Chapter 3: Fire Risk Analysis

Chapter Three provides a detailed account of the methods and parameters used to assess and predict the fire risk hazards within the El Dorado CWPP area. For those less interested in the specifics of fire modeling methods, a brief overview of this CWPP's methods is offered below and the reader is invited to skip to Chapter Four for recommended strategies for mitigating fire risk in Western El Dorado County.

First, the history of fire in the mixed conifer forests of El Dorado County from the 1700's to the present is reviewed, including frequency, number of fires, acres burned, and severity.

Second, fire modeling is used to map and predict potential fire behavior and intensity across various vegetation types in the CWPP area. Fire behavior modeling was completed with the FlamMap (Finney 2006) software and incorporates current landscape and fuels conditions, realistic wind and weather conditions (based on historical and current weather data in the CWPP area), and the effects of current and planned fuel treatments, such as fuel breaks or other barriers. Modeling provides a best estimate of the fire hazard and risk to natural and community resources within the CWPP area.

Third, priorities are assessed and identified for reducing and mitigating fire risk at both the county and community levels using existing fire protection plans, collaborative stakeholder meetings, interviews, and an on-line community survey. The online survey helps identify each community's priorities for fuel treatment projects on private lands.

Finally, the fire hazard and risk assessment as well as the community priorities are incorporated to create Community Base Maps, covering the communities listed in Table 2. These maps identify current fire hazards and risks to natural and infrastructure resources, as well as identify potential treatments that may be implemented to help mitigate that risk. The Community Base Maps were presented at public stakeholder meetings in order to further refine potential treatment areas as well as identify any additional resources at risk.

By modeling potential fire behavior, mapping risks to community resources, gathering and integrating community input, and identifying priority mitigation strategies, this CWPP is intended to provide a valuable tool to guide fuel treatment planning in western El Dorado County.

3.1 Fire History

Fire perimeters, vegetation burn severity, and ignition points were derived from the Region 5 Vegetation Burn Severity Database (1984-2015), fire perimeter data from the Fire and Resource Assessment Program (FRAP) (CALFIRE 2015), and the most recently available ignition point data. All fire point locations or fire perimeters that intersected or were completely within the analysis area boundary were included.

3.12 Historic Role of Fire in Conifer and Oak Woodland Forests

Fire was a common ecosystem process in the mixed conifer forests of El Dorado County before the policy of fire exclusion began early in the 20th century. Between 1750 and 1900, the median composite fire interval at the 35–60 acre spatial scale was 4.7 years with a fire interval range of 4–28 years, as measured at Blodgett Forest Research Station, a few miles east of the Community of Quintette (Stephens and Collins, 2004). This generally meant that fires, both lightning and human caused, occurred on average every five years in any given 60 acre area, although on occasion the fire-fire period could extend up to 28 years. Many areas of El Dorado County have not experienced wildfire for 50-100 years (Figure 1). Forested areas across El Dorado County have been repeatedly harvested and subjected to fire exclusion for the last 90 years, reflecting a management history common to many forests in California (Laudenslayer and Darr, 1990; Stephens, 2000) and elsewhere in the western United States (Stephens and Moghaddas, 2005; Graham et al., 2004).

3.13 Historic Role of Fire in Conifer and Oak Woodland Forests Shrub Dominated Ecosystems

With the implementation of fire suppression policies in the early 20th century, the frequency of fires burning on a given area of the landscape has decreased, resulting in a decrease in the area of shrub fields previously maintained by repeated burning (Nagel and Taylor 2005).

3.14 Total Ignitions by Source (Human- or Lightning-Caused) for El Dorado County- 1992-2013

During the period 1992-2013, there were 265 ignitions per year on average, with more than 80% of those ignitions occurring within the WUI (Appendix 3a). Within the WUI, human-caused ignitions generally made up over 75% of all ignitions, a trend that was relatively stable during the 21-year analysis period. Outside of the WUI, human-caused ignitions typically made up a smaller percentage of ignitions, though they still exceeded lightning-caused ignitions by a factor of two.

3.15 Acres Burned by Wildfire Annually for El Dorado County 1916-2014 by Cause and Within or Outside the WUI

Acres of wildfires by year and location (within or outside of the WUI) and cause (i.e., human-caused, lightning-caused, or unknown cause) are shown in detail in Appendix 3b. Individual fires by year and acreage for all causes and locations (WUI/non-WUI) are shown in Appendix 3b. Over the entire period for which data is available (1916-2014), an average of 4,200 acres burned annually. This trend was consistent until the most recent 20-year period when the 2014 King and Sand Fires skewed the average up to 5,200 acres burned annually.

