Draft workplan: Learning how to apply adaptive management to land management in the Sierra Nevada.

Feb 20, 2006

1.0 INTRODUCTION

The goal of this research proposal is to learn how to use an adaptive management and monitoring system to understand ecosystem behavior, to incorporate stakeholder participation and thus to inform the implementation of adaptive management for Forest Service lands in the Sierra Nevada of California. Nearly a century of fire management in the Sierra has had the unintended consequence of placing millions of hectares of forest at risk of catastrophic fire (Biswell 1989, van Wagtendonk 1998). This regional assessment of fire hazard and fuel loads is reflected in the Sierra Nevada Forest Plan Amendment (SNFPA 2004) where modifying wildland fire behavior is a management priority. The preferred response is to apply strategic fuel management at the landscape level. The approach is based on the theoretical demonstration (Finney 2001) that disconnected fuel treatment patches that overlap in the direction of the head fire spread reduce the overall rate and intensity of the fire. Simulations have shown that with as little as 30% of the area in these strategically placed area treatments (SPLATs), fire risk can be decreased for the entire landscape. However, despite the sound theoretical underpinning of strategic fuel treatments, there is considerable uncertainty regarding their efficacy in modifying fire behavior and concerns regarding potential impacts on wildlife and water resources.Moreover given the history of debate over land and resource management in the Sierra Nevada, a lasting solution must engage stakeholders and promote active public participation in all phases of the process.

In February 2005, federal and state agencies responsible for the management of forest resources in California signed a Memorandum of Understanding (MOU 2005) in which the Parties agreed to take the first step toward development of a framework for cooperation among the Parties and other stakeholders. The initial goal is to design and apply a multiparty adaptive management and monitoring system consistent with the Sierra Nevada Forest Plan Amendment (SNFPA 2004). Toward this end, the University of California was invited to serve as a neutral third party with expertise in this area to assist the Forest Service with this goal.

The fundamental mission of the University of California (UC) is to conduct basic research, educate University students, and provide public outreach. Given this mission and the importance of the questions posed, we accepted the invitation in the Memorandum of Understanding (MOU 2005). Our charge was to develop an adaptive management and monitoring plan that informs and contributes to the improvement in implementation of land management practices, as prescribed in the Sierra Nevada Forest Plan Amendment. In this workplan, we describe a strategy to integrate stakeholder involvement with a research program to measure ecosystem responses to planned landscape prescriptions. To date, there is not enough information available to definitively assess the trade-offs implicit in this plan. Thus we propose to apply an adaptive management framework that describes how to collect and integrate information across scales, disciplines, and stakeholders in order to 1) create a synthetic understanding of forest ecosystem responses to the proposed treatments and 2) generate an inclusive appreciation of the inevitable trade-offs involved in forest management decisions. Critical to the success of this adaptive management endeavor is adequate funding and timely execution of the strategic fuels management as prescribed.

2.0 CONCEPTUAL FRAMEWORK

Adaptive Resource Management is an approach to management that acknowledges uncertainty about the resource to be managed and the need to learn (Walters 1986, 1993). This learning is produced by treating management as deliberate experimentation (Walters and Green 1997). Since the effects of any management activity are likely to be confounded by concurrent ecological and environmental changes, this confounding must be limited by the experimental design. The premise that adaptive management involves deliberate experimentation rather than a passive trial-and-error approach provides the first pillar of our conceptual foundation for this proposal.

Our second conceptual pillar is that adaptive management must be a participatory process that engages scientists, stakeholders, and managers in a long-term relationship grounded in shared learning about the ecosystem and society. This process not only includes assessing management actions but also evaluating the values and implicit assumptions that underlie management goals. We expect objectives to change as society, environment, and knowledge change (Tear et al. 2005).

In this model of adaptive management, the products from the monitoring process are used to inform further experiments or management initiatives (Lee 1999). Adaptive management brings monitoring into the experimental process, using monitoring of outcomes to refine ecosystem understanding in a systematic way. Thus experimental design is a crucial part of management and monitoring because it ensures that that outcomes are meaningful and provide feedback on a rigorous basis.

Adaptive management in the context of our aspirations for collaborative and participatory management inherently requires a way of gathering information and incorporating it into an integrated model of how the ecosystem works that, ultimately, is accessible to all participants (Box 1). It is our premise that grounding collaborative and participatory processes in a common body of knowledge about the area to be managed supports more effective decision-making. This approach provides for a common understanding of the dynamic behavior of ecosystems, and of the dramatic changes both long and short term that ecosystems have undergone.

