Appendix A

2004 Annual Report: Fuels and Fire at the Landscape Scale
Plumas and Lassen Administrative Study (PLAS)

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Project Goals:

In this study, we are investigating how landscape-level fuels and silvicultural treatments affect potential fire behavior and fire effects across the forested landscape of the project area in the Plumas National Forest. This analysis is critical for assessing the potential of severe or extensive fire occurring on the landscape.

In addition, both fuels treatments and fire alter forest structure, pattern and composition and thereby modify wildlife habitat that depends on the vegetation. Our assessments of potential change to landscape-scale vegetation will be instrumental when coupled with assessments of wildlife habitat conducted by the owl research module. This linking of module research relies on an integrative analytical model developed by our team. That model is described here, as the last part of this study.

Objectives and Overview

Past management activities including fire suppression, timber harvesting, and livestock grazing have changed the structure and composition of many coniferous forests in the western United States, particularly those that once experienced frequent, low-moderate intensity fires (Biswell 1961; Hartesveldt and Harvey 1967; Parsons and Debenedetti 1979; Beesley 1995; Erman 1996; Menning 2003). These changes in vegetation have altered habitat for a variety of species. Correspondingly, changes in vegetation and fuel loading have changed the probability of fire spreading across the landscape.

The USDA Forest Service aims to actively manage vegetation with the goal of reducing the probability of large, intense, or severe fires while minimizing negative effects on wildlife habitat and ecosystem stability. Proposed treatments include group selections and defensible fuel profile zones (DFPZs). Group selection treatments involve the harvest of all trees smaller than 30” diameter at breast height (DBH) over a one to two acre area (Stine et al. 2002). DFPZs are areas with extensive forest thinning intended to reduce surface and canopy fuel loads. They are also known as shaded fuel breaks and are designed to allow access for active fire suppression. DFPZs are spatially-extensive, covering hundreds to thousands of hectares (Stine et al. 2002).

Currently, there is limited information on the effects of landscape fuels treatments on reducing severe fire behavior and effects, especially at the landscape scale (Erman 1996; Agee et al. 2000; Fites-Kaufman et al. 2001). Elsewhere in the Sierra Nevada, group selections have been shown to have little effect on the landscape-level behavior of fire (Stephens and Finney 2002); the proposed group selections in the Plumas, however, retain more large trees per acre than typical group selections. To date, the modeled effects of group selections with large tree retention have not been published for this forest type.

Assessing the effects of these vegetation management strategies—group selections and DFPZs—across the forested ecosystems of the Plumas and Lassen National Forests is the goal of the Plumas-Lassen Administrative Study (Stine et al. 2002). The study is composed of five research teams with distinct focuses: California spotted owls, small mammals, songbirds, fuels and fire, and vegetation. Due to practical considerations of a study as spatially extensive as this, we have to mix research with monitoring. The overall study does not comprise a formal scientific experiment in that the scientists involved have little control over actual treatments. The study amounts to far more than monitoring, however, in that we are independently assessing a large landscape and modeling changes to that landscape given a set of prescriptive treatments.

For the Fuels and Fire Module, which is the focus of this study plan, we aim to address the landscape-scale effects of the proposed forest treatments by answering a suite of questions: First, what are current conditions, in terms of fuel loads and vegetation, measured directly in the field? Second, what is the current potential fire behavior and effects given these measured fuel and vegetation conditions? Third, how would landscape fuels treatments affect vegetation condition and fire behavior and effects?

Fourth, in addition to these efforts to characterize fuels and fire relationships, it is essential to link results of our research with findings from the other research modules (figure 1). It is clear that any landscape-level fuels or forest management strategy will affect many interrelated components of forest ecosystems (Erman 1996; Bahro 2004). Therefore, it is important to understand the synergistic effects between potential treatments and various areas of concern—forest conditions, risks of severe or extensive fire, and habitat alteration. Our goal in answering this fourth question is to produce an analytical model in which we integrate maps of current conditions with models that project responses of fire behavior and effects given prescriptions of treatment and weather scenarios. The vegetation component of the current conditions maps would act simultaneously as input to the Spotted Owl Module's habit suitability models. By coupling these data layers and models between research modules we will model the likely effect of a landscape fuels strategy on both *fire* and *owl habitat* given various prescriptions and weather scenarios.

Taken together, these four research goals form the top level of a hierarchical set of research goals that may be best expressed in a table. Hence, we have shown these research objectives and their supporting details and questions in table 1. Details supporting the modeling efforts follow the table.

Fig 1: Ecosystem Relationships Examined in PLAS
(Topics addressed in this module emphasized in bold)

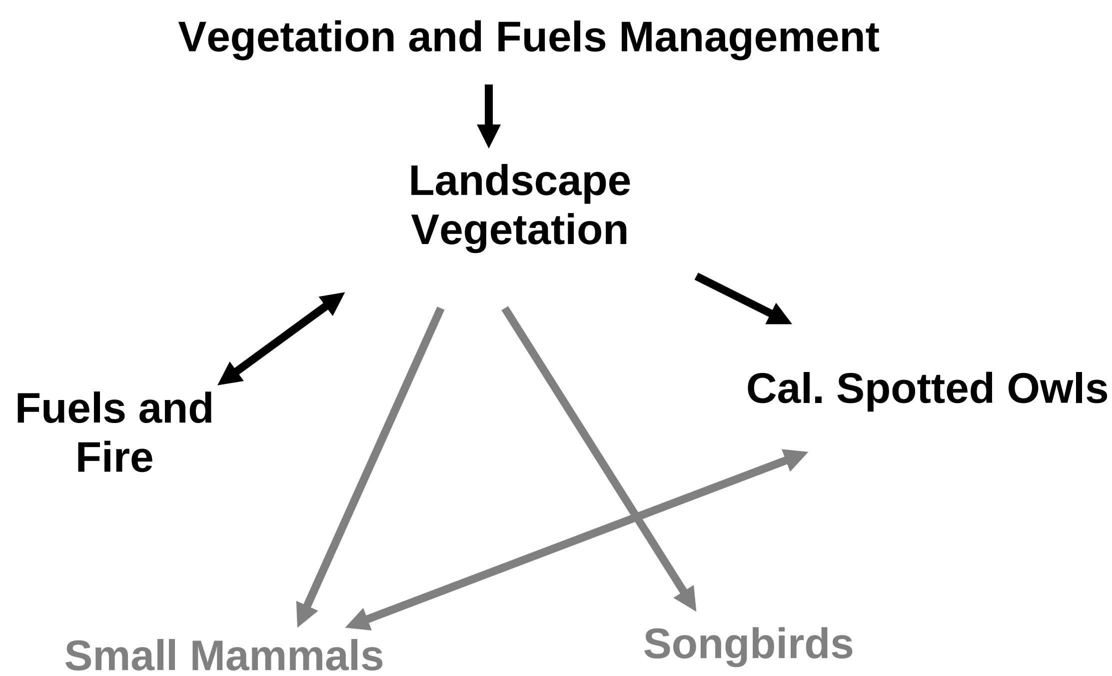

Table 1: Fuels and Fire Module: Summary of hierarchical arrangement of study topics