Over the entire period for which data is available (1916-2014), an average of 63% of all areas burned by wildfire were within the 1.5 mile WUI. This pattern has remained relatively consistent regardless of the period of analysis. It should be noted that the WUI makes up a larger percentage of the county (58%) than non-WUI (42%), which may influence the total acres of fires classified as burning within it.

3.16 Fire Severity 1985-2014

Fire severity is measured as the reduction of canopy cover within 1 year of the fire using remotely sensed infrared imagery (Miller et al 2009). The categories (Appendix 3c) for canopy cover loss are broken into 5 categories as follows:

1 = No measurable change in canopy cover
2 = Up to 25% reduction in canopy cover
3 = 25-50% reduction in canopy cover
4 = 50-75% reduction in canopy cover
5 = >75% reduction in canopy cover

For all fires in El Dorado County, there were 15 between 1984 and 2015 with fire severity data available (USDA 2016). Of these, 2 fires (Gondola and Angora) and 1 fire had very limited acreage within the analysis area (Rahlston). Over all recorded fires, more than 53% of the area burned had greater than 50% of the canopy lost, with the majority of acres categorized as having more than 75% canopy cover loss. The fires over 5,000 acres with the greatest canopy cover loss within the analysis area include the King (2014), Fred's (2004), and Cleveland (1992) fires.

With respect to trends in burn severity, a general trend of increased fire severity in the Sierra Nevada has been noted in previously published studies (Miller et al. 2009). The data available indicate that particularly for large fires (5,000 acres), the majority of the fire tends to burn with high severity, reducing canopy cover by at least 50% and typically by 75% or more.

3.2 Fire Modeling Approach

Fire modeling is a critical component of the CWPP update process. Commonly-used and freely-available data and software were utilized to map potential fire behavior across the CWPP area. Objectives were to:

1) Provide maps depicting potential wildfire intensity for the entire CWPP area
2) Produce maps to support the fuel treatment design process

All fire behavior modeling was completed with the FlamMap software (Finney 2006), which is the de facto standard for spatial fire behavior analysis. FlamMap requires spatial data describing the landscape and fuels as well as a scenario of relevant weather conditions in order to output spatial data that describe potential fire behavior. FlamMap can run in either of two modes:

1) *Basic,* in which FlamMap outputs wall-to-wall spatial fire behavior data such as rate of spread, flame length, and crown fire activity for a specified weather scenario.
2) *Minimum Travel Time (MTT),* in which FlamMap simulates hundreds or thousands of ignition points, each of which burns for a specified duration under the specified weather scenario. MTT outputs include fire perimeters, fire size, and conditional burn probability.

3.21 Fire Risk Assessment Area

The assessment area for this project includes the entirety of El Dorado County, with the exception of lands within the Lake Tahoe Basin (Lake Tahoe Hydrologic Unit Code or "HUC" 8 watershed). The lands within the Lake Tahoe Basin have a recently completed Community Wildfire Protection Plan that covers this area (TFFT 2015). For fire modeling purposes, the assessment area is buffered by an additional 1 mile, allowing simulated fires to spread past the boundaries of El Dorado County without encountering artificial barriers. Maps, however, are displayed without the 1-mile buffer.

3.22 Fire Weather

Weather data from four Remote Automated Weather Stations (RAWS) were used to create a realistic weather scenario based on historic patterns (Table 6). The 98th percentile weather conditions were used with the intent to model the potential for extreme fire behavior, such as what occurred during the 2014 King Fire. The Pilot Hill (station ID 042609) and Ben Bolt (042612) RAWS were used to represent low-elevation weather and the Bald Mountain (042603) and Owens Camp (042611) weather stations to represent mid-elevation weather. The full range of available data for each station was downloaded using the Kansas City Fire Access Software web portal (KCFAST, 2014).

