictates the use of appropriate management response on public lands, considering the full range of alternatives (USDA Forest Service, 2008).

### Forest Service Manual (FSM) 5100 – Fuels Management

The objective of Fuel Management 5150.2 states, "To identify, develop, and maintain fuels profiles that contribute to the most cost-effective fire protection and use programs in support of resource management direction in the forest plan" (FSM 5100, 1991). Fuels may be redistributed onsite to a condition that is less hazardous, or allows for more rapid deterioration or more effective disposal. Fuels may be removed offsite for further utilization, and methods for disposal of fuels may include manual, mechanical, biological, and prescribed fire (FSM 5100, 1991).

### The Healthy Forest Initiative and Healthy Forest restoration Act (HFRA)

In HFRA, the USDA Forest Service is directed in accordance with A Collaborative Approach for Reducing Wildland Fire Risk to Communities and the Environment: 10-Year Comprehensive Strategy Implementation Plan to, "develop an annual program of work for federal land that gives priority to authorized hazardous fuels reduction projects that provide for protecting at-risk communities or watersheds" (USDA Forest Service, 2004). The city of Red Lodge is located at the confluence the Main Fork of Rock creek

and has been designated a community at risk in the Federal register (Federal Register, 2001).

## Assumptions, Methodology and Scientific Accuracy, and Information Used

Information used in this analysis is a combination of available data, research material, literature, field reviews, personal communications and modeling. The measurement criteria used to display effects of alternatives is a qualitative change in future fire behavior within the treatment areas based on modeling results. Summaries of results, data collected, analyzed data and maps can be found in the project record.

### Stand Data

There is a very limited amount of stand data available for the Beartooth Ranger District. Stand conditions such as canopy base height, canopy bulk density, fuel loading and canopy fuel loading were determined through several methods. A fuel loading photo guide (Mackay, 1981) was used to determine existing fuel loads and desired fuel loads based on modeled fire behavior in the guide. Two General Technical Reports, Standard Fire Behavior Fuel Models: A Comprehensive Set for Use with Rothermel's Surface Fire Spread Model (Scott and Burgan, 2005), and Stereo Photo Guide for Estimating Canopy Fuel Characteristics in Conifer Stands (Scott and Reinhardt, 2005) were used to determine stand characteristics used for modeling. Data from the field guides was verified and calibrated as needed through ocular estimations of the analysis area. Stand attributes were also calibrated using representative stand data from a Technical Fire Management (TFM) project (Hale, 2006) done in the Snow and Sheep creek summer home areas in the Main Fork of Rock creek. Stand exam data in the TFM project was collected using Northern Region common stand exam procedures, and then analyzed using Forest Vegetation Simulator (FVS) and Fire and Fuels Extension (FFE) version 6.21, to model silviculture prescriptions and fire behavior. Methodology for identifying stand characteristics was coordinated through conversations with the CNF Silviculturist, Dennis Sandbak (Sandbak, 2008).

### Weather and Fuel Conditions

Weather data and fuel conditions for model inputs were determined for a "worst case" scenario fire event. Weather data for calculating fine fuel moistures and temperature was collected for Timbercrest weather station which is in the West Fork of Rock Creek drainage, which flows into the Main Fork of Rock creek. Timbercrest weather station was utilized for weather observations as it was determined to be the most representative weather station for the project areas. Historic weather data for this station was collected using Kansas City Fire Access Software (KCFAST) and loaded in to FireFamily Plus (FFP) software, version 3.05. Weather data for June 1 through September 30 for a ten year period (1998-2007) was analyzed. June 1 through September 30 was selected for analysis as it represents the core of extreme fire weather during the fire season on the Beartooth Ranger District. The 97$^{th}$ percentile fine fuel moisture and temperature were calculated using percentile weather function in Season Reports, utilizing a SW wind.

Southwest winds were a predominate wind direction common to all three drainages where projects are proposed, as per communications and e-mails with Todd Chambers and Don Moore from the National Weather Service (Chambers, 2008 and Moore, 2008). Foliar moisture values were based on data collected from foliage within the West Fork of Rock creek drainage during August, 2007. A value of 60% was used for live woody fuel moisture for model inputs, as it is just above the dormancy state and would represent late fall or drought conditions. A value of 30% was used for herbaceous fuel moistures which indicates completely cured dead fuel. Wind speeds can be set to a reasonable value based on expert knowledge of local conditions (Scott, 2003). Based on 11 years experience with actual fires on the Beartooth Ranger District, District Fire Management Officer (DFMO), Jeff Stockwell (Stockwell, 2008) considered a 25 mile per hour (mph), 20 foot windspeed, as an appropriate value for use in modeling fire behavior under extreme conditions. Wind adjustment factors and shading used in modeling were calibrated to best represent conditions for each fuel model.

**Fire Occurrence and Burn Area Probabilities**

Geographic Information Systems (GIS) was utilized to determine fire occurrence and causes. Areas within the drainages where fires could impact the project treatment units were screen digitized to create a shapefile. The digitized areas were then used to clip the 2007 CNF fire point shapefile, to determine fire occurrence and cause for each drainage. GIS fire point data for the Beartooth Ranger District covers a period from 1953 to 2007.

Probability of unplanned fire impacting the project areas was determined using the computer program PROBACRE. The purpose of PROBACRE is to estimate the risk that a significant portion of the management area will burn over a period of time. The program uses the Poisson probability model (Figure 1), fire size and frequency of past fire to determine future fire event probabilities. Recorded fire history, on the Beartooth Ranger District, only goes back to 1948. Based on personal accounts ,historic photos, and tree age, the last known large fire event for the for Fishtail and Little rocky creek drainages was 104 years ago, and 118 years ago for the Main Fork of Rock creek drainage. 104 and 118 years (fire data periods) were used to find the annual fire frequency by size class by drainage. A Poisson random process is characterized by counting individual events over space and time (Wiitala 1999). A polygon of areas with potential to impact the project site based on continuous fuels and topography was digitized using ArcGIS to determine acres, for input into the model. Acres for each area were, 47767 acres for the Main Fork of Rock creek, and 37,500 acres for Fishtail creek and Little Rocky creek. Fires were tallied by size class and each size class divided by fire data period to establish the frequency by size class. A size of 15,000 acres was used to represent the historic stand replacement fires from the turn of the century in each of the three drainages. This size was based on the Shepard mountain fire (14,809 acres), a stand replacement fire in East Rosebud drainage on the Beartooth Ranger District in 1996. Fifteen years was used as a time period over which probability estimates were made. Fifteen years is the length of time that the proposed treatments are expected to meet purpose and need.

**FIGURE 1**: Poisson Probability Model

$$f(x) = \lambda^{x} * e^{-\lambda} / x!$$

Where;

$\lambda$ = Mean number of successes in the given time interval (i.e. annual fire frequency

x = random variables with possible values 0, 1, 2, ….

e = the base of the natural logarithm, 2.71828

**Fuel Models**

Fuel models for project units were determined using GIS. A Fuel model shapefile was developed for the Greater Yellowstone Area (GYA) (Seth and others, 2004), which includes the project areas. The Fuel model shapefile was clipped by the project unit shapefile to determine fuel models within project areas. In November of 2007 a wind event caused wind damage to approximately 15,000 acres on the Beartooth Ranger District of the Custer National Forest. Ocular estimates were made to readjust changes in fuel types within project units to more properly represent current conditions.