1.0 Current conditions: measurement of vegetation and fuels at the landscape scale
- 1.1 Current vegetation: What are current vegetation conditions prior to treatment?
  - 1.1.1 Forest sampling in the field (forest plots)
  - 1.1.2 Remote sensing of forest conditions
    - 1.1.2.1 Forest and vegetation classification (LANDSAT imagery)
    - 1.1.2.2 Forest structural diversity analysis (IKONOS imagery)
- 1.2 Current fuels: What are current fuel loads prior to treatment?
  - 1.2.1 Fuels sampling in the field (forest plots)
  - 1.2.2 Remote sensing of annual fine fuels production using LANDSAT
  - 1.2.3 Ladder fuels: probability of fire ascending forest canopy (LaFHA)
  - 1.2.4 Integration of data sources into a fuel model/map for the study area

2.0 Fire modeling: how might current conditions (above) affect fire *behavior* and *effects*?
- 2.1 Fire *behavior*: What is the range of potential fire behavior given current conditions & a range of weather scenarios? (FARSITE & FlamMap models)
- 2.2 What are likely *effects* of fire behavior on these landscapes as determined by simulation models? (Stephens approach using FARSITE & FlamMap outputs)

3.0 Effects of treatments: how might landscape-scale treatments change fire behavior and effects (using FlamMap)?
- 3.1 Group Selections (GS) and Defensible Fuel Profile Zones (DFPZs)
  - 3.1.1 Measure: how does the installation of GSs & DFPZs affect fuel loads?
  - 3.1.2 Model: how does the placement of GSs & DFPZs affect potential fire behavior? Do they reduce the probability of catastrophic fire under extreme weather conditions?
  - 3.1.3 Modeling: how does the installation of GSs & DFPZs affect fire effects such as mortality to different species and size classes of trees? Would the reduction in fire extent and intensity reduce the severity of canopy fires?
- 3.2 Spatial allocation and efficiency: DFPZs and Strategically Placed Landscape Area Treatments (SPLATs)
  - 3.2.1 How does the installation of alternative treatments affect fuel loading?
  - 3.2.2 How does the placement of alternative treatments affect potential fire behavior?
  - 3.2.3 How do different levels of management intensity (extent of treatment) affect the treatment's ability to reduce the size or intensity of fires?

3.2.4 What effect would alternative treatments have on resulting fire *effects*?

4.0 Fire and habitat model integration

4.1 Link current vegetation coverages to potential fire behavior & effects (as above)

4.2 Provide link from vegetation coverage to Keane's owl habitat assessment

4.3 Model interaction between vegetation management and both fuels and fire, and owl habitat given current conditions, prescriptions and weather scenarios

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Study Area

Our study area is a subset of the Plumas National Forest in Northern California, USA. The Plumas and Lassen National Forests cover hundreds of thousands of acres, and sampling an area this size with a limited field crew and small remote sensing budget is beyond our capacity. As a result, we have chosen to focus on the study area's treatment units (TU) 2, 3 and 4 (Stine et al. 2002), which present widely varying topographical conditions and contain a variety of owl habitat quality. The total area of these three TUs is about 60,000 ha (150,000 ac) (Keane 2004). Vegetation varies widely through this region, presenting a good opportunity to examine fire behavior and end effects across a spectrum of conditions. The town of Quincy lies directly eastward of TU 4 and would be immediately affected by fire in this area and the resulting smoke. In addition, TU 2 has been evaluated to have high quality spotted owl habitat while areas 3 and 4 have lower qualities (Keane 2004). As a result, these three treatment units present a good range of conditions in which to conduct this research and test our model integration.

Vegetative cover in this area is primarily mixed conifer forest. The mixed conifer forest community comprises a mix of three to six conifers and several hardwoods (Barbour and Major 1995; Holland and Keil 1995; Sawyer and Keeler-Wolf 1995). Common conifers include ponderosa pine (*Pinus ponderosa*), Jeffrey pine (*P. jeffreyi*), sugar pine (*P. lambertiana*), incense-cedar (*Calocedrus decurrens*), Douglas fir (*Pseudotsuga menziesii)* and white fir (*Abies concolor*). Red fir (*Abies magnifica*) is common at higher elevations where it mixes with white fir (Holland and Keil 1995; Sawyer and Keeler-Wolf 1995). At mid to lower elevations, common hardwoods include

California black oak (*Quercus kelloggii*) and canyon live oak (*Q. chrysolepis*) (Rundel et al. 1995).

In addition, a number of species are found occasionally in or on the edge of the mixed conifer forest: western white pine (*P. monticola*) at higher elevations, lodgepole pine (*P. contorta*) in cold air pockets and riparian zones, western juniper (*Juniperus occidentalis*) on dry sites, California hazelnut (*Corylus cornuta*), dogwood (*Cornus spp.*) and willow (*Salix spp.*) in moister sites, California bay (*Umbellularia californica*) and California nutmeg (*Torreya californica*) in lower, drier areas (Griffen and Critchfield 1976; Holland and Keil 1995; Rundel et al. 1995).

A variety of vegetation types currently comprise the matrix of covers in which the mixed conifer forest is arrayed. Vegetation in the matrix ranges from chaparral on exposed, poorly watered south and west facing slopes to oak woodlands and riparian meadows. At higher elevations, particularly toward the Bucks Lake Wilderness, some red fir may be found in pure stands (personal experience).

Methods

This study is conducted under a passive adaptive management framework administered by the USDA Forest Service; we have no control over the implementation of the landscape fuels treatments. The HFQLG Act outlines the landscape fuels treatment strategies, and defines the types of timber harvest to be implemented. Decisions on the timing and placement of fuels treatments will be determined at a local level by the Plumas National Forest.

We do have control over the data collection and modeling aspects of the project. Our research topics (table 1) can be divided into several methodological groupings. Here, we present summaries of methodologies for field data collection, remote sensing, and model integration. Data are collected from a series of field plots (discontinuous data) as well as from satellites (continuous forest canopy data). Additional data products are derived through modeling.

Methods: Field data collection

Plot Layout and Design

Data on forest cover and fuels is being collected in 0.05ha (0.125 ac) plots 12.6m (41.3 ft) in radius (figure 2). Plot locations are established using a stratified-random approach. Strata of elevation, aspect and vegetation type were defined using the layers previously supplied by the contractor VESTRA (Stine et al. 2002). This process identified over 700 plot locations in treatment units 2, 3 and 4. In addition to the randomly-stratified plot locations described above, similar data will be collected at locations identified by the other modules: plots are located at each owl nesting site and mammal study grid in the three treatment units.