Fire Family Plus (FF+; Bradshaw and McCormick 2000) was used to summarize the weather station data. For the fire behavior modeling the period of analysis was limited to 1995-2015 and the fire season was defined as 15 June to 01 November. We then combined the four weather stations to run a Fire Family Plus analysis to obtain the parameters listed in Table 5. A southwesterly wind direction (225 degrees) was used based on weather records and discussions with local specialists. In the event that the average wind speeds recorded by the weather stations would result in under-predicted fire behavior in FlamMap the approach in Crosby and Chandler (2004) was used to convert steady wind speed to probable 1-minute gust speed, which was then used in the modeling scenario. Based on feedback from the Fire Safe Council, the herbaceous fuel moisture value was lowered from 11% to 3% by excluding the herbaceous fuel moisture value from the Bald Mountain RAWS, which was possibly an outlier.

Table 6. Fuel moisture and other modeling parameters used in FlamMap simulations. The hour classes are defined as the time lag required for a fuel particle to reach 63% of the difference between the initial moisture content and the equilibrium moisture content (or equilibrium with changed atmospheric conditions; Pyne et al. 1996).

Weather Parameter*	Value	FlamMap Parameter	Value
1-hour fuel moisture	2%	**Minimum Travel Time (MTT) Calculation Resolution**	60 meters
10-hour fuel moisture	3%	**Maximum simulation time**	720 mins (12 hours)
100hour fuel moisture	5%	**Number of random ignitions**	10,000 (125 per HUC-12 watershed)
Live herbaceous fuel moisture	3%	**MTT Interval**	500 meters
Live woody fuel moisture	65%	**Spot probability**	2%
Wind speed	20 mph**	**Foliar moisture content**	75%
Crown fire calculation method	Scott and Reinhardt (2001)		

*Fuel moistures are unconditioned.
** Wind speed and direction were modeled for the terrain using the built-in Wind Ninja model at 90-meter resolution. 20 mph wind speed is at the 20 foot level above the ground.

3.23 Incorporation of Existing and Planned Fuel Treatments

Once the operating parameters were set, the input data was refined to reflect current conditions. Spatial data from LANDFIRE (www.landfire.gov) was used to provide canopy base height, canopy bulk density, canopy cover, fire behavior fuel model, and stand height inputs for FlamMap. The most recent LANDFIRE data available was current in 2012 and therefore was not reflective of the more recent fires, including the King Fire, or of any post-2012 fuel treatments. Three changes were applied to the LANDFIRE input data: (1) the blue oak/foothill pine fuel models were adjusted in the lower-elevation region of El Dorado County, (2) the input data was updated to reflect recent fuel treatments, and (3) the input data was updated to reflect recent wildfires including the 2014 King Fire.

In collaboration with CAL FIRE, expert opinion (Dave Sapsis, Personal Communication, Tadashi Moody Personal Communication) was used to reclassify several shrub and grass/shrub fuel models in the study area. This was based on observations that fire intensity was being overestimated using fuel models provided by LANDFIRE.
Current spatial data describing federal fuel treatments were obtained from the US Forest Service (USFS) FACTS database and state fuel treatments from CAL FIRE. The King Fire perimeter was obtained from the US Forest Service (USFS). Next, a new fuel disturbance shapefile was

created according to the disturbance codes used by LANDFIRE's Total Fuel Change Tool (LFTFCT). Each treatment polygon was assigned a code that described disturbance type, disturbance severity, and time since disturbance (cite LFTFCT documentation). The same approach was used for the wildfire updates and disturbance intensity came from the relative differenced Normalized Burn Ratio (RdNBR) canopy cover mortality raster produced by the USFS. Before running the LFTFCT, the existing vegetation cover (EVC) raster from LANDFIRE needed to be manually updated to reflect recent disturbances. This was accomplished with ArcGIS software through the use of a table of disturbance types and their expected effects on canopy cover. The table was developed from the scientific literature and expert opinion. The LFTFCT then applied the LANDFIRE Map Zones 5 and 6 rule sets to update the fuel model raster based primarily on existing vegetation type and the disturbance codes. Upon completion, new rasters of fuel model, canopy bulk density, canopy base height, and canopy cover were current through 2015.

3.24 Fire Hazard and Risk Assessment Methods

Numerous simulations were run to calibrate FlamMap parameters. Objectives were to obtain realistic fire behavior from FlamMap that matched the expectations of the Fire Safe Council, as well as to refine the Minimum Travel Time (MTT) parameters to obtain sufficient resolution without incurring excessive computation time.

