Appendix B

Fire Behavior Modeling Inputs

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FLAMMAP INPUT FILES AND ASSUMPTIONS

A FlamMap fire behavior prediction simulation involves the input of several spatial data layers as well as settings for specific weather parameters. The base input layers were compiled as part of the nation-wide Landscape Fire and Resource Management Planning Tools Project (LANDFIRE). The project consists of data describing vegetation, wildland fuel, and fire regimes across the United States (www.landfire.gov). This dataset was chosen for this assessment for its consistent, landscape-scale, cross-boundary strategic products for fire management planning. LANDFIRE data was chosen because it characterizes tree canopy characteristics and mid-story information that allows for the prediction of crown fire. These two Fuel Model layers, though describing the same phenomena, were derived from two very different processes and for varying purposes. The data layers describe existing vegetation composition and structure, wildland fuel (crown and surface) The consistent and comprehensive nature of LANDFIRE methods ensures that data will be nationally relevant, while the 30-meter grid resolution assures that data can be locally applicable. (LANDFIRE, 2008).

To model fire behavior a number of data themes must be developed for the FLAMMAP program. These include:

Elevation: Measured in feet above sea level. This is necessary for adiabatic adjustment of temperature and humidity between elevations and for conversion of fire spread between horizontal and slope distances

Slope: Percent of inclination from the horizontal. Slope is used to compute steepness effects on fire spread and solar irradiance.

Aspect: Azimuth values degree clockwise from north. Aspect is used to compute effects on fire spread and solar irradiance.

Fuel Model: Fuel models, organized and described as Fire Behavior Prediction System Fuel Models in terms of fuel volume, structure, and chemistry. Fuel types were mapped by CAL FIRE (and provided by the Amador El Dorado Unit).

Canopy Cover: Canopy cover is necessary to compute shading and wind reduction factors. Canopy cover is mapped within the LandFire mapping process using LiDAR.

Tree Height: Tree height is used to compute spotting distance and crown fire characteristics. Canopy cover is mapped within the LandFire mapping process using LiDAR..

Crown Base Height, or Height to Live Canopy: Crown base height is an important parameter for determining the transition from surface fire to crown fire. This value incorporates the effects of ladder fuels in increasing vertical continuity and assisting

transition to crown fire. Canopy cover is mapped within the LandFire mapping process using LiDAR.
Weather: Weather is important to determine environmental conditions for the simulation. The weather data theme describes the maximum and minimum temperature and relative humidity, and the time in which the maximum and minimum temperature occurs in order to dry and moisten fuels accordingly. For purposes of comparing weather conditions throughout the state, the Sierra Nevada Ecosystem Project developed a standard set of weather conditions that defines an "average high fire danger", representing approximately 90th percentile weather conditions[1]. This set of weather conditions were used for the FlamMap simulations.

Wind: Wind provides a heat transfer mechanism and influences the direction of fire spread. The wind data theme describes the wind speed and direction every hour throughout the simulation. A wind speed of 15 miles per hour, with wind blowing uphill, was selected as the FlamMap input because this is the maximum speed that the FlamMap reliably predicts surface spread, flame length and crown fire potential.

FlamMap and FARSITE Inputs Files
The following discussion describes files used as inputs to the wildfire simulation program, FARSITE. These consist of:

1. ***conversion files*** (*.cnv), where the fuel model specified in the spatial categorization of fuels is changed to another fuel model, or a custom fuel model.
2. ***adjustment files***, where the rates of spread for each fuel model are adjusted to account for the inherent over-prediction of spread rates by the heat transfer models,
3. ***custom fuel models*** (*.fmd) where fuels are defined that are not part of the standard fuel models (such as grazed grass, or an interpretation of mature landscaping),
4. ***fuel moisture files*** (*.fms), where for each fuel model, the initial fuel moisture for each size class of fuels is defined for each fuel model. The moisture content of live woody fuels and live herbaceous fuels are similarly defined for each fuel model.

In all files, the format follows that required by the FARSITE version 4.0, 1997, by Mark A. Finney. FARSITE is available from Systems for Environmental Management, PO Box 8868, Missoula, MT, 59807, or from www.fire.org/tools.

<u>Conversion file</u>
No conversion files were used.

<u>Fuel Moisture file</u>
This file specifies the moisture in the fuels of various sizes, and specifies how much moisture is in leaves as well. The weather files then dry out or add moisture depending on ambient conditions. The first column is the fuel model number, the remaining columns are moistures by size class and live material. These values were taken from a range of moistures monitored throughout the state for the last 20 years.

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[1] *Sierra Nevada Ecosystem Project: Final report to Congress,* vol. III, *Assessments and scientific basis for management options*. Davis: University of California, Centers for Water and Wildland Resources, 1996.

Fuel Model	Dead Fuels			Live Fuels	
	¼-1”	**1-3”**	**> 3”**	**Woody**	**Herbaceous**
1	2	3	7	70	70
2	2	3	7	70	70
3	2	3	7	70	70
4	2	3	7	70	70
5	2	3	7	70	70
6	2	3	7	70	70
7	2	3	7	70	70
8	2	3	7	70	70
9	2	3	7	70	70
10	2	3	7	70	70
11	2	3	7	70	70
12	2	3	7	70	70
13	2	3	7	70	70

DESCRIPTION OF FIRE BEHAVIOR OF FUEL MODELS

From: Anderson, Hal E; Aids to Determining Fuel Models for Estimating Fire Behavior. Gen. Tech Report INT-122, 1982, and Rothermel, Richard C. How to predict the Spread and Intensity of Forest and Range Fires, Gen. Tech. Report INT-143.