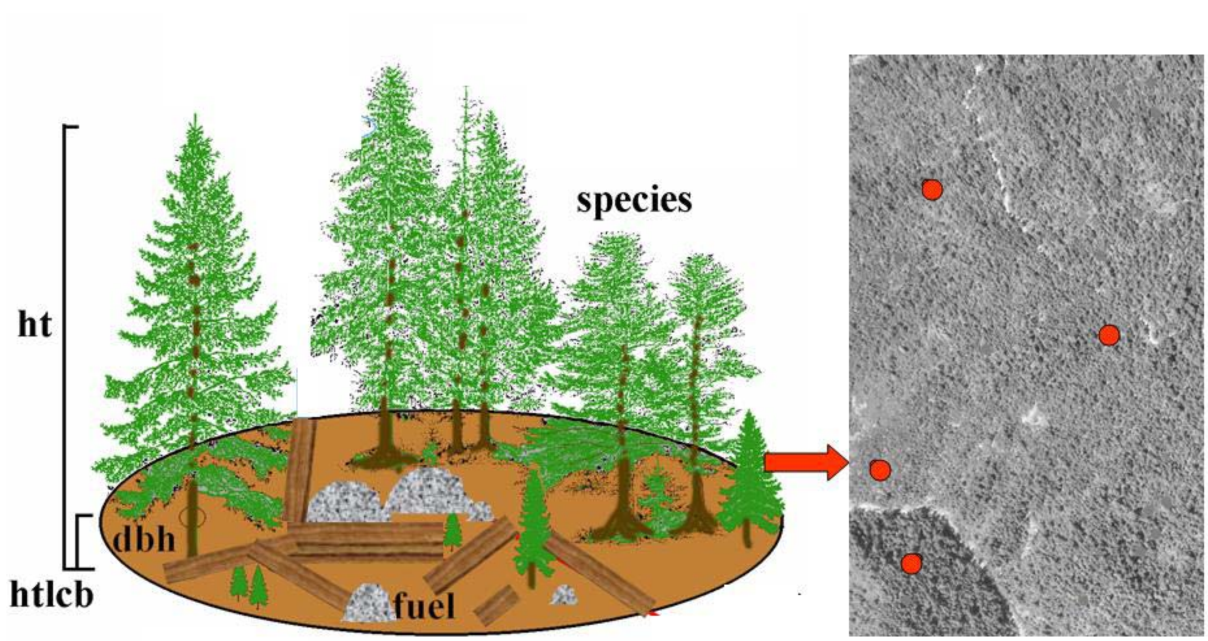
Forest Structure and Composition; Site Data

We collect data on tree species, diameter at breast height (DBH), categorical estimate of height, and height to lower crown (see Appendix A for sample data sheet). Site data collected include location (using high-precision GPS), slope, and aspect. Canopy cover is assessed at 24 points (every 1 meter) along two linear fuels transects (described below).

Ground based sampling of ladder, surface, and ground fuels

Surface and ground fuels are sampled in each plot using the line intercept method (Brown 1974; Brown et al. 1982). Ground and surface fuels are sampled along two transects radiating from plot center. The first transect is located along a random azimuth and the second falls 90 degrees clockwise from it. We sample 1 and 10 hour fuels from 10-12 meters along each transect, 100 hour fuels from 9-12 meters, and 1000 hour fuels

Figure 2: Data sources: field plots and satellite imagery
(plots shown scattered on landscape on satellite image to right)



data from 1-12 meters. Duff and litter depth (cm) are measured at 5 and 8 meters along each transect. Maximum litter height is additionally sampled at three locations from 7 to 8m (Brown 1974; Brown et al. 1982). Total fuel loads for the sites are occularly estimated using fuel photo series developed for the Northern Sierra Nevada and Southern Cascades (Blonski and Schramel 1993).

Ladder Fuel Hazard Assessment (LaFHA)

We have devised and implemented a mixed quantitative-expert system for assessing ladder fuels (Appendix B). The Ladder Fuel Hazard Assessment (LaFHA) requires a trained field crew member to rapidly assess the presence and continuity of fuel ladders in each of four quadrants in a plot using a flowchart (Appendix B). The first step is to determine the presence of low aerial fuels: the fuels that would create sufficient flame lengths to reach several meters from the forest floor. Sparse vegetation, or vegetation widely distributed, probably has too little fuel per volume of air to create and sustain large flames. Therefore, we define a clump of low aerial fuels to be brush or small trees covering an area of at least 4 square meters (2m x 2m) with gaps of less than 50cm. If it is particularly dense, or tall and brushy, a clump may cover a small area. A particularly dense clump may cover as little as $2m^2$ on the forest floor, for example. Branchy dead fuel or stems may be included in the assessment. The size and density of these clumps of fuel and vegetation are based upon personal experience (S. Stephens, K. Menning). If there is no clumping of low aerial fuels, the site would fall in the two lowest ladder fuel hazard categories (C, D); conversely, if there is a clumping of low aerial fuels, the site would fall in one of the two higher-risk categories (A, B). It is important to note that isolated clumps of low aerial fuels, well removed from any ladders, are discounted.

Letters (A, B, C, and D) are assigned to hazard ratings instead of numbers to prevent confusion: categories are not of interval or ratio quality (e.g., "Is category 4 twice as risky as category 2?" No, we would not know the quantitative relationship without a direct test).

The second step is to make a determination about the vertical continuity of the fuel ladder from the ground to the canopy. Gaps of more than 2m might be enough to prevent the spread of flames vertically (S. Stephens). Vegetation with gaps of less than 2m from the ground to the upper canopy may present a good ladder to conduct flames. Sparse vegetation lowers the probability and reduces the quality of the ladder. The technician is expected to look at the vegetation and determine whether there are gaps of 2m or more. If the maximum gap is less than 2m, then the site would be categorized as the higher hazard of the two options.

After placing the site in one of the four categories (A, B, C, or D), the technician records the minimum height to live crown (HTLCB) and the size of the maximum gap in the best ladder. These two values may later be used to help verify the classification is correct. The process is repeated for each of the four quadrants of the plot.

The effect of slope is not considered during the hazard evaluation in the field, slope data are used later, to modify the hazard rating. Because the effect of slope on flame length is non-linear (Rothermel 1972), the slope must have a non-linear multiplicative effect on the hazard rating. Final analysis of the plot is performed in the laboratory by combining the ratings of the four quadrants and applying a non-linear slope factor. A plot with one quadrant of high ladder fuel hazard and three low hazard ratings is certainly not as great a risk as a plot with continuous, high-risk ladders in each quadrant.

While this semi-quantitative, semi-qualitative process is experimental, and the exact numerical relationships between slope and hazard are yet to be determined, we feel the method has merit; importantly, the field crews report consistent ratings after training and repetition (K. Menning).

Methods: Remote sensing

Two different remote sensing methods are being implemented. First, high spatial resolution IKONOS provides information on continuous forest pattern, structure, cover and variability using methods developed by Menning (2003) including spectral entropy canopy diversity analysis (SpECDA—see appendix E of Fuel and Fire Study Plan). These data and analyses have the benefit of being linked to analyses of vegetation and wildlife habitat conducted by other researchers in the project (see model integration, below). In 2003, high-resolution (1-4m) IKONOS imagery of several treatments was collected covering treatment units 3 and 4. In 2004, IKONOS imagery covering TU 2 and 3—overlapping the data collected in 2003—was collected to provide additional coverage of the area with high owl population.

Second, an approach similar to that developed by van Wagtendonk and Root (2003) in Yosemite National Park is being used to provide information on vegetation and the annual cycle of fine fuel production. Two thematic mapper (TM) scenes are used to help differentiate the forest types. One TM scene is obtained in June and another over the same area from October. The two scenes are used to differentiate the vegetation types including forests, deciduous hardwoods, montane chaparral, wet meadows, and dry meadows. These are verified using data from the extensive network of field plots.