Box 1. Steps in Adaptive Management

1. Determine current management goals.
2. Gather and synthesize existing knowledge to develop working model(s) about how the ecosystem works in order to make first approximation predictions of management outcomes.
3. Design and implement management in accordance with principles of experimentation.
4. Monitor and evaluate the results of the management action.
5. Incorporate what is learned into the working model of how the ecosystem works, basing future management on improved understanding of ecological processes.
6. Adjust management as indicated by results evaluation and re-assessment of project goals.
7. Begin the process again.

3.0 USFS MANAGEMENT PLAN

The record of decision regarding the Sierra Nevada Forest Plan Amendment (SNFPA 2004) adopts “an integrated vegetation management strategy with the primary objective of protecting communities and modifying landscape-scale fire behavior to reduce the size and severity of wildfires." Under the approved plan (Alternative S2, SNFPA), Forest Service managers will use thinning, salvage, and prescribed and natural fires to make forests less susceptible to severe wildfires, as well as invasive pests and diseases. While goals previously established for the conservation of old forest ecosystems and associated species would be retained, this plan also provides for other important elements, including the objectives of reducing stand density and regenerating shade intolerant species (SNFPA 2004).

An innovative aspect of this plan is an explicit landscape planning approach epitomized by an emphasis on fireshed assessments. Firesheds are large landscapes (1,000's of acres) delineated based on fire regime, condition class, fire history, fire hazard, and potential wildland fire behavior. Fireshed assessment is an interdisciplinary and collaborative process to achieve changes in fuels and vegetation at the landscape scale. Within the context of the Sierra Nevada Forest Plan Amendment, these changes include the strategic placement of treatment (SPLAT) areas across the landscape to interrupt potential wildland fire spread, to reduce the extent and severity of these fires, and to improve the continuity and distribution of old forests across landscapes (Bahro and Barber 2004). See attached illustrations from Bahro and Barber (2004) of fireshed delineation and SPLAT arrangement.

Our adaptive management plan is designed to address the uncertainties associated with the application of fireshed treatments. We have little experience by which to predict responses of wildlife, water, and forest health to the imposition of treatments distributed across 30% of a fireshed. Moreover, the concept of fireshed planning is new to the public. Thus an important goal is to learn how to engage stakeholders in this novel process to improve available information and to foster understanding and trust. As a team we are committed to an integrated, multimetric, adaptive management and monitoring plan. However, for project planning and management, we have identified four research themes: Fire and Forest Ecosystem Health, Participatory Processes, Water Quantity and Quality, and Wildlife. For each theme, we identify below the focal questions and our a priori expectations regarding the impact of the planned management regime.

4.0 FOCAL QUESTIONS

4.1 **Fire and Forest Ecosystem Health.**

The three main questions that we will address concern modification of fire behavior across a fireshed, tree morbidity and mortality patterns associated with treatment design, and secondary effects of SPLATs on forest health through insect interactions. We expect that the strategic fuel manipulations will modify fire behavior in the treated fireshed as predicted by Finney's (2001) model. That is, if area treatments are placed strategically, the spread rate and intensity of the fire over the entire area burned will likely be reduced (Finney 2003). In terms of tree morbidity and mortality across the fireshed, we expect that the management regime will improve tree growth and survival within the treated areas and the immediate edge environments. The removal of some fraction of the vegetation will reduce competitive stress on the remaining trees. However, the extent of improvements of tree health across the landscape will depend on the specific spatial arrangements of the treatments. More numerous smaller treatment areas laid out in more linear shapes will maximize the edge to interior ratios and thereby reduce the effective neighborhood density of more trees in the fireshed. At the local level, there may be

Figures from Bahro and Barber 2004.

Sample Products from Fireshed Assessment

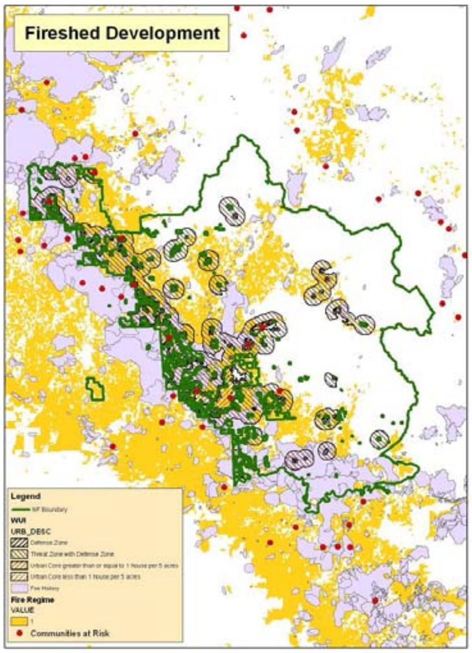

Figure 1. Fireshed delineation.