**Fire Behavior Modeling**

Nexus v2.0 (Scott, 2004) was used to model potential fire behavior. Fuel mode 8 (Closed Timber Litter) Fuel Model SB2 (Low Load Blowdown) and fuel model SB4 (High Load Blowdown) were the predominate fuel models determined in the proposed treatment areas, based on sight visits, and were used to assess treatment effectiveness. Fuel Model 8 is the predominate fuel model surrounding most of the treatment areas. Approximate slopes for modeling were calculated through the project units, along the travel corridors with 4% slopes best representing modeled areas. Most large fire events on the Beartooth Ranger District are down canyon wind driven events, such as the Shepard Mountain fire (1996), Derby (2006) and Willie fire (2000). Predominate southwest winds for the three drainages where activities are proposed, are conducive to down canyon fire events; therefore, fire behavior was modeled for downslope winds. The predominate tree species in the project areas is lodgepole pine (*Pinus contorta* Douglas var. *latifolia* Engelm). Nexus v2.0 doesn't model probability of ignition or spotting distance, so BehavePlus 3.0.2 (Andrews and others, 2004) was used with lodgepole pine as the Spot Tree species for calculating those values. BehavePlus 3.0.2 was also used to model probability of lightning ignition under modeled conditions. Canopy bulk density for modeling current and post treatment conditions were based on values previously used for a TFM project on the Beartooth Ranger District (Hale, 2006), and ocular comparisons of the project area using Stereo Photo Guide for Estimating Canopy Fuel Characteristics in Conifer Stands (Scott and Reinhardt, 2005). Canopy base heights were determined through ocular estimates and and 12 feet was used for modeling. A bulk density value for fuel model SB2 (Low load blowdown) was estimated between current and post treatment bulk densities to account for removal of canopy from the November, 2007 wind event.

**Assumptions and Limitations**

- Analysis results will be valid as long as management directions do not change significantly.
- Weather data collected from Timbercrest weather station best represents weather on the project sites. 10 years of weather data, 1998-2007, were used as they best represented current weather trends. Drought is part of the normal climate patterns for the Northern Rockies (Moore, 2008). The Beartooth Ranger district has been experiencing drought conditions over approximately the last 10 years.
- Predominate fuel model and species outside the proposed treatment areas were estimated to be fuel model 8 and lodgepole pine. Fire Behavior outside of the proposed treatment units was assumed to be the same or more extreme, depending on elevation, slope amounts of blowdown and sheltering of fuels.
- Optimal surface fuel loading was determined using a fuel loading photo guide based on fire behavior estimates for post treatment, modeled with a 10-15 mph, 20 foot windspeed, 0% slope and 100% foliar moisture (Mackay, 1981). This may somewhat underestimate fire behavior, compared to fire behavior modeled with parameters used in BehavePlus 3.0 and Nexus v2.0. Long range spotting, firewhirls and crown fires were outside the scope of this model; however, some inferences can be made from the photographs in the guide (Mackay, 1981).
- PROBACRE estimates assume that the expected size to which a fire grows at any time of occurrence is independent of both the number of fires and burned acres that recently precede it. When threshold acreage is set high, the risk of exceeding the threshold is overestimated because the fire behavior on average would be reduced in areas where fires had burned previously. Changes in the ecosystem, fire protection levels and fuels management programs would also affect fire size/frequency relationships through time. The shorter the time horizon of the analysis, the more reasonable is the assumption that fire size/frequency inputs will remain constant over the horizon. The number of annual fire frequency will remain constant.
- Global warming was not considered as an impact during the effective duration of this project. Long term weather models are usually based on large geographic areas making it hard to judge the degree of or effects of climate change at a local level (Moore, 2008). Long term weather models cannot predict specific events (Rapp, 2004). According to Don Moore of the National Weather Service, temperature trends are easier to model, in regards to global climate. Don also stated that precipitation has a greater influence on results for fire modeling than temperature, but no consistent long term precipitation modeling, is currently available (Moore, 2008).

## Existing Condition/No Action

### Main Fork of Rock Creek

Very little recorded fire history exists for the Beartooth Ranger District before 1948. On September 14th -15th , 1948, the Hellroaring and Rock Creek fires burned approximately 3,000 acres in Hellroaring and Rock creek drainages south of M-K campground. Reports from the fire on the 15th stated, that the fire was actively crowning. A 40 mph down canyon wind and 1.5 %, 10 hr fuel moisture were recorded on the 15th, during the most active fire runs. Rates of spread of 160 chains per hour were observed between Mirror creek and Chain creek (Akers and Park, 1948). Forest ecologist Jeff DiBenedetto (2008) stated that the north end of the canyon is mostly even aged lodgepole that aged approximately 110 to 120 years old, putting the last potential stand replacement fire in the 1890s. Lodgepole pine is the predominant tree species in the drainage. DiBenedetto stated that the Main Fork of Rock fire regime can be predominantly described as biophysical setting (BpS) SPFl1, with transition zones at the lower (BpS: PPDF1) and upper elevations (BpS: SPFI2) (DiBenedetto, 2008). BpS SPF11, is described as occurring in the lower subalpine zone on gentle to moderately steep terrain (e.g., 10-60% slopes); relatively dry sites generally are dominated by lodgepole pine, and moist sites are dominated by Engelmann spruce, subalpine fir, or by quaking aspen. Fire return intervals are generally moderate long to long intervals of (e.g., 100-200 yr) stand replacement fires, with a substantial amount of terrain influenced by moderately long interval (e.g., 50 to 100 yr) mixed severity fires (FRCC, 2008). Since 1953 there have been 80 recorded wildfires in the Main Fork Drainage ranging in size from .1 to 1503 acres. Of those, 33 have been lightning (41%) and 47 human or other ignition sources (59%). Over the last ten years, there have been 20 fires, or and average of 2 fires per year. Of those fires, 8 were lightning (40%) and 12 were human caused or other ignition sources (60%). From 1953 to 2007, 3 recorded fires have occurred within or on the edge of the proposed treatment units in the Main Fork of Rock Creek. Two fires were human caused and 1 caused by lightning.

Five fuel models for a total of 235 acres were identified within the project prior to the 2007 wind event (Table 1). After the wind event, approximately 102 acres of fuel model 8 spread across the project area was converted to blowdown fuel models (Table 2). Outside the proposed treatment units, within the Main Fork of Rock Creek drainage, there is estimated to be an additional 310 acres of heavy to moderate blowdown. Of those acres, approximately 260 acres are a heavy blowdown fuel model SB4, and approximately 50 acres are moderate blowdown fuel model SB3. Blowdown acres outside the proposed treatment units and in the Main Fork drainage were estimated using fixed wing aircraft. Area fuel loading for fuel model 8 ranges approximately 6-40 tons per acre, and approximately 90-100 tons per acre in FM SB2, and between 105-150 tons per acre in FM SB3. Canopy base heights varied throughout the Main Fork. There were areas along the road corridor that had previous activity such as thinning or were post and pole units, with the overall base heights being approximately 13 feet. Most of the canyon and project area has ladder fuels from regeneration. Blowdown and snow damaged tops

and downed trees are prevalent. Estimated canopy bulk densities in lodgepole were .09 kg $m^3$.