FUEL MODEL 1: (Grass) Primary carrier of the fire is grass. Expected rate of spread in ungrazed grass is moderate to high, with low to moderate fireline intensity (flame length). Fires are surface fires that move rapidly through cured grass and associated material. Grazed grass produces significantly lower flame lengths and spreads slower by one-quarter to one-half the rate.

FUEL MODEL 2: (Oak Savanna) Primary carrier of the fire is shrub or litter beneath the shrub. Expected rate of spread and fireline intensities are moderate to high. Fire spread is through the fine herbaceous fuels, either curing or dead. These are surface fires where the herbaceous material, besides litter and dead-down stemwood from the open shrub or timber overstory, contribute to fire intensity.

FUEL MODEL 4: (Chaparral) Fire intensity and fast-spreading fires involve the foliage and live and dead fine woody material in the crowns of a nearly continuous secondary overstory. Stands of mature shrub, 6 or more feet tall, such as California mixed chaparral…are typical candidates. Besides flammable foliage, there is dead woody material in the stand that significantly contributes to the fire intensity. Height of stands qualifying for this model depends on local conditions. There may be also a deep litter layer that confounds suppression efforts.

FUEL MODEL 5: (Coastal Scrub) Fire is generally carried in the surface fuels that are made up of litter cast by the shrubs, and the grasses or forbs in the understory. The fires are generally not very intense because surface fuel loads are light, the shrubs are young with little dead material, and the foliage contains little volatile material.

FUEL MODEL 6: (Riparian Shrubs) Fire carries through the shrub layer where the foliage is more flammable than fuel model 5, but requires moderate winds, greater than 8 mi/hr at midflame height. Fire will drop to the ground at low windspeeds or openings in the stand. The shrubs are older, but not as tall as shrub types of model 4, nor do they contain as much fuel as fuel model 4. A broad range of shrub conditions is covered by this model. Fuel situations to consider include intermediate-aged stands of chamise, chaparral, and oak brush.

FUEL MODEL 8: (Closed Canopy Oak Forest) Slow burning ground fires with low flame heights are generally the case, although an occasional “jackpot” or heavy fuel concentration may cause a flare up. Only under severe weather conditions involving high temperatures, low humidities and high wind do the fuels pose fire hazards. A compact litter layer (composed of needles, leaves, and some twigs) supports fire, since little undergrowth is present in the stand.

FUEL MODEL 9: (Mixed Hardwood stands with little debris) Fire runs through the surface litter faster than model 8 and has a higher flame height. Both long-needle conifer and hardwood stands…are typical. Fall fires in hardwoods are representative, but high winds will actually cause higher rates of spread than predicted. This is due to spotting caused by rolling and blowing leaves. Closed stands of long-needled pine like ponderosa, Jeffrey, and red pines …are grouped in this model. Concentrations of dead-down woody material will contribute to possible torching out of trees, spotting, and crowning.

FUEL MODEL 10: (Forests and Woodlands with large dead logs) The fires burn in the surface and ground fuels with greater fire intensity than the other timber litter models. Dead down fuels include greater quantities of 3-inch or larger limbwood resulting from over-maturity or natural events than create a large load of dead material on the forest floor. Crowning out, spotting, and torching of individual trees is more frequent in this fuel situation, leading to potential fire control difficulties. Any forest type may be considered if heavy down material is present; for example, insect- or disease-ridden stands, wind-thrown stands, over-mature stands with deadfall, and aged slash from light thinning or partial cutting.

The following table identifies 13 standard fuel models. These fuel models were identified by Hal E. Anderson in *Aids to Determining Fuel Models for Estimating Fire Behavior. Gen. Tech Report INT-122, 1982* and Richard C. Rothermel in *How to predict the Spread and Intensity of Forest and Range Fires, Gen. Tech. Report INT-143*. T/A indicates tons per acre. 1-H is an abbreviation for fuels smaller than ¼ inch in diameter. 10-H, for fuels ¼ - 1 inch in diameter, 100-H for fuels 1 – 3 inches in diameter. "Live" indicates living herbaceous fuels, and "woody" indicates foliar fuels of woody shrubs. Fuel Bed Depth is the height above ground in which the fuel is distributed. The moisture of extinction is the amount of dryness at which fire will not be sustained. ROS is Rate of fire spread, and FL is flame length.

Table 1: Description of Fuel Models

Fuel Model	Typical Fuel Complex	Fuel Loading (T/A)				Fuel Bed Depth (ft)	Moist. of Extinction Dead Fuels (%)	ROS* ch/h	FL* (ft)
		1-H	10-H	100-H	Live				

1	Short Grass	0.74	0	0	0	1	12	78	4
2	Timber	2	1	0.5	0.5	1	15	35	6
3	Tall Grass	3.01	0	0	0	2.5	25	104	12
4	Chaparral	5.01	4.01	2	5.01	6	20	75	19
5	Brush	1	0.5	0	2	2	20	18	4
6	Dormant brush	1.5	2.5	2	0	2.5	25	32	6
8	Closed Timber Litter	1.5	1	2.5	0	0.2	30	2	1
9	Hardwood Litter	2.92	0.41	0.15	0	0.2	25	8	3
10	Timber	3.01	2	5.01	2	1	25	8	5
11	Light Logging Slash	1.5	4.51	5.51	0	1	15	6	4
12	Medium Logging Slash	4.01	14.03	16.53	0	2.3	20	13	8
13	Heavy Logging Slash	7.01	23.04	28.05	0	3	25	14	11
*ROS and FL are represented under a fine dead fuel moisture of 8%, a midflame windspeed of 5 mi/h, and live fuel moisture, if present, of 100% (Anderson, 1982).									
Custom fuel models 14-21, 30, 40, 50, 60, 61, and 80 are described in Appendix A.									