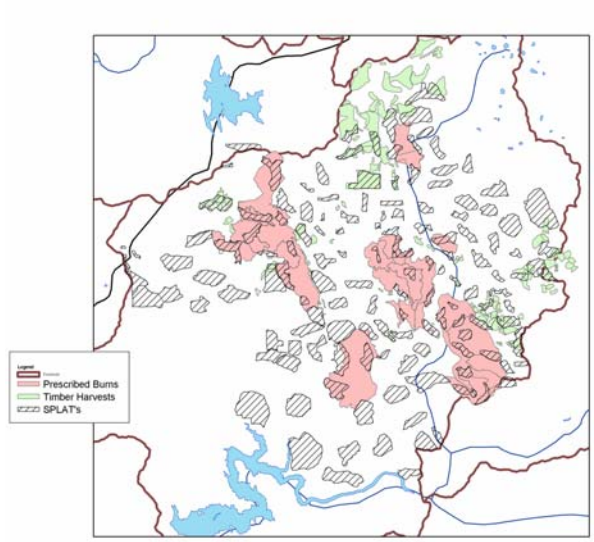

Figure 2. Treatment area opportunities.

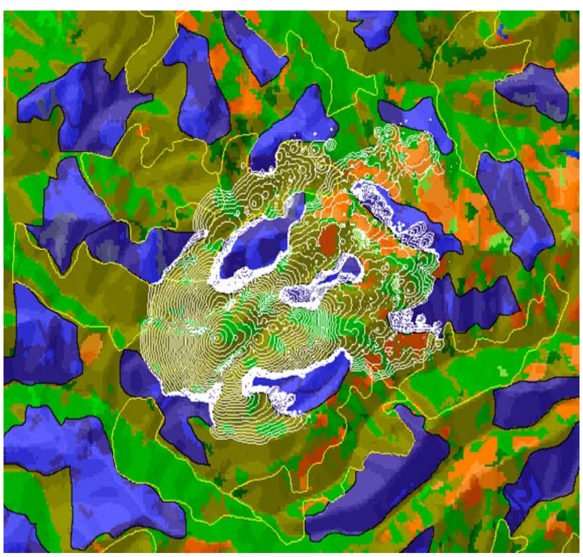

Figure 3. Potential wildland fire behavior in the treated landscape.

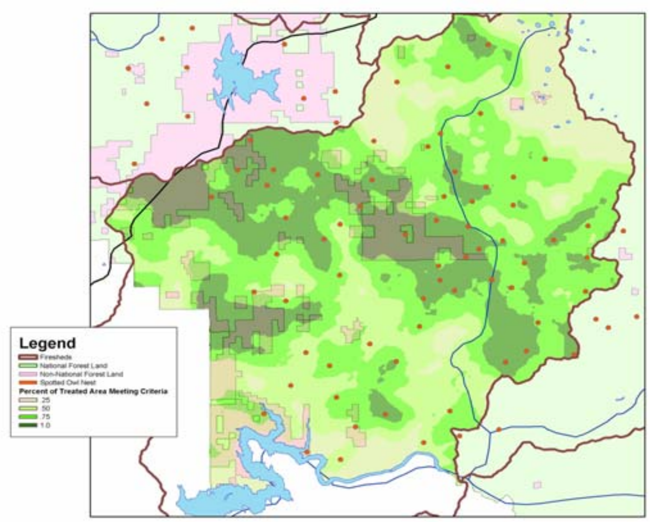

Figure 4. Focal mean analysis of California spotted owl habitat in the treated landscape.

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instances where insect interactions in the residual forest left after the creation of SPLATs have a negative effect on tree health. For example, if mechanical methods are used alone to reduce small tree density and the resultant activity fuels (i.e., slash) is left on site, it could provide habitat for *Ips* beetles to multiply. *Ips* beetles can seriously injure and kill trees under outbreak conditions. Alternatively, if prescribed fire is used to consume natural and activity fuels, we expect red turpentine beetles to attack residual pine trees (ponderosa, sugar, and Jeffrey pines). Such attacks may predispose these trees to the often lethal predation of mountain and western pine beetles. Our tree measurement and monitoring program is designed to capture both landscape and local impacts on tree health. This complexity related to issues of scale and ecological interactions further reinforces the need for a strong adaptive management program to reduce the uncertainty associated with SPLATs implementation.