**Table 1:** Fuel Models and acres for the project area in the Main Fork of Rock creek

| Fuel Models (FM) | GIS Acres prior to wind event 11/2007 | Acres after wind event | % of Project Area post wind event |
|---|---|---|---|
| FM 1 | 31 | 31 | 13.2% |
| FM 2 | 0 | 0 | 0.0% |
| FM 5 | 17 | 17 | 7.2% |
| FM 8 | 172 | 70 | 29.8% |
| FM10 | 15 | 15 | 6.4% |
| FM SB2 | 0 | 98 | 41.7% |
| FM SB3 | 0 | 4 | 1.7% |
| FM SB4 | 0 | 0 | 0.0% |
| Totals | 235 | 235 | 100.00% |

Main Fork of Rock creek can be described as a long narrow canyon oriented south to north. Highway 212 is paved, and Forest Road (FR) 2421 is a winding narrow road paved to Limberpine campground, where it turns to gravel to the end of the road at Glacier Lake trailhead. Stand conditions throughout the canyon and project area consist predominantly of even aged stands of lodgepole pine. Under predicted fire behavior, access by firefighters and emergency personnel could be limited. Crown fire rates of spread and long range spotting in the canyon bottom could compromise egress on Highway 212 and FR 2421. Highway 212 is the only egress opportunity for vehicles exiting the canyon. Structures within the proposed treatment units, and within the Main Fork of Rock creek drainage, could be left without fire resources for structure protection. Some structures have had previous fuels treatment, and may be defendable in the event of a surface fire. Under current conditions, an active crown fire in the Main Fork of Rock Creek drainage could limit access to firefighting resources to prepare or defend structures. Many of the structures are surrounded by heavy dense timber with trees growing next to the structures. Current fuel loads in conjunction with structure conditions, could make many structures in the Main Fork of Rock creek drainage un-defendable and reduce survivability.

The Main Fork of Rock creek drainage has openings of grass (Fuel Model 1), talus slopes, rock outcrops, and area of grass/sage and timber mix (Fuel Model 2). These openings with discontinuous tree canopy could be potential fire safe zones within the canyon where the general public or firefighters could go to ride out the flaming front. These areas, along Highway 212 and FR 2421, may need to be modified to be fire safe, in the event of a wildfire. Access to these potential zones under extreme fire behavior could be compromised. Crown fire rates of spread and long range spotting in the canyon bottom could compromise egress on Highway 212 and FR 2412.

Values at risk within and adjacent to the Main Fork include numerous residences and Forest Service infrastructure. The city of Red Lodge and outlying subdivisions are located at the mouth or north end of the canyon. Sixty-six summer homes are located

north of the project area on the east and west sides of the canyon. These are bordered to the north by the 400 Ranch subdivisions, with 73 structures, and Rock Creek Resort. Three organizational camps, Westminster Spires (13 structures), Lions camp (21 structures) and Yellowstone Bighorn Research Association (34 structures) are located in the lower end of the canyon. Most residences and summer homes are located on the canyon bottom along the travel corridor, but several homes and Yellowstone Bighorn Research Association Camp are located on steep side slopes of the canyon. Forest Service infrastructure within the canyon bottom includes 5 trailheads, and 6 campgrounds. Parkside, Greenough, Limberpine and M-K campgrounds are all located within the project area. Highway 212 located in the canyon bottom is a paved road that was designated an All American Highway in 2003. Highway 212 winds through the north portion of the project area. An estimated 1200 vehicles a day, travel this highway during peak use to access Yellowstone National Park and recreate in the Rock Creek valley (Beartooth All-American Road Steering Committee, 2002). Forest Road 2412 which turns off Highway 212, runs through the remainder of the project area. Vehicle use during the week on FR 2412 averages 200 vehicles a day, with peak days of 500 on the weekend (Christensen, 2008). Forest products utilized within the canyon, include post and pole, and firewood. Multiple public water systems exist within the Main Fork of Rock Creek as defined by the Safe Drinking Water Act (42 USC 300f). Additionally, numerous privately owned groundwater wells and springs used for residential drinking water and ditches and wells used for irrigation purposes, are fed by water from the Main Fork of Rock Creek (See Hydrologist Specialist Report).

**Fishtail Creek/Little Rocky Creeks**

Very little recorded fire history exists for the Beartooth Ranger District before 1948. North facing slopes, between Red Lodge, MT and Fishtail and Little Rocky creeks predominantly consist of even aged lodgepole. District Fire Management Officer, Jeff Stockwell (2008), stated that he had talked with landowners who's grandparents remember the north face of the of the Beartooth Ranger District, which includes the Fishtail and Little Rocky creek drainages, burning in a stand replacement fire, around 1904. Jeff DiBenedetto (2008) stated that the Fishtail/Rocky creeks fire regime can be predominantly described as Biophysical Setting (BpS) SPFl1, with transition zones at the lower (BpS: PPDF1) and upper elevations (BpS: SPFI2). BpS SPF11, is described as occurring in the lower subalpine zone on gentle to moderately steep terrain (e.g., 10-60% slopes); relatively dry sites generally are dominated by lodgepole pine, and moist sites are dominated by Engelmann spruce, subalpine fir, or by quaking aspen. Fire return intervals are generally moderate long to long intervals of (e.g., 100-200 yr) stand replacement fires, with a substantial amount of terrain influenced. Since 1953 there have been 28 recorded wildfires in the Fishtail creek and Little Rocky creek drainages, and surrounding area ranging in size from .10 to 380 acres. Of those, 12 have been lightning (43%) and 16 human or other ignition sources (57%). Over the last ten years, there have been 2 lightning fires, both in 2007. From 1953 to 2007, 3 recorded fires have occurred within or on the edge of the project area. Two fires were lightning caused and one human caused (Benbow fire). The Benbow fire (380 acres, 1980) occurred in portions of units 3 and 59. This was a human caused fire which destroyed one primary residence in a

small subdivision along Meadow creek. Several wind driven stand replacement fires have occurred in the local area around Fishtail and Little Rocky creeks, including Shepard Mountain (14,890acres, 1996), Storm Creek (61,300 acres, 1988) and Derby (281,000 acres, 2006). The Shepard Mountain fire occurred in the East Rosebud drainage, which has approximately the same orientation as both Fishtail and Little Rocky creek drainages. At the height of burning on the Shepard Mountain fire, the crown fire spread 5 miles in three hours, burning 35 homes and cabins.

Three fuel models for a total of 377 acres were identified within the project area prior to the November, 2007 wind event (Table 2). After the November, 2007 wind event approximately 265 acres of fuel model 8 spread across the project area was converted to blowdown fuel models (Table 3). Outside the proposed treatment units, within the Fishtail and Little Rocky Creek drainages, there is estimated to be an additional 5900 acres of heavy to moderate blowdown. Of those acres, approximately 2400 acres are a heavy blowdown fuel model SB4, and approximately 3500 acres are moderate blowdown fuel model SB3. Blowdown acres outside the proposed treatment units, and in Fishtail and Little Rocky Creek drainages, were estimated using fixed wing aircraft. Area fuel loading for fuel model 8 ranges approximately 6-40 tons per acre, and approximately 90-105 tons per acre in fuel model SB2. Fuel loads in blowdown FM SB3 and SB4 range between 105-150 tons per acre. Canopy base heights varied throughout the area. There were areas along road corridors that had previous activity such as thinning or firewood cutting, which had higher base heights, but the overall base average height was approximately 12-13 feet. Most of the proposed treatment units and project area have ladder fuels from regeneration. Blowdown and snow damaged tops and downed trees are very prevalent. Estimated canopy bulk densities in lodgepole were .09 kg $m^3$.

**Table 2:** Fuel Models and acres for the project area in Fishtail/Rocky Creek Drainages

| Fuel Models (FM) | GIS Acres prior to wind event 11/2007 | Acres after wind event | % of Project Area post wind event |
|---|---|---|---|
| FM 1 | 13 | 13 | 3.4% |
| FM 2 | 83 | 83 | 22.1% |
| FM 8 | 281 | 16 | 4.2% |
| FM SB2 | 0 | 133 | 35.3% |
| FM SB3 | 0 | 45 | 11.9% |
| FM SB4 | 0 | 87 | 23.1% |
| Totals | 377 | 377 | 100.00% |

Fishtail and Little Rocky creeks can be described as a narrow canyons oriented south to north. Both creeks come off the plateau on steep slopes, becoming more gradual as they descend to the valley floor. The area surrounding Fishtail and Little Rocky creeks is a continuous stand (approx. 35,000 acres) composed primarily of even-aged lodgepole pine, which reaches to the edge of Stillwater canyon west, and east to the into the West Rosebud Drainage. Main forest roads in the area include FR 2414 which is a gravel road that winds up to the Beartooth Mountain Christian Ranch, where it begins to narrow and

becomes very rough with potholes and rock cobble. FR 2415 which is a 4-wheel/ATV road, ties in with FR 2414 to form a loop.