A 12-hour simulated burn period and 10,000 random ignitions were used for the MTT runs. With these settings there were enough ignitions burning for long enough to ensure that every burnable pixel burned at least once, but not so long that most fires spread outside of the buffered study area. Input spatial data was set at 30-meter resolution, which constrained the resolution of outputs, but most simulations were run at 60 meters to reduce processing time. Spot probability was set to 2%.

For the MTT runs gridded wind speeds were generated with FlamMap's Wind Ninja model at 300-meter resolution, foliar moisture content of 75%, and fixed fuel moistures. The Scott and Reinhardt (2001) crown fire calculation method was used.

For each of the calibration runs, the fire perimeters were exported to ArcMap for further processing. Average fire size was calculated after combining each spot fire with its parent fire. The portion of fires whose perimeters remained completely within the fireshed bounds were also calculated.

Once the LANDFIRE inputs were updated, FlamMap was re-run with the final weather scenario (Table 6) and the flame length, rate of spread, and crown fire activity output rasters were saved.

Conditional Burn Probability (CBP) provides an indication of the likelihood of a given pixel burning during the simulation. FlamMap computes this by letting the specified number of ignitions burn for the specified burn time and then it derives CBP from the overlapping fire perimeters. Fuel treatments or natural barriers that slow fire spread have an effect on CBP by reducing the frequency at which a downwind pixel burns. CBP therefore allows useful comparisons between pre-treatment and post-treatment landscapes.

When CBP was mapped for the Placerville area, the Fire Safe Council was concerned that the values in and around Placerville were unrealistically low when compared to other areas of the landscape and historic fire patters. To explore this problem further, two simulations were run for each of eight wind directions (N, NE, E, etc.) and the results were averaged with the goal of reducing the effect of wind direction on CBP. This, in essence, eliminated the fire shadow effect produced downwind of barriers (primarily urbanized areas, lakes, and large rivers) to surface fire spread.

3.25 Assessment of Risk Mitigation Priorities

Risk mitigation priorities were assessed at the county and community levels using a combination of existing data, collaborative meetings (Appendix 1), interviews, and an on-line survey. The on-line survey allowed for identification of priority areas for fuel treatment implementation that is reflective of each community's unique characteristics and needs. The priority resources identified through this process were utilized to help create the community base map. For the purposes of the El Dorado CWPP, proposed treatments were confined to private lands only, as parallel efforts are already occurring on public lands.

3.3 Community Risk Analysis

3.31Creation of Community Fire Hazard Map

Draft maps by area for modeled flame length, rate of spread, and fire type are included in Appendices 4-6. Maps are color coded to reflect general influence on suppression efforts per tables 7-9 below.

Table 7. Fire Suppression Interpretations from Flame Length (NWCG 2004)

Flame Length	Description
Less than 4 feet	Fires can generally be attacked at the head or flanks by firefighters using hand tools. Hand line should hold fire.
4 to 8 feet	Fires are too intense for direct attack on the head with hand tools. Hand line cannot be relied on to hold the fire. Bulldozers, engines, and retardant drops can be effective.
8 to 11 feet	Fire may present serious control problems: torching, crowning, and spotting. Control efforts at the head will probably be ineffective.
Over 11 feet	Crowing, spotting, and major fire runs are probable. Control efforts at the head of the fire are ineffective.

Table 8. Fire Suppression Interpretations from Rate of Spread (NWCG 2004)

Rate of Spread (Chains per hour	**Description**
Up to 10 Chains per hour	Generally within sustained production rates of Type 1, 20 person hand crews.
10-16 Chains Per hour	Generally within initial attack production rates for a 20 person hand crew, or 4 person wildland engine crew using a hose lay.
16-25 Chains per Hour	Generally within maximum downhill line production rates for a type 2 dozer; exceeds production rates for fire and engine crews.
>25 chains per hour	Rate of spread exceeds typically available resource (fire crew, engine crew, or dozer) production rates.

Table 9. Definitions for Crown Fire Activity (Scott and Reinhardt 2001)

Flame Length	**Description**
Non Burnable	Water, pavement, rock, and similar cover types.
Surface Fire	A fire burning along surface fuels without significant movement into overstory.
Passive Crown Fire	A type of crown fire in which the crowns of individual trees or small groups of trees burn, but solid flaming in the canopy cannot be maintained except for short periods.
Active Crown Fire	A crown fire in which the entire fuel complex is involved in flame, but the crowning phase remains dependent on heat released from surface fuel for continued spread.