The spatial resolution of this second class of remotely sensed data is 30m by 30m. Bands 3 and 4 are being used from the TM data to calculate Normalized Difference Vegetation Index (NDVI). The result of this procedure will be a forest ecosystem map that will include rock, meadows (dry and wet), bare ground, montane chaparral, riparian areas over 30 m in width, and the three most common forest types (ponderosa pine, mixed conifer, white fir). Comparison of the pre- and post-summer growing season images will allow us to quantify the production of fine fuels in a variety of vegetation types. This will lead to more realistic inputs the fire modeling process.

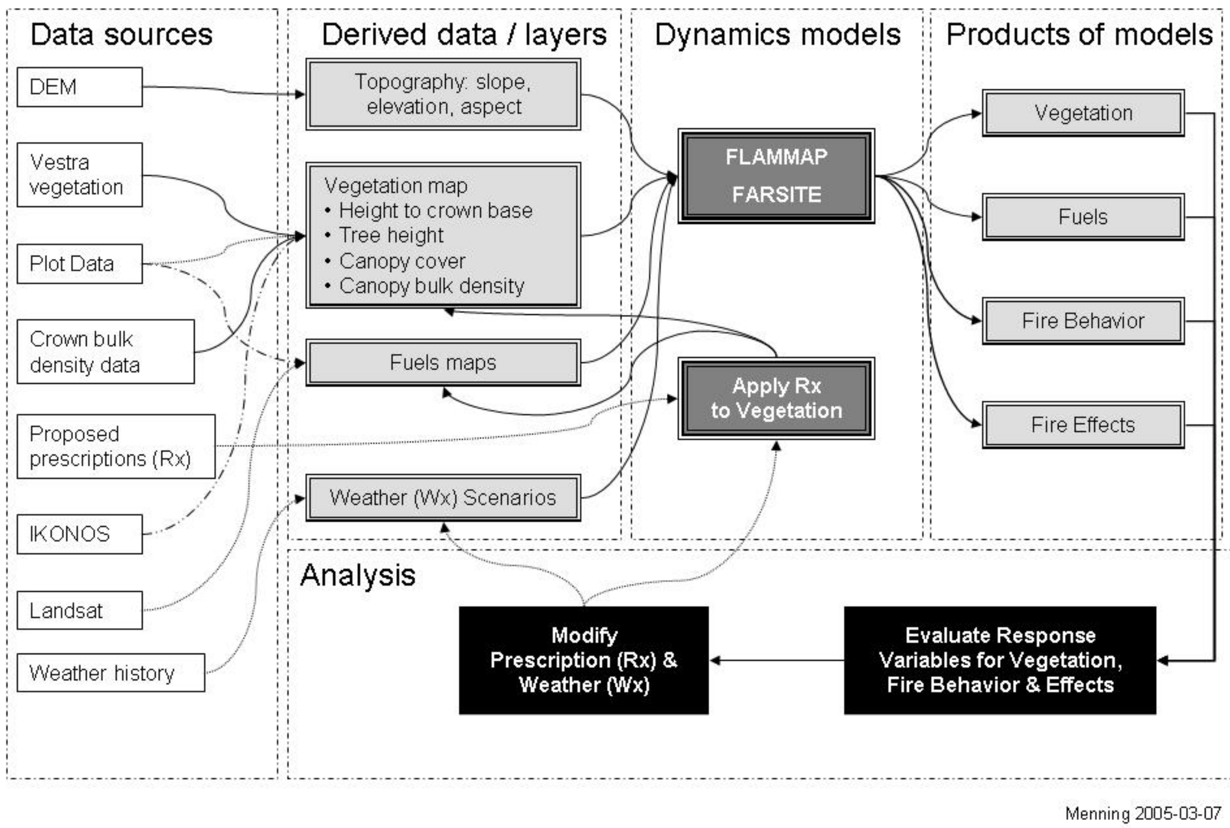
Methods: Data Processing, Analysis and Model Integration

Fire behavior models such as FARSITE require maps of vegetation, topography, and fuels, as well as weather scenarios, in order to model the spatial behavior of fire (figure 3). These data are integrated from a variety of different sources. Development of the vegetation map has been described above, in the remote sensing methodology. Topographic variables—slope, elevation and aspect—are mapped across the study area using pre-existing Digital Elevation Models (DEM) on a 30x30m grid. Assembling fuels maps requires that fuels be measured at select sites (a discontinuous set) and then extrapolated across the landscape where fire may burn (continuous coverage).

Calculation of Fuel Loads and Development of Fuel Models

Many fuel inventories done in the Sierra Nevada have assumed that the fuel particles being inventoried had similar properties to those found in the northern Rocky Mountains (Brown 1974) but Van Wagtendonk's work in quantifying Sierra Nevada surface and ground fuel properties allows custom fuel load equations to be developed for a site-specific project such as this. This methodology previously has been used to produce accurate estimates of fuel loads (Stephens 2001). Additional validation of these fuel load coefficients are provided by Menning's research in Sequoia National Park (Menning 2003). As tree species in the northern Sierra Nevada are the same as those sampled by Menning and van Wagtendonk, the data should be relevant to this study site.

Figure 3: PLAS Landscape Vegetation, Fuels and Fire



Field measurements provide data on species mixes and fuel particle size distribution. Using these data, ground and surface fuel loads are calculated by using equations developed for Sierra Nevada forests (van Wagtendonk et al. 1996; van Wagtendonk and Sydoriak 1998; Menning 2003) as well as the production of fine fuels as determined by Landsat imagery analysis (van Wagtendonk and Root 2003). Coefficients required to calculate all surface and ground fuel loads are arithmetically weighted by the basal area fraction (percent of total basal area by species) that are collected in the plots.

Plot based fuel measurements are being used to create a set of customized and spatially-extensive fuel models for the study area (Burgan and Rothermel 1984) for this area. Fuel model development includes a stochastic element to more closely model actual field conditions that have a large amount of spatial heterogeneity. Stochastic fuel models are being produced for each stratum identified using van Wagtendonk and Root's methods (forest type, aspect, seral stage, etc.). Plot data provide crown cover, height to live crown base, and average tree height at each site. Canopy bulk density estimates are based on previous work by Stephens (Stephens 1998). All of these spatially-discontinuous data derived from plot-specific measurements are extrapolated across the landscape using the remote sensing imagery maps of vegetation.

Simulations: Potential fire behavior

Potential fire behavior is being estimated using a similar technique developed by Stephens (1998) but at much broader spatial scales. The effectiveness of the different restoration treatments will be assessed with computer models such as FARSITE (Finney 1996; Finney 1998; Finney 2000) and FlamMap (Finney 2003). FARSITE is a deterministic, spatial, and temporal fire behavior model that requires as inputs fuel measurements and models; topographic data, including slope, aspect, and elevation; forest structural data including canopy cover, tree height, height-to-live crown base, and canopy bulk density; and weather. A historic fire occurrence map is being produced to estimate the probability of ignitions in the study area. Data come from the Plumas National Forest archives and current GIS layers. This derived map will be used to generate an actual ignition point in each FARSITE simulation. FlamMap is similar to FARSITE but does not use a user-determined ignition but burns the entire landscape using one set of weather data. These models will be used to quantify the potential fire behavior of the different treatment approaches.