Firefighter initial attack capabilities to suppress and contain wildfires under current conditions are limited by several factors. Predicted fire behavior under extreme conditions along the road corridor could preclude direct attack and potentially limit access and egress. Lack of access through private lands along the Forest Service boundary near Fishtail and Little Rocky Creek drainages, and a general lack of usable roads, also hinders firefighter capabilities.

Currently there are potential fire safe zones within the area where the general public could go to ride out the flaming front. These zones are along FR 2414 and FR 2415 including the old Benbow mill site, may need to be modified to be fire safe in the event of a wildfire. Openings consist of grass (Fuel Model 1), talus slopes, rock outcrops, and areas of grass/sage and timber mix (Fuel Model 2). Access to these potential zones under extreme fire behavior could be compromised. Crown fire rates of spread and long range spotting in the area could compromise egress on forest FR 2414 and FR2415. Structures in the area along FR 2414 could be left without fire resources for structure protection.

Values at risk include the towns of Dean and Nye, a small subdivision consisting of 6 structures along Meadow creek off forest road 2414, and the Stillwater Mine. The Beartooth Mountain Christian Ranch and several private residences including 4k Ranch, also border the project area to the north. 4-K Ranch is listed on the National Register of Historic places (Lorash, 2008). Forest road 2414 and FR 2415 create a loop that is heavily used by Jeep and ATV traffic. Portions of FR 2415 are only travelable by 4-wheel drive Jeeps and ATVs. Peak ATV use on this loop systems ranges from 100 to 200 ATVs daily (Gildehaus, 2008). No motor vehicle use statistics were available for FR 2414, or FR 2415, but the road does get use from the surrounding communities of Billings, Columbus, Nye, Dean, Fishtail and Absarokee. Forest products utilized from this area include post and pole, and firewood. Numerous privately owned groundwater wells and springs used for residential drinking water and wells used for irrigation purposes, are fed by water from Fishtail and Little Rocky Creeks (See Hydrologist Specialist Report).

**Direct Effect**

There are no known direct effects to fire behavior or change to fuel loading in the short term by taking no action.

**Indirect Effect**

In the absence of wildfire or any fuels treatment, fuel loading will continue to increase. Severe fires are most likely to occur where dead fuels have accumulated. With concentrations of dead fuels, individual trees or groups of trees may torch, and fire can continue through the crowns aided by high winds (Anderson, 2003).

Fire behavior was modeled for all fuel models found within the proposed treatment areas (Table 3). Fuel model 8, fuel Model SB2and fuel model SB4 were the predominant fuel models in the proposed treatment units. Analysis shows that under extreme fire weather conditions, active crown fire was modeled in FM SB2, with flame lengths of 60.1 feet, and crowning index of 24.2 miles per hour (mph). Crowning index is the wind speed necessary to cause a fire that is torching to become a running crown fire. Crown fires pose great risk to firefighters and public, and can force indirect suppression strategies that increase acres burned and potential loss of structures. Flame lengths in excess of 11.6 feet were modeled for a surface fire for FM SB2. In FM SB2, spotting distances of ½ a mile or more are possible with probabilities of ignition from a firebrand of 100%. Current fuel loads in blowdown fuel models range from 90 to 150 tons per acre. Fuel loads which exceed 40 tons per acre, cause excessive soil heating which can lead to organic matter being destructively distilled (Brown, Reinhardt and Kramer, 2003).

There are very little if any standing trees in fuel model SB4 allowing for very high rates of spread, extreme fireline intensities and very high flame lengths. Surface fire was modeled for fuel model SB4, with flame lengths of 39.9 feet. Rates of spread where modeled at 451.7 chains per hour, which translates to 5.6 miles per hour, or 492.8 feet per minute, or 8.2 feet per second. Spotting distances in SB4 would be ½ mile or more, with 100 percent probability of ignition from firebrands, and 46 percent probability of ignition from lightning.

Conditional surface fire was modeled in fuel model 8 with a crowing index of 20.1 mph. Conditional surface fire, can be interpreted in that, if a fire originates as a surface fire in a timber stand, it is expected to remain a surface fire. If it originates as an active crown fire in an adjacent stand, active crown fire will continue through adjacent stands (Reinhardt and Crookston, 2005). Spatial continuity and density of tree canopies in combination with wind and physical setting provide for conditions required for rapidly moving fires that consume tree crowns (Graham, McCaffrey, and Jain, 2004). Spread rates for crown fires can vary from 1 to 7 mph, possibly faster in mountainous terrain (Rothermel, 1991). In FM 8, flame lengths at 51 feet during a crown fire were modeled, with surface fire flame lengths of 2.5 feet. Spread rates of 133.8 chains per hour were modeled. Spotting distances of ½ a mile or more are possible with probabilities of ignition from a firebrand of 100%. With blowdown occurring throughout the project area and surrounding canyon, there is a greater chance of crown fire initiating or transferring within the drainage, into adjacent fuel model 8. Probability of ignition from lightning for all fuel models was 46%.

**Table 3:** Modeled fire behavior for Fuel Models found in the Proposed Treatment Units

| | No Action Fire Behavior Characteristics | | | | |
|---|---|---|---|---|---|
| Fuel models | Fire Type | Rates of Spread (Chains/Hour) | Flame Lengths (Feet) | Fireline Intensity (BTU/ft) | Crowning Index (mph) |
| | | | | | |
| FM 1 | Surface | 1101.8 | 17.2 | 2757 | n/a |
| FM 2 | Surface | 249.3 | 18.2 | 3118 | n/a |
| FM 5 | Surface | 118.09 | 14.3 | 1842 | n/a |
| FM 8 | Conditional Surface | 133.8 | 51.5 | 4129 | 20.1 |
| FM 10 | Active | 133.8 | 77.9 | 7685 | 20.1 |
| FM SB2 | Active | 133.8 | 60.7 | 5281 | 24.2 |
| FM SB3 | Passive | 139.1 | 65 | 6552 | 27 |
| FM SB4 | Surface | 451.7 | 39.9 | 17126 | n/a |

Firefighter initial attack capabilities to suppress and contain wildfires under current conditions are limited by several factors. Predicted fire behavior under extreme conditions along the corridor could preclude direct attack and potentially limit access and egress. Initial attack forces locally, generally consist of engine crews, handcrews and bulldozers.

Under current conditions, fireline production rates in the project area would be slower due the 2007 wind event. The addition of blowdown fuel models has decreased firefighter line construction capabilities (Table 4).

**Table 4:** Fireline production Rates (NWCG, 2004)

| **Fireline Production Rates in Chains per Hour** | | |
|---|---|---|
| Resource Type | Fuel Model (FM) | |
| | FM 8 | FM 12 |
| Handcrews (20 person) | 7 | 7 |
| Engines (3 person crew0 | 15 | 10 |
| Bulldozers (Type II D5H, ) | 105-120 | 40-55 |
| *FM SB2 and FM SB4 are not listed in the Fireline Handbook , so FM 12 was used to best represent blowdown conditions. Bulldozer production rates were for downslope line construction. | | |

Models of existing conditions predict flame lengths in the event of a crown fire at 51 feet in FM 8, and 61 feet in FM SB2. In the event of a surface fire, flame lengths would be 2.5 in FM 8,11.6 feet in FM SB2, and 39.9 feet in FM SB4. According to the National

Wildfire Coordinating Group (NWCG) Fireline Handbook (NWCG, 2004), flame lengths less than 4 feet can generally be attacked at the head and flanks by firefighters using handtools, and handline should hold the fire. Flame lengths 4-8 feet are too intense for direct attack on the head with hand tools, handline cannot be relied on to hold, and bulldozers, engines and retardant drops can be effective. At eight to eleven feet flame lengths, fire control becomes a problem, due to crowing, torching and spotting, with direct attack on the head of the fire questionable. Above 11 feet, fire behavior becomes extreme and direct attack methods ineffective. With the exception of a surface fire in FM 8, predicted flame lengths would preclude direct attack by local resources.

**Cumulative effects**

Fuels reduction has occurred on Forest Service land in the project areas. The project areas have had previous post and pole harvest units along drainage bottoms, and some timber salvage in the Main Fork of Rock Creek over the last 20+ years. Some mechanical treatment has occurred in areas of Storm damage, from the November, 2007 wind event, in recreation areas, within the Main Fork of Rock Creek. All these treatments fell into the proposed treatment units. Fuels were treated in and immediately adjacent to the recreational facilities, and due to the small areas treated, would probably have little impact on preventing stand replacement fire, within adjacent proposed treatment units. Turn of the century activities from mining and timber harvest have occurred within these drainages. Under the current CNF Land Management Plan (1986), fire suppression will continue. In the absence of stand replacement fire from suppression efforts, fuels within the project area will continue to accumulate. Under the current fuel loading and stand conditions, there is potential to have stand replacement fire. PROBACRE runs showed the probability of acres burned within the drainages, over time. Probabilities of acres burned, infer that through a single fire event or through cumulative fire events, there is the potential for large areas or portions of the drainages to burn during the 15 years period, that the proposed treatments will be effective (Table 5).

**Table 5:** Probabilities for acres burned over a 15 year period within the project areas.

| Main Fork of Rock Creek | | Fishtail/Little Rocky Creeks | |
|---|---|---|---|
| **Acres** | **Probabilities** | **Acres** | **Probabilities** |
| | | | |
| 47767 | <1% | 37500 | <1% |
| 42990 | <1% | 33750 | <1% |
| 38213 | <1% | 30000 | 1% |
| 33436 | <1% | 26250 | 1% |
| 28660 | <1% | 22500 | 1% |
| 23883 | 1% | 18750 | 1% |
| 19106 | 3% | 15000 | 13% |
| 14330 | 14% | 11250 | 13% |
| 9553 | 15% | 7500 | 13% |
| 4776 | 26% | 3750 | 13% |

Ignitions from human caused fires represent the highest percentage of fire cause in the project area. Road improvements within project areas may increase accessibility to the areas by forest visitors, and thus, increase the annual probability of human caused fires. Lack of good safety zones exist within the project areas. Lack of fire safe areas may prohibit access and egress under extreme fire conditions, potentially increasing chances for loss of life and property. Impacts to the watershed, municipal drinking water, and economics would be dependant on intensity duration and amount of area burned. Effects would be highest where stand replacement, high intensity fires occur.

## Desired Conditions/Proposed Action

### Direct Effects

The Proposed action would directly result in the reduction of surface and canopy fuels, by removing crowns of standing trees and removal of down and dead fuels within the project area. Thinning would reduce ladder fuels, increase canopy base height and reduce canopy bulk densities. Mechanical treatment would change distribution and arrangement of existing surface and activity fuels, and crush shrubs and small trees, further reducing potential ladder fuels within the proposed treatment units. There would initially be an increase in fine dead surface fuels from mechanical activities, the first year, which could increase surface flame lengths and rates of spread. Fine fuel increase from mechanical activities, would begin to dissipate after approximately 1 year, as fine dead fuels would become more compact and begin to decompose, reducing potential fire behavior.

### Indirect Effects

Desired conditions for the project areas would be conditions that reduce fire behavior with the purpose of improving access and egress for firefighters, emergency personnel and the general public; and improve firefighter capabilities in suppressing fires in the project area. Duration of project effectiveness is based on previous studies in similar conditions (Hale, 2006). In this study, under No Action, potential fire behavior in FM 8 was conditional surface fire, which can also be active crown fire under certain conditions. Hale (2006) showed that modeled fuel load modification and modeled stand growth over a 15 year period, revealed that 10 X 10 crown spacing was effective in reducing potential fire behavior to acceptable levels for up to 15 years. Reviews of environmental documentation will occur at least every 3-5 years as required by law, to determine if environmental analysis and documentation should be corrected, supplemented, or revised (Forest Service Handbook (FSH).15, 2004)

Fuel loading would be reduced through treatments that would conversely reduce fire behavior. Thinning from below to a 10 X 10 crown spacing, would break up canopy fuel continuity, potentially increase canopy base heights, and reduce canopy bulk densities within the units, from .09 kg/ft$^3$ (FM 8) and .07 kg/ft$^3$ (FM SB2), to .06kg/ft$^3$. Graham (1999) stated that,

Crown bulk density, surface fuel and crown base height are primary stand characteristics that determine crown fire potential. Thinning from below, free thinning, and reserve tree shelterwoods have the greatest opportunity for reducing the risk of crown fire. Selection thinning and crown thinning to maintain multiple layers, along with individual tree selection systems will not reduce the risk of crown fire.

Modeled fire behavior decreased, promoting a surface fire in the project area (Table 6). This should allow for safer egress and access, and increased initial attack efficiency.

**Table 6:** Modeled fire behavior for No action Vs Proposed Action for fuel model 2, fuel model 8 and blowdown fuel models SB2 and SB4.

| | No Action | | | Proposed Action | |
|---|---|---|---|---|---|
| Fuel models | FM 8 | SB2 | SB4 | FM 8 | FM 2 |
| Fire Type | Conditional Surface | Active Crown | Surface | Surface | Surface |
| Rates of Speed (Chains per Hour) | 133.8 | 133.8 | 451.7 | 5.88 | 249.3 |
| Flame Lengths (Feet) | 51.5 | 60.7 | 39.9 | 2.1 | 18.2 |
| Fireline Intensity (BTU/ft) | 413 | 5281 | 17126 | 28 | 3118 |
| Crowning Index (mph) | 20.1 | 24.2 | n/a | 27 | n/a |

** In fuel model 8, under No Action, if a fire started in the stand as a surface fire, rates of spread were modeled to be 3.3 chains per hour and flame lengths of 1.6, as this is a closed stand. Closed stands tend to have more shading and thus higher moisture content in fine dead fuels. Rates of spread and flame length differences between the Proposed Action surface fire are due to the stand being opened up. The wind adjustment factor was increased to account for a more opens stand which increases the potential midflame wind. A more open stand with less shading would also have more thermal heating to surface fuels, which could also increase fire behavior.
** Fuel model 2 was used to best represent post treatment in areas with pre-treatment fuels of SB4. Fire behavior may be less, in areas of lodgepole pine with poorer soils.