The duration of each simulation would be seven days, a period that approximates the duration of many landscape-scale wildfires in the Sierra Nevada before they are contained (Stephens, personal experience). Weather scenarios using data from the 50th (average) and 90th (extreme) percentile condition is being used and this data is being collected from local weather stations. Fire simulations would be constrained by suppression activities. Constrained simulations will use realistic suppression elements (15 person hand crews, aircraft, bulldozers, etc.; Stephens, personal experience).

Outputs from the fire simulation include GIS files of fire line intensity (kW/m), heat per unit area (kW/square meter), rate of spread (m/s)**,** area burned (ha), emissions (tons) and if spotting and crowning occurred. Scorch height (m) would be calculated from fireline intensity, air temperature, and wind speed. This information will be used to compare the effects of the different landscape level restoration treatments on altering fire behavior.

Simulation: Fire effects

After the fire has passed, the effects of the fire linger: trees die, exposed soils erode, and insects invade. Some fire effects such as tree mortality are being modeled using the GIS outputs from the FARSITE and FlamMap simulations coupled to previously-tested quantitative models that estimate tree mortality (Stephens and Finney

2001). In addition to the tree-mortality measure of fire severity, the amount of bare mineral soil exposed by the simulated fires is being estimated for each 30m by 30m pixel.

Analytical response variables for simulations

Landscape Fire Behavior

The differences in landscape-scale suppression efficiencies among fuels treatments is an essential aspect of this study (Agee et al. 2000; Bettinger et al. 2002). Defensible Fuel Profile Zones (DFPZs) should aid the ability of a wildfire suppression crew to successfully extinguish a fire during initial attack. FARSITE is being used with realistic suppression elements to determine if these landscape level fuel treatments will increase suppression efficiency when compared to the current untreated conditions. To test this efficiency in suppression, one landscape-scale fire response variable is the percentage of wildfires contained below 5 ha (12.5 ac) in size in one burning period before and after landscape fuel treatments.

Second, it is common for wildfires to be propagated by spotting and this can exponentially increase the size of the fire, particularly during the early periods such as the first 24 hours (Pyne et al. 1996). Treatments may reduce the spread of fire into a canopy where flaming brands may be carried into adjacent unburned areas(Pyne et al. 1996). Hence, the ability of a treatment to reduce the number of spot fires is an important measure of the treatment’s ability to reduce fire severity or frequency. The number of spot fires is being estimated before and after treatments to determine if treatments reduce fire spread from spotting. Here, the second fire response variable is the percentage change in spot fire initiation before and after landscape level fuel treatments.

A third critical response variable focuses on escapements of fire across the landscape during a longer time period. We will report the probability of simulated fires escaping from or crossing DFPZs and spreading at least another 200 ha (500 ac). This probability will be defined as the percentage of fires given 90th percentile fire conditions. This will be an important measure of the effectiveness of the DFPZs at reducing the chance of fire spreading across the landscape.

The total spatial extent of fire, given treated or untreated areas, is the fourth response variable. Simulated fires will be allowed to burn either until they burn out or are contained. The extent of forested area burned will be compared between treated and untreated areas.

Fifth, ground and canopy fires are dramatically different in behavior, severity, intensity and likelihood to spread across a forested landscape (Pyne et al. 1996). Ground fires are often beneficial, reducing fuel from the ground and surface, and reducing competition for small trees (Stephenson et al. 1991; Stephenson 2000). The fifth response variable, therefore, is a simple ratio of the area of canopy fire to total fire extent.

Analyzing Spatial Efficiency of the Placement of Landscape-Level Fuels Treatments

Location of fuel breaks can play a significant role in the efficiency of fire suppression (Finney 1999; Finney 2001). This is discussed more thoroughly in our Study Plan. SPLATs are passive in nature—no active suppression is performed—and thereby differ markedly from DFPZs which are meant to be the base of active suppression. The efficacy of SPLATs, however, will be tested the same way as the DFPZs, as previously described with the same response variables and over the same time periods. SPLATs, like DFPZs, would be placed on the landscape over a period of years rather than being applied all in the same time period. Performing this analysis with the same base data layers of vegetation and topography will allow us to analyze the efficiency of these different landscape-scale forest fuels management strategies.

We plan to test SPLATs at several spatial extents. The first set of SPLATs tested will have the same spatial extent as the proposed DFPZs. We will test increasing increments of landscape treated by SPLATs by 5% until we find the level of treatment that corresponds with similar degrees of suppression efficiency with the DFPZ network.

Further, we will try re-allocating the DFPZ treatment areas spatially to see if we can improve their efficiency for suppressing large or severe fires. A response variable here would be the percentage of the landscape burned given different configurations given the same weather scenarios and suppression efforts.

Landscape Vegetation and Habitat Response to Fire

A primary concern of this study is the effect of fires on forest structure, pattern and condition. Of particular concern are the older, late-successional forest remnants (Erman 1996). These provide essential habitat to the spotted owl. Wildfires in the Sierra Nevada are commonly low to moderate severity events with patches of high severity fire (Stephenson et al. 1991). Low severity fires may kill only the smallest pole or seedling size-class trees while moderate severity fire may kill both small and moderately sized trees. Fire in the high severity patches—or landscapes in the case of an extensive high severity fire—kills the majority of the small and medium sized and many of the large trees within the perimeter. High severity fire and the corresponding large tree mortality will significantly reduce canopy cover.

Many wildlife species such as California spotted owls prefer diverse forest structure for foraging and breeding and the presence of such variation may affect the success of reproduction (Hunsaker et al. 2002; Blakesley et al. In Press; Lee and Irwin. In press). Telemetry studies indicate that owls prefer to nest in areas with high canopy cover. Some areas of lower cover can also be included in the foraging habitat but this should probably only comprise a fraction of the area. Reduction of canopy cover may reduce the nesting habitat quality for the owl.

While there is a certain link between vegetation structure, pattern and composition and spotted owl core areas and home ranges (Keane and Blakesley 2005) exact measures of vegetation condition or change are not yet well defined. In addition, the link between different spatial scales of vegetation—extent and variation—and habitat selection is unknown. As a result, the definition of meaningful measures of vegetation condition and change, including appropriate scales of analysis from $30m^2$ to hundreds of hectares, will evolve along with the active analyses conducted in the Spotted Owl module (Keane and Blakesley 2005).