Fuel loading of 10 tons per acre residual surface fuels was deemed acceptable based on knowledge from Jeff Stockwell ( Stockwell, 2008), Dennis Sandbak (Sandbak, 2008) ), and using a fuel loading photo guide (Mackay,1985). Surface and activity fuels would be removed through a combination of methods, including; machine piling and pile burning; hand piling and pile burning; and biomass removal potentially through firewood permits, post and pole permits, and other available timber products. Prescribed burning of piles would put smoke into airshed 10 that could affect the City f Red Lodge and surrounding residential areas. All approvals for prescribed burning are submitted to the Montana Department of Environmental Quality (DEQ) who determine conditions meet DEQ standards allowing for prescribed burning on a given day. According to Graham (1999), unless the surface fuels created by thinning are themselves treated, intense surface wildfire may result, likely negating positive effects of removing crown fire potential. Flame lengths for residual fuel loading based on modeling in the photo guide, showed flame lengths of approximately 1 foot and rates of spread of 2-3 chains per hour after treatment. Reduced surface and canopy fuel loads should increase firefighter production (Table 7).

**Table 7**: Changes in production rates No Action Vs Proposed Action

| Fireline Production Rates in Chains per Hour | | | | |
|---|---|---|---|---|
| | No Action: Predominant Fuel Models in the Proposed Treatment Units | | Proposed Action: Predominant Fuel Models in Proposed Treatment Units, Post Treatment | |
| Resource Type | Fuel Models (FM) | | Fuel Model (FM) | |
| | FM 8 | FM 12 | FM 8 | FM 2 |
| Handcrews (Type 1, 20 person) | 7 | 7 | 40 | 24 |
| Engines (3 person crew) | 15 | 10 | 15 | 15 |
| Bulldozers (Type II D5H, ) | 105-120 | 40-55 | 105-120 | 125-145 |
| *FM SB2 and SB4 are not listed in the Fireline Handbook, so FM 12 was used to best represent blowdown conditions. Bulldozer production rates were for downslope line construction.<br>**Current fuel conditions in fuel mode 8 through ocular estimates showed that there were small amounts of blowdown added to existing surface fuel loads. This could impact fireline construction, reducing potential chains per hour of line constructed as stated in the Fireline handbook. | | | | |

**Cumulative effects**

Fuels in several day use areas and campgrounds within the Main Fork of Rock Creek have had fuel reduction work within these facilities to allow public use. All these treatments fell into the proposed treatment units. Fuels were treated in and immediately adjacent to the facilities, and due to the small areas treated, would probably have little impact on preventing stand replacement fire, within adjacent proposed treatment units. Proposed treatment areas and past timber harvest have and would only change small portion of the total fuels loads present within the three drainages. These treatments are designed to enhance egress and access in the canyons by public and firefighters and improve firefighter capabilities in suppressing wildfires. The proposed action would reduce the potential for ignitions from any source to result in undesirable effect within the project area. The potential exists for burning large acreages within the three drainages as modeled in PROBACRE, during the effective period for the treatment (Tables 6). The highest percentage of ignitions within the proposed project units are from human causes. Many fires occur in dispersed camping areas from unattended or un-extinguished campfires. Due to heavy dense vegetation and days of poor air quality, campfires left un-extinguished, may smolder for long periods undetected, becoming a wildfire under the right condition. Proposed treatments will limit fire intensity and duration within the treatment units, which would be less impactive to riparian areas and soils, and potentially allowing these areas to recover faster. In the event of a large stand replacement fire in the canyons, outside the proposed project area, vegetative and soil recovery may play an important role in reducing water quality from sedimentation from burn areas.

**Action Alternative and No-Action Alternative** Short-term vs. Long-term Productivity

There are no short-term versus long-term productivity issues for fuels resources under any alternative.

**Action Alternative and No-Action Alternative** Irreversible/irretrievable Commitments

There are no irreversible/irretrievable commitments on fuels resources under any alternative.

**Action Alternative and No-Action Alternative** Unavoidable Adverse Effects

There are no unavoidable adverse effects on fuels resources under any alternative.

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## Glossary and Definitions

**Active crown fire:** A **crown fire** in which the entire **fuel complex** becomes involved, but the crowning phase remains dependent on heat released from the **surface fuels** for continued spread. Also called **running** and **continuous crown fire**.

**Appropriate Management Response**: Specific actions taken in response to a wildland fire to implement protection and fire use objectives.

**Available canopy fuel:** The mass of **canopy fuel** per unit area consumed in a crown fire. There is no post-frontal combustion in canopy fuels, so only fine canopy fuels are consumed. It is assumed that only the foliage and a small fraction of the branchwood is available.

**Available fuel**: The total mass of ground, surface and canopy fuel per unit area consumed by a fire, including fuels consumed in postfrontal combustion of duff, organic soils, and large woody fuels.

**Canopy base height:** The lowest height above the ground at which there is a sufficient amount of **canopy fuel** to propagate fire vertically into the canopy. Canopy base height is an effective value that incorporates ladder fuels such as shrubs and understory trees. See also **fuel strata gap** and **crown base height**.

**Canopy bulk density:** The mass of **available canopy fuel** per unit canopy volume. It is a bulk property of a stand, not an individual tree.

**Canopy closure:** The degree to which the canopy (forest layers above one's head) blocks the sunlight or obscures the sky. It can only be determined from measurements taken under the canopy as openings in the branches and trees must be accounted for

**Canopy fuels**: The live and dead foliage, live and dead branches, and lichen of trees and tall shrubs that lie above the **surface fuel**s. See also **available canopy fue**l.

**Catastrophic**: A violent or sudden change in a feature of the earth.

**Chain**: A measuring instrument consisting of 100 wire links each 7.92 inches long, or 792 inches, or 66 feet. There are 80 chains in one mile.

**Conditional surface fire**: A potential type of fire in which conditions for sustained active crown fire spread are met but conditions for crown fire initiation are not. If the fire begins as a surface fire then it is expected to remain so. If it begins as an **active crown fire** in an adjacent stand, then it may continue to spread as an active crown fire.

**Continuous crown fire**: See **active crown fire**.

**Crown base height:** The vertical distance from the ground to the bottom of the live crown of an individual tree. See also **canopy base heigh**t.

**Crown bulk densi**ty: The mass of available fuel per unit crown volume. Property of an individual tree, not a whole stand. See also **canopy bulk densi**ty.

**Crown fire:** Any fire that burns in **canopy fuel**s.

**Crown fire cessatio**n: The process by which a **crown fire** ceases, resulting in a **surface fir**e. Crown fire cessation is a different mechanism than crown fire initiation.

**Crown fire hazard:** A physical situation (fuels, weather, and topography) with potential for causing harm or damage as a result of crown fire.

**Crowning Index:** The open (6.1:m/ 20 ft) windspeed at which **active crown fire** is possible for the specified **fire environmen**t.

**Defensible Space**: 1) Defensible space is the area within the perimeter of a parcel, development, neighborhood or community where basic wildland fire protection practices and measures are implemented, providing the key point of defense from an approaching wildfire or defense against encroaching wildfires or escaping structure fires. The perimeter is defined as the area encompassing the parcel or parcels proposed for construction and/or development, excluding the physical structure itself. The term "defensible space" was first used in the foreword of the 1980 *Fire Safe Guide for Residential Development in California.* 2) Defensible space is an area around a structure where fuels and vegetation are treated, cleared or reduced to slow the spread of wildfire towards the structure. It also reduces the chance of a structure fire moving from the building to the surrounding forest. **(3)** Area around a structure or other improvement where fuels and vegetation are treated cleared or reduced to slow the spread of wildfire, the slope of the ground on which the structures are built, surrounding topography, and sizes towards the structure. It also reduces the chance of a structure fire moving from the building to the surrounding forest. Creating an effective defensible space involves developing a series of management zones in which different treatment techniques are used. The actual design and development of the defensible space depends on several factors: size and shape of buildings, materials used in their construction and types of vegetation on the property. (Colorado State Forest Service)

**Duff:** Partially decomposed organic matter lying beneath the litter layer and above the mineral soil. It includes the fermentation and humus layers of the forest floor (02 soil horizon).

**Duration of Fire:** The length of time that combustion occurs at given point. Relates closely to downward heating and fire effects below the fuel surface as well as heating of tree boles above the surface.

**Ecosystem:** The complex of a community of organisms and its environment functioning as an ecological unit in nature. *(Webster's dictionary)*

**Ecosystem Process**
The actions or events that link organisms and their environment, such as predation, mutualism, successional development, nutrient cycling, carbon sequestration, primary productivity, and decay. Natural disturbance processes often occur with some periodicity *(From Webster's dictionary, adapted to ecology.)*

**Ecosystem Integrity**

The completeness of an ecosystem that, at multiple geographic and temporal scales, maintains its characteristic diversity of biological and physical components, spatial patterns, structure, and functional processes within its approximate range of historic variability. These processes include: disturbance regimes, nutrient cycling, hydrologic functions, vegetation succession, and species adaptation and evolution. Ecosystems with integrity are resilient and capable of self-renewal in the presence of the cumulative effects of human and natural disturbances.
*(Proposed Rule, Section 219.36, 1999.)*

**Ecosystem Management**
The careful and skillful use of ecological, economic, social, and managerial principles in managing ecosystem integrity and desired conditions, uses, products, and services over the long term.

**Environmental conditions:** That part of the **fire environment** that undergoes short-term changes: weather, which is most commonly manifest as windspeed and dead fuel moisture content.

**Fire-Adapted Ecosystem:** An ecosystem with the ability to survive and regenerate in a fire-prone environment.

**Fire Behavior:** The manner in which a fire reacts to the influences of fuel, weather and topography.

**Firebreak:** A natural or constructed barrier to stop or check fires that may occur, or to provide a control line from which to work

**Fire environment:** The characteristics of a site that influence fire behavior. In fire modeling the fire environment is described by surface and canopy fuel characteristics, windspeed and direction, relative humidity, and slope steepness.

**Fire Event**: See **Wildland Fire**. For the purposes of fuels analysis it is a wildfire, with a probability of occurrence, that is modeled using representative weather inputs (usually the 90$^{th}$ percentile) for the purpose of effects analysis to compare alternatives.

**Fire Exclusion:** The policy of suppressing all wildland fires in an area.

**Fire Frequency (Fire Return Interval)**: A general term referring to the recurrence of fire in a given area over time. Sometimes stated as number of fires per unit time in designated area. Also used to refer to the probability of an element burning per unit time. How often fire burns a given area; often expressed in terms of fire return intervals (e.g., fire returns to a site every 5-15 years).

**Fire Hazard:** A fuel complex, defined by volume, type, condition, arrangement and location, that determines the ease of ignition and the resistance to control. A physical

situation (fuels, weather, and topography) with potential for causing harm or damage as a result of wildland fire.

**Fire intensity**: See **frontal fire intensit**y. Contrast with **fireline intensit**y.

**Fire Intensity Level (FIL)**: A measure of fire behavior used in the Interagency Initial Attack Assessment Model (IIAA) (A NFMAS term). It is based on the calculated flame length

FIL 1: 0-2 feet
FIL 2: 2-4 feet
FIL 3: 4-6 feet
FIL 4: 6-8 feet
FIL 5: 8-12 feet
FIL 6: greater than 12 feet

The NFDRS Burning Index (BI) is calculated flame length x 10. FIL is used in the IIAA model as an indicator of fire danger for dispatch purposes, to categorize rate of spread, and in the assessment of fire effects. Each FIL has an associated suppression cost.

**Fireline intensity:** The rate of heat release in the **flaming front** per unit length of fire front (Byram 1959). Can be converted to flame length . ($FL = 0.45*(I^{0.46})$). This expression is commonly used to describe the power of wildland fires.

**Fire Management Plan (FMP):** A strategic plan that defines a program to manage wildland and prescribed fires and documents the Fire Management Program in the approved land use plan. This plan is supplemented by operational plans such as preparedness plans, preplanned dispatch plans, prescribed fire plans, prevention plans and operational wildland fire use plans.

**Fire Regime:** A generalized description of the role fire plays in an ecosystem. It is characterized by fire frequency, seasonality, intensity, duration and scale (patch size), as well as regularity or variability. *(Agee, as modified by Sexton.)* General pattern of fire frequency, season, size, and prominent ,immediate effects in vegetation type or ecosystem.

**Fire Return Interval:** Number of years between fires at a given location.

**Fire Risk**: applies to the probability of an ignition occurring as determined from historical fire record data.

**Fire Rotation:** The length of time necessary for an area equal in size to the study area to burn.

**Fire Severity:** A qualitative measure of the immediate effects of fire on the ecosystem. Relates to the extent of mortality and survival of plant and animal life both above and below ground and to loss of organic matter.

**Fire Use:** The combination of wildland fire use and prescribed fire applications to meet resource objectives

**Fire Safe Conditions:** As defined by Agee (1996), fire safe conditions are include those where

1. surface fuel conditions that limit surface fireline intensity;
2. forest stands that are comprised of fire-tolerant trees, described in terms of species, sizes and structures;
3. a low probability that crown fires will either initiate or spread through the forest.

**Flaming Front:** The zone at a fire's edge where solid flame is maintained.

**Foliar moisture content**: Moisture content (dry weight basis) of live foliage, ex-pressed as a percent. Effective foliar moisture content incorporates the moisture content of other canopy fuels such as lichen, dead foliage, and live and dead branchwood.

**Frontal Fire Intensity:** Similar to **fireline intensit**y, it is the rate of heat release per unit length of fire front, including the additional heat released from postfrontal flaming and smoldering combustion (Forestry Canada Fire Danger Group 1992).

**Fuelbreak:** A natural or manmade change in fuel characteristics which affects fire behavior so that fires burning into them can be more readily controlled

**Fuel Characteristics:** Factors that make up fuels such as compactness, loading, horizontal continuity, vertical arrangement,, chemical content, size and shape, and moisture content.

**Fuel Continuity:** The degree or extent of continuous or uninterrupted distribution of fuel particles in a fuel bed thus affecting a fire's ability to sustain combustion and spread. This applies to aerial fuels as well as surface fuels.

**Fuel complex:** The combination of ground, surface, and canopy fuel strata.

**Fuel Loading:** Weight per unit area of fuel often expressed in tons per acre or tonnes per hectare. Dead woody fuel loadings are commonly described for small material in diameter classes of 0 to 1/4-,1/4 to 1-,and 1 to 3-inches and for large material in one class greater than 3 inches.

**Fuel model:** A set of surface fuel bed characteristics (load and surface-area-to-volume-ratio by size class, heat content, and depth) organized for input to a fire model. Standard fuel models (Anderson 1982) have been stylized to represent specific fuel conditions.

**Fuel strata gap:** The vertical distance between the top of the **surface fuel** stratum and the bottom of the **canopy fuel** stratum.

**Fuel stratum:** A horizontal layer of fuels of similar general characteristics. We generally recognize three fuel strata: ground, surface, and canopy.

**Full-range fire behavior simulation**: The simulated behavior of a wildland fire whether it is a surface fire, passive crown fire, or active crown fire. Ground fire behavior is usually not included.

**Ground fire**: A slow-burning, smoldering fire in **ground fuels**. Contrast with **surface fire**.

**Ground fuels**: Fuels that lie beneath surface fuels, such as organic soils, duff, decomposing litter, buried logs, roots, and the below-surface portion of stumps. Compare with **surface fuel**s.