Fire and Habitat Model Integration

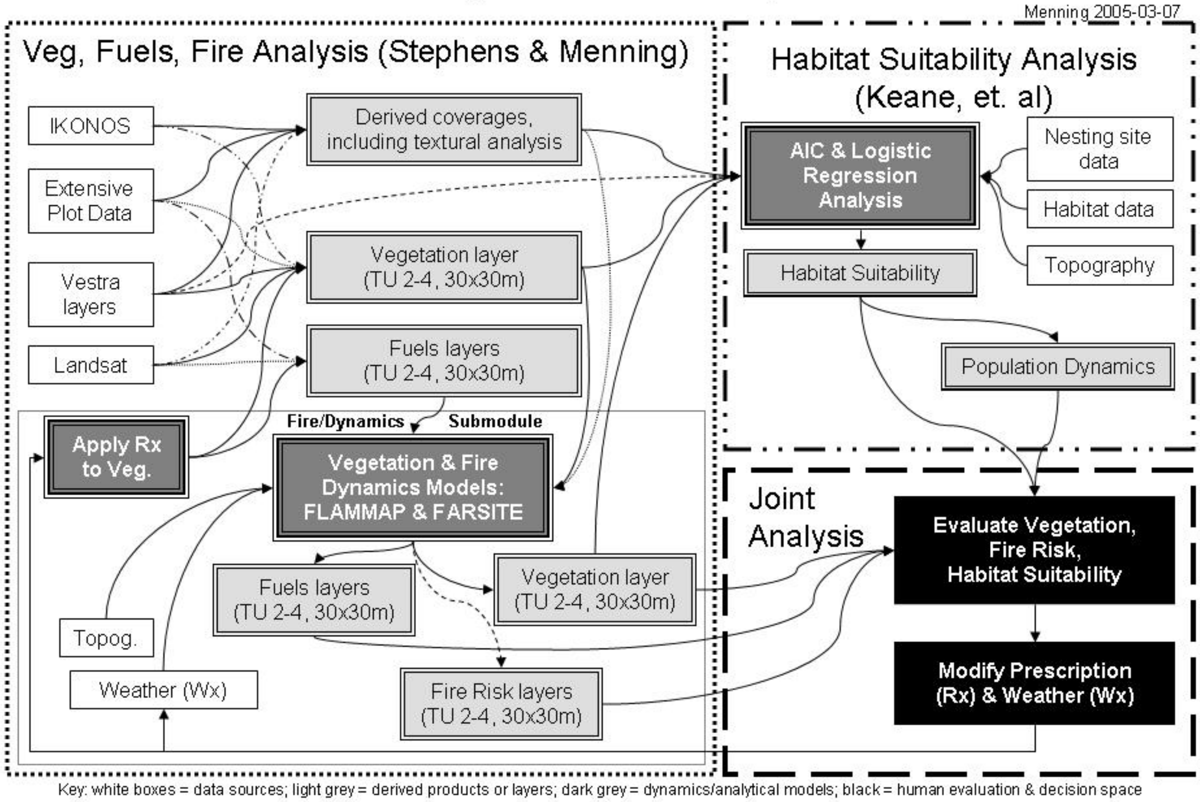
The final goal of the Fuels and Fire Module research is to coordinate with the Spotted Owl Module to produce a system in which an input of landscape-scale vegetation layers, weather scenarios, and fire events can be used to derive simultaneous assessments of fire and owl habitat (figure 4, appendix C). This effort requires separate but linked analyses by both our module and the Spotted Owl Module analysts (Keane and Blakesley 2005). The fuels and fire module will use inputs of IKONOS and LANDSAT imagery (described above, and in appendix E of Study Plan), extensive plot data, and pre-existing

VESTRA vegetation classification data to produce derived coverages, including base vegetation layers. These vegetation layers will be passed to both the Owl Module and the fire behavior and effects part of this module's study. Analysts in the Owl Module use the layers in their Akaike Information Criteria (AIC) and regression analyses to determine owl habitat suitability (Keane and Blakesley 2005).

These paired analytical efforts—fire and wildlife habitat—will yield results covering the same landscape at the same time given the same weather and treatments. Fire behavior and effects and habitat will be evaluated jointly. Revised prescriptions for landscape fuels treatments (such as DFPZs) will be drafted along with a defined set of potential weather scenarios. These prescriptions and scenarios will be used to update the base vegetation layer to a post-treatment condition. Then, the whole process is repeated, with emphasis on analysis of the results (figure 4, Appendix C).

Figure 4: PLAS Landscape Vegetation, Fire and Habitat Model Integration and Projection

Note: Vegetation, Fuels and Fire module diagram (left column) simplifed from Figure 4.



The net result of this collaborative effort will be an integrated analysis of the landscape-level effects of any potential fuels treatments and weather scenarios on both fire and owl habitat. We anticipate that other modules—Small Mammals and Songbird—may be able to develop habitat suitability analysis from vegetation layers that will enable them to integrate with this model, as well. As an interim step, we can probably crudely assess habitat of songbirds and small mammals using the California Wildlife Habitat Relationships system which links vegetation characteristics to the known habitat needs of different wildlife species. Eventually, empirical models derived from the research of the Songbird and Small Mammal Modules could supplant these coarser models.

Coordination with Interested Parties

We plan to work closely with Mark Finney, a fire-modeling expert in Missoula, Montana on FARSITE and FlamMap fire assessments. In addition, we anticipate close coordination with fire management offices at the Forest Service districts. In 2003, for example, we supplied forest structural data to the Plumas National Forest to use in its forest management planning.

Accomplishments in 2004

Field

In the summer of 2004, we put two field crew members—Randy Karels and James Graves—in the field with a part-time supervisor, Kurt Menning. The crew visited and inventoried 198 new plots in TUs 2 and 3. At each of these plots, the crew inventoried site conditions, fuel loads, and forest structure and composition, as per the methods described above. Combined with the 68 plots visited by the vegetation module crew, with which we coordinated on data collection in 2003, we have now collected data from 266 plots.

In addition to these core plot areas, additional data on fuel loads and forest structure are collected by the songbird module crews at their observation points. Each transect they run has twelve sites. At two of these observation sites the team collects plot data in a fashion similar to our module. At the other ten sites, the team rapidly assesses fuel loads using the fuel photo series (Blonski and Schramel 1993) and the LaFHA flowchart. These rapid assessments were conducted at 625 sites in 2004.

Initial analysis of the ladder fuel data from 240 field plots and 510 songbird observation sites (750 plots, 3000 total observations) are being analyzed. Initial analysis, before slope data are used to quantitatively modify the ratings, indicated that 17% of the observations were placed in the highest ladder fuel hazard category, 22% in the second, 25% in the third and 36% in the lowest. The best measure of these numbers will come first when the results are modeled to link them to fire behavior; and second, when the observations may be repeated after fuels treatments to gauge the reduction in ladder fuels.

Remote Sensing

In 2003, high-resolution IKONOS imagery was acquired for TUs 3 and 4. In 2004, we contracted the acquisition of this imagery covering TUs 2 and 3. The overlap in TU 3 will allow cross-calibration between the two years. TU 2 was added since that area has now been included in the core area of our analysis (TUs 2-4). Processing of this imagery is underway.

LANDSAT imagery, which does not require a special contract for acquisition, is available and will be purchased in 2005 for these areas covering the summer of 2004. These data will be processed during the 2005-2006 academic year.

Analytical

Much of the work to date has involved the transfer of data from datasheets and spreadsheets to databases. Raw field data, which come from discontinuous points on the ground, are processed and extrapolated across the landscape to form continuous coverages. These base layers are essential inputs to all fire and integrative habitat modeling efforts.

Goals for 2005

Field

In 2005, we plan to put another two-person field crew in place to continue sampling plots in TUs 2 through 4. We plan to add an additional 200 forest plots to the 266 already in place. The songbird module teams will be able to add more rapid observations of fuels at their sites, pushing the total of these sites well over 1000.

We hope to place one field crew supervisor at the site full-time during the summer. This individual would act as an on-site analyst, processing incoming data and developing base layers for the fire behavior and effects modeling. Whether we fill this position or not depends on availability of personnel.

Remote Sensing & Geographic Information Systems (GIS)

By this summer, we expect to have a fully-functioning GIS operational with our topographic data and remote sensing imagery. Integrating the processed imagery into the spatial database (GIS) is essential for completion of the base layers for modeling.

Whether we acquire new IKONOS imagery for the study area is dependent upon analysis of the existing imagery this spring. LANDSAT imagery will be acquired post-field season.

Analytical

Our primary analytical goal during the 2005 field season and following academic year is to finalize the base layers of fuels and vegetation for fire behavior and effects simulations in FARSITE and FlamMap. Once these layers are complete, and initial runs in the fire models have been completed, we can proceed with the initial integrated modeling runs with owl module. Key to this effort will be the processing of the remote imagery and performing the forest canopy spectral analysis that links our assessments of vegetation cover with the owl module's habitat analysis.

Additionally, we would like to find a setting in which we can begin testing and validating our LaFHA approach. We need to find an area—outside the study area—where prescribed fire is planned with potential escapes of flame into the canopy. Using the LaFHA method to assess ladder fuel hazards before fire and comparing the assessment with data on where fire actually reached the canopy can help us refine this model.

Expected Products (Deliverables)

Results will be published regularly in the Plumas-Lassen Administrative Study Annual Reports. We will present results directly, as they are derived, to interested parties. More formal scientific publications are targeted covering a variety of areas including the LaFHA approach being piloted in this study, SpECDA analyses of forest structure and its variability, fire behavior and effects, integrated model results with the Owl Module, and assessments of the efficiency of DFPZs and other treatments in moderating the landscape-level effects of fire. We plan to present initial results of the LaFHA approach at the Ecological Society of America meeting in August, 2005.

Data Management and Archiving

All data will be archived with the USDA Forest Service's Sierra Nevada Research Center (SNRC) in Davis, California, as well as the Fire Science Lab (Stephens Lab) at the University of California, Berkeley. Some derived products will be put on-line by the SNRC or Stephens Lab.

Appendix A1: Datasheet for field data collection, page 1 of 2

Plumas Veg Module — Data sheet

3/4/2004

Data for the whole plot / **50m radial plot**

Plot	Date						Habitat typ		Logs	
		UTM-E		UTM-N			Habitat typ		Snags <10	
		Aspect		Slope			Water Y/N		Snags 10-30	
		Recorders		Photo #			% Road		Snags >30	

Variable Radius (50m) Plot Species Tallies (panama angle gauge)

Species (live)											
Number stems											

50m Plot Layers + -->

	Herb (+seed) (<50cm)	Real Shrub (0.5-5m)	Small tree (Tree shrub)	All veg 0.5-5 (Tot. shrub)	Big tree (Tree)
%cover					
Low Bnd					
Low Bnd Sp					
Up Bnd					
Up Bnd Sp					
DBH min					
DBH min sp					
DBH max					
DBH max sp					

Species and their percent cover

Real shrub (0.5-5m) Species	% Cover	Small Trees (tree shrub, 0-5m) Size class	Species	% Cover
		Small Tree		
		(Tree Shr)		
		(<5m)		
			total	100%
		Big Tree		
		(Tree, >5m)		
total	100%		total	100%

12.6 m Radial Plot Fuels & Fire Risk Assessments

Fuel Photo Series		LaFHA			
Fuel size	Count	Quadrants	Haz. Rating	Min Cr Ht	Max Lad Gap
0-3"		N (1)			
3-9"		E (2)			
9-20"		S (3)			
>20"		W (4)			

Brown's Transects 12.6m

Tallies		1 hr (0-0.6cm)	10 hr (0.6-2.5)	100 (2.5-7.6)	Litter @ 5	Duff @ 5	Litter @ 12	Duff @ 12	max depth 1	max depth 2	max depth 3	Sight tube
A												
B = A+90												
A: 1000hr	Diam											
	Sound/Rot											
Shrubs	Species											
	Length											
	Ht class											
B: 1000hr	Diam											
	Sound/Rot											
Shrubs	Species											
	Length											
	Ht class											

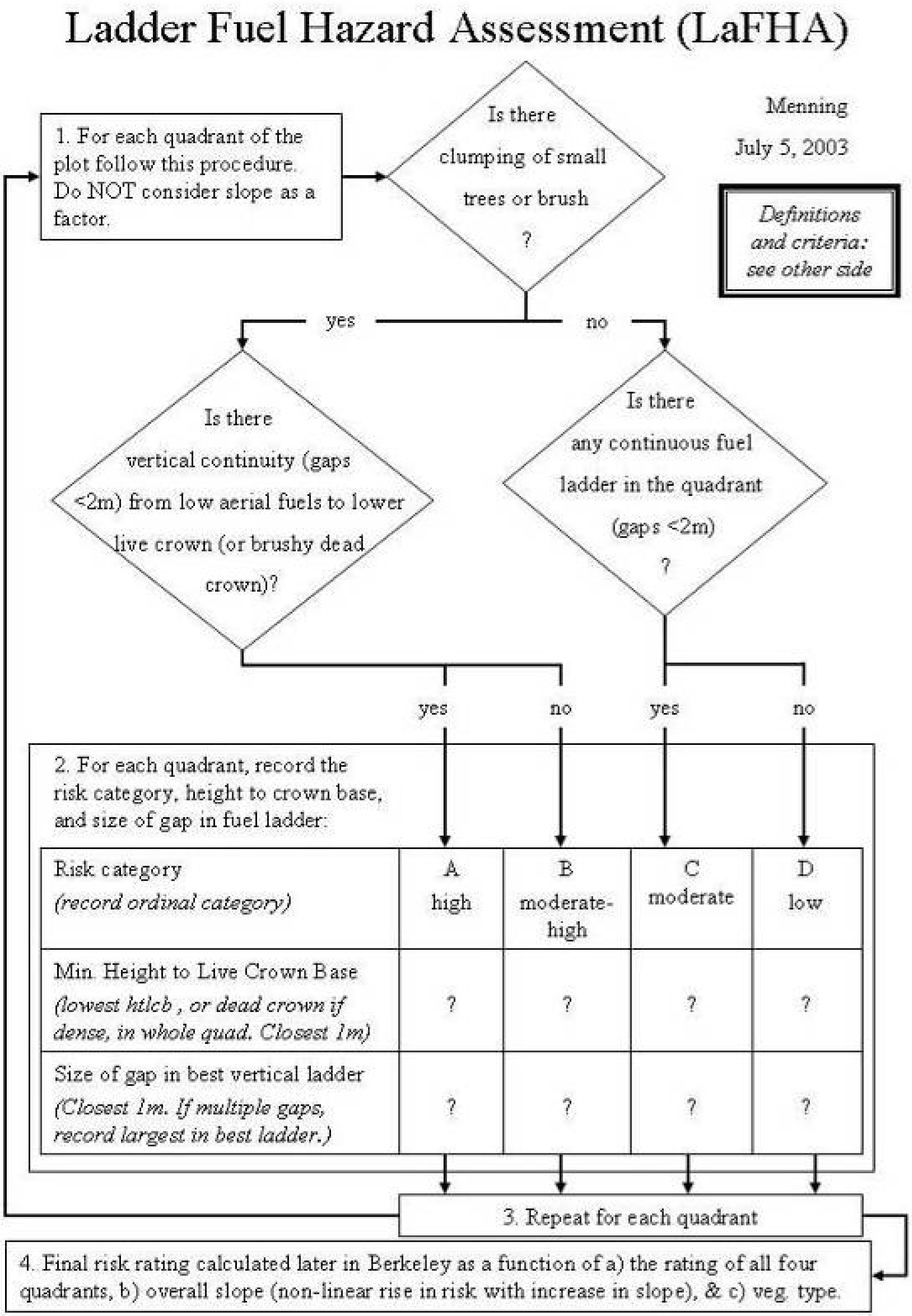
Appendix A1 (continued): Datasheet for field data collection, page 2 of 2