**Home Ignition Zone:** The home and its immediate surroundings. The characteristics of a home and its immediate surroundings determine a home's ignition potential during wildland fires. The home ignition zone generally extends to a few tens of meters from the structure. The ignition potential within the home ignition zone is home ignitability.

**Independent crown fire:** A **crown fire** that spreads without the aid of a supporting **surface fire**.

**Intermittent crown fire**: A **crown fire** that alternates in space and time between active crowning and surface fire or passive crowning. See also **passive crown fire**.

**Ladder Fuels:** Shrubs and young trees that provide continuous fine material from the forest floor into the crowns of dominant trees.

**Landscape:** An area composed of interacting and inter-connected patterns of habitats (ecosystems) that are repeated because of the geology, landform, soils, climate, biota, and human influences throughout the area. Landscape structure is formed by patches (tree stands or sites), connections (corridors and linkages), and the matrix. Landscape function is based on disturbance events, successional development of landscape structure, and flows of energy and nutrients through the structure of the landscape. A landscape is composed of watersheds and smaller ecosystems. It is the building block of biotic provinces and regions.

**Litter:** The top layer of the forest floor (01 soil horizon);includes freshly fallen leaves, needles, fine twigs, bark flakes, fruits, matted dead grass, and a variety of miscellaneous vegetative parts that are little altered by decomposition. Litter also accumulates beneath rangeland shrubs. Some surface feather moss and lichens are considered to be litter because their moisture response is similar to that of dead fine fuel.

**Mean Fire Return Interval:** The arithmetic average of all fire intervals in given area over a given time period.

**Mechanical Fuels Treatments:** Mechanical Treatments include all methods of modifying the fuels profile except for fire use applications, chemical treatments and livestock grazing. Mechanical treatments include: biomass removal, biomass thinning, rearrangement, chipping, piling, felling and piling, crushing, and mastication.

**Mixed Severity Fire Regime:** Regime in which fires either cause selective mortality in dominant vegetation, depending on different species ' susceptibility to fire, or vary between understory and stand replacement.

**Operational Wildland Fire Use Plans**: A supplement to the FMP, which identifies the prescription under which a wildland fire may be managed to accomplish prestated resource management areas. It supports the development of a WFIP when a event occurs.

**Passive crown fire:** A crown fire in which individual or small groups of trees torch out, but solid flaming in the canopy cannot be maintained except for short periods. Passive crown fire encompasses a wide range of crown fire behavior from the occasional torching of an isolated tree to a nearly active crown fire. Also called torching and candling. See also **intermittent crown fire**.

**Percent Cover:** Percentage of ground area that is directly covered with tree crowns. Generally, the crown area of a tree is computed using the formula for a circle as a function of crown radius or it is estimated in the field either visually or with a densiometer.

**Plume-dominated fire:** A fire for which the power of the fire exceeds the power of the wind, leading to a tall convection column and atypical spread patterns. Contrast with **wind-driven fire**.

**Prescription:** Measurable Criteria that define the conditions under which a prescribed fire may be ignited, guide selection of appropriate management responses, and other required actions. Prescription criteria may include safety, economic, public health, environmental, geographic, administrative, social or legal considerations.

**Prescribed Fire:** Any fire ignited by management actions to meet specific objectives. A written approved prescribed fire plan must exist and NEPA requirements must be met, prior to ignition. This term replaces management ignited prescribed fire.

**Presettlement Fire Regime:** The time from about 1500 to the mid-to late-1800s,period when Native American populations had already been heavily impacted by European presence but before extensive settlement by European Americans in most parts of North America, before extensive conversion of wildlands for agricultural and other purposes, and before fires were effectively suppressed in many areas.

**Probability:** A number representing the chance that a given event will occur. The range is from 0% for an impossible event, to 100% for an inevitable event.

**Purpose:** an intended result, something for which an effort is being made (Objective)

**Representative Fire Location (RFL):** A NFMAS term. A delineated portion of an Fire Management Zone (FMZ) for which a single Net Value Change table and a single set of initial attack dispatch data will be used. It is the basic analysis area, and represents a defined number of annual fires

**Restoration:** In the context of the cohesive strategy, restoration means the return of an ecosystem or habitat toward: its original structure, natural complement of species, and natural functions or ecological processes.

**Risk:** The possibility of meeting danger or suffering harm. When used relative to wildland fires it refers to the probability of escape resulting in financial and ecological loss. Alternative management scenarios generate different degrees of risk and ultimately a different set of economic outcomes (Hesslin and Rideout, 1999)

**Running crown fire**: See **active crown fire.**

**Severity**: See **fire severity**.

**Site characteristics**: The characteristics of a location that do not change with time: slope, aspect, elevation.

**Stand Replacement Fire Regime:** Regime in which fires kill or top-kill aboveground parts of the dominant vegetation, changing the aboveground structure substantially. Approximately 80 percent or more of the aboveground dominant vegetation is either consumed or dies as a results of fires. Applies to forests, shrublands, and grasslands.

**Structure Ignition Zone:** see Home Ignition Zone:

**Surface fire**: A fire spreading through **surface fuels.**

**Surface fuels:** Needles, leaves, grass, forbs, dead and down branches and boles, stumps, shrubs, and short trees.

**Surfacing Index**: The Surfacing Index is the open windspeed at which an **active crown fire** can be expected to drop to the surface, either due to insufficient **mass-flow rate** through the canopy or insufficient contribution of **surface fuels** to **fireline intensity**.

**Threat:** An indication of something impending. An expression of intention to inflict injury or damage.

**Torching Index:** The open (6.1-m/20 ft.) windspeed at which crown fire activity can initiate for the specified **fire environmen**t.

**Total biomass:** The mass per unit area of all living and dead vegetation at a site.

**Total fuel load:** The mass of fuel per unit area that could possibly be consumed in a hypothetical fire of the highest intensity in the driest fuels.

**Uncharacteristic Wildfire Effects:** An increase in wildfire size, severity and resistance to control, and the associated impact to people and property, compared to that which occurred in the native system.

**Understory Fire Regime:** Regime in which fires are generally not lethal to the dominant vegetation and do not substantially change the structure of the dominant vegetation. Approximately 80 percent or more of the aboveground dominant vegetation survives fires. Applies to forest and woodland vegetation types.

**Value:** See also **Values at Risk:** The monetary worth of something.

**Values at Risk:** Include property, structures, physical improvements, natural and cultural resources, community infrastructure, and economic, environmental, and social values. They may be on or off-site values.

**Wildfire:** An unwanted wildland fire. This is not a separate type of fire.

**Wildland Urban Interface:** The line, area, or zone where structures and other human development meet or intermingle with undeveloped wildland or vegetative fuels.

**Wildland Fire:** Any non-structure fire, other than prescribed fire that occurs in the wildland. This term encompasses fires previously called both wildfires and prescribed natural fires.

**Wildland Fire Use:** The management of naturally ignited wildland fires to accomplish prestated resource management objectives in predefined areas in Fire Management Plans. Operational Management is described in a Wildland Fire Implementation Plan. This term replaces prescribed natural fire.

**Wildland Fire Implementation Plan (WFIP):** A progressively developed assessment and operational management plan that documents the analysis and selection of strategies and describes the appropriate management response for a wildland fire being managed for resource benefits.

**Wind-driven fire:** A wildland fire in which the power of the wind exceeds the power of the fire, characterized by a bent-over smoke plume and a high length-to-width ratio.

**Wind reduction factor:** The ratio of the midflame windspeed to the open (6.1-m/20 ft.) windspeed. For convenience of measurement eye-level winds are usually substituted for midflame winds.

The sources for most definitions are:

*National Wildfire Coordinating Group. 1996. Glossary of Wildland Fire Terminology, National Wildfire Coordinating Group, Boise ID*

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