Sheet 2

Plot

Trees in 12.6m radius plot							Snags in 12.6m radius plot			
Species	DBH	Height	Ht. Low Cr.	Cr. Width	Shape	Mistletoe 0-6	DBH	Ht. Class	Decay class	Cav >10cm

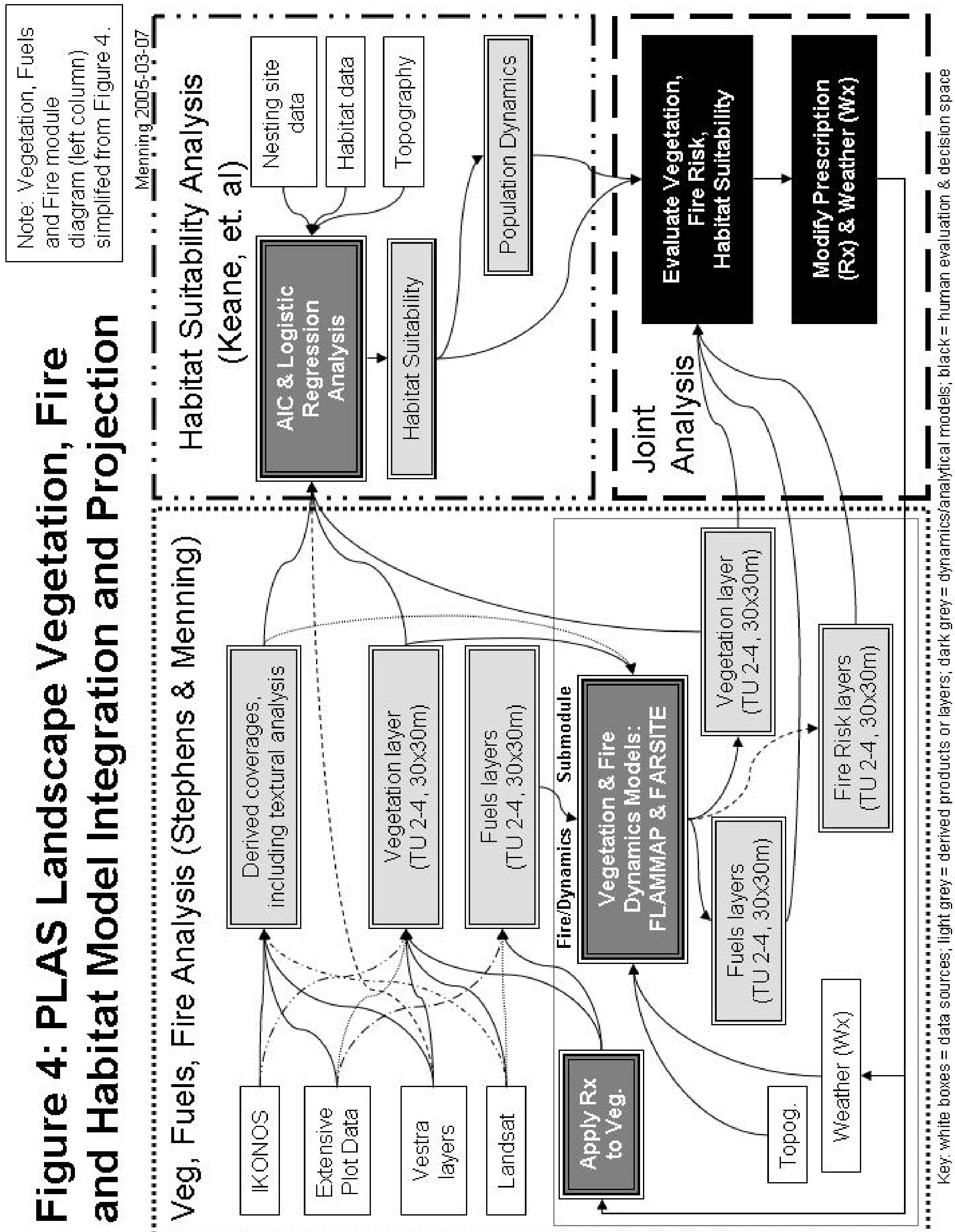
Appendix A2: Ladder Fuel Hazard Assessment (LaFHA)



Definitions

- **Division of plots**: Use a compass to quickly divide plots into four quadrants: northeast, southeast, southwest and northwest. Use trees for reference.
- **Clumping:** Brush or small trees covering an area of at least 4 square meters (2m x 2m) with gaps of less than 50cm. If it is particularly dense, or tall and brushy, a clump may cover a small area. A particularly dense clump may cover as little as 2m2 on the forest floor, for example. Branchy dead fuel or stems may be included in the assessment. Remember not to worry too much about definitions but to return to the question, "is this a dense clump of potential fuel?"
- **Risk categories** are given letters (A, B, C, and D) instead of numbers to prevent confusion: categories are not of interval or ratio quality ("Is category 4 twice as risky as category 2?" Probably not). Also, final ratings depend on additional information (see Step #4 at bottom of flowchart page).
- **HTLCB**: Height to live crown base: The live crown base is the lowest extent of the live canopy. Note: if the crowns of small trees are completely separate from the overhead canopy do not consider them. If they connect, or are close, do consider them.
- **Dead Crown** and when to consider it: Include dead branches in a tree's crown if they are particularly branchy or brushy. This will almost never happen in pines, but is common in white fir and Douglas-fir. If the branches radiate laterally and are well spaced (common with incense-cedar) do not consider them to be part of the ladder fuel matrix (live crown and brushy dead crown). In order to be considered part of a ladder, the branches should be dense and mostly vertical. Lichens, moss and needles increase the fuel hazard. Consider this in your assessment.
- **Ground and surface fuels**: do not adjust your assessment of the risk category by the presence or absence of ground or surface fuels (litter and duff with branches and cones mixed in). Consider only clumping and the presence of ladder fuels.
- **Canopy or No Canopy:** Consider only conifer and oak tree species as part of the canopy. Do not consider chaparral to have a canopy for this analysis. If there is no higher canopy, then record the gap as –99. This is important to distinguish from empty fields which may mean a datum was or was not recorded. A –99 value indicates that data were recorded and that the gap was infinite because there was no crown.

Appendix A3: Model integration with California Spotted Owl team (Keane)



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