4.2 **Participatory Processes**

How should an adaptive management process be structured to effectively engage stakeholders and what types of stakeholder participation best integrate their issues and expertise into the adaptive management process? A premise of the overall project is that a neutral third party, such as UC, can be helpful in this process. Thus far we have been working to develop the capacity for working with stakeholders among members of the science team and the MOU partners. As we proceed, we want to engage stakeholders in a program of mutual learning so that the values, knowledge, and needs of stakeholders will be part of research development, implementation, and interpretation. Part of this plan is to work with stakeholders in developing local histories for each site so that we establish common ground. We also want to test methods of stakeholder engagement. One method is the use of an interactive website and web-based tools. Another is public meetings. There are numerous additional methods of engaging stakeholders described in the literature, as well as numerous ways of measuring the success of stakeholder engagement. We will research the efficacy of two suites of methods from the risk communication literature, a "community of learning" and a "community of collaboration", at the study sites and develop measures of success by working with stakeholders, including the Forest Service. This research agenda will require personnel trained in facilitation and community collaboration. We are committed to transparent process, to stakeholder involvement as early as possible in the program, and to clarifying at each phase the places where stakeholders can have a significant impact on decisions.

4.3 **Water Quantity and Quality**

We expect that the catchment water cycles and the resulting stream water quality in Sierra Nevada forests will be directly affected by strategic fuel treatments in at least three ways. First, treatments may alter the partitioning of rain and snowmelt into runoff versus infiltration, affecting the timing and magnitude of both peak flows and the overall flow regime. This alteration is expected to be linked to canopy changes, which will affect interception, evapotranspiration and soil moisture. Second, changes in the water cycle may affect water quality through effects on erosion and sedimentation and through changes in biogeochemical and nutrient cycling. Third, these changes, plus soil disturbance from roads/tracks may affect terrestrial and aquatic flora and fauna, and the water resource serving downstream users. Effects of treatments on high flows vs. low flows vs. annual water yields may all differ in terms of magnitude, persistence, and relative impact to other resources. It is thus important to understand how different treatment strategies affect water quality (e.g. stream temperature, turbidity/sediment, dissolved oxygen), catchment water cycle (e.g. infiltration and soil moisture versus runoff and evapotranspiration), and ecological response (e.g. stream macroinvertebrates). In order to support an effective adaptive management plan for Sierra Nevada forests, information must be developed for representative areas and scaled across different hydroclimatic, physiographic, and forest regimes. Having a scaling strategy is important given the practical need to focus field measurements of treatment effects on the scale of a small headwater fireshed/watershed, versus the need to manage at the scales of a forest and bioregion. In this case, scaling refers to effects on lower-order catchments and streams throughout the forest rather than the cumulative effect on larger streams and catchments. Results should provide the basis for continuing operational assessments of how Framework treatments (SNFPA 2004) will impact streams, water cycle, water quality, and forest health.

4.4 **Wildlife**

What is the response of wildlife species dependent on old-forest conditions to changes in habitat structure and composition at multiple geographic scales? We expect that SPLATs will reduce the viability of sensitive species (e.g., fisher, goshawk, spotted owl, and marten). However, we remain uncertain as to the extent and persistence of these impacts. Thus it is important to quantify changes in vital rates and population growth trends to make informed decisions about the trade-offs between reducing fire risk and the viability of sensitive wildlife species.

5.0 RESEARCH DESIGN

As noted above, the challenge implicit in management as experimentation is to control for confounding influences (Walters and Green 1997). This control is particularly challenging when the experimental unit is a whole landscape (Hobbs 2003) and the inferential reference is an entire region. To meet our goal of providing credible scientific information (sensu Tear et al. 2005) we have identified three specific needs: 1) control for a host of ecosystem drivers in order to measure impact of SPLATs; 2) accommodate multiple measuring and monitoring objectives (e.g., fire behavior, fisher viability, water quality); 3) extend level of inference beyond research areas.

The management plan (SNFPA 2004) defines the experimental unit chosen for our study as a fireshed (Bahro and Barber 2004). While firesheds are a new concept, they share the scalability of watersheds in that large firesheds can be subdivided into smaller “catchment” firesheds. The largest experimental unit considered will be a fireshed on the order of 120 km^2 (30,000 acres) in size. We are focusing our efforts on the westside of the Sierra Nevada. In particular we are evaluating performance of strategic fuel reductions in relatively mature mixed conifer forests without a recent (last 50-100 years) major disturbance (e.g., natural fires, severe timber harvests). Regionwide these forests pose the greatest risk of catastrophic wildfire.

We cannot statistically sample the inherent heterogeneity present in firesheds throughout the Sierra Nevada. There are thousands of km^2 of potential study areas that span a large range of conditions (Table 1). A sufficiently large random sample, one that captures this heterogeneity, would prove prohibitively expensive. As a feasible alternative, we have decided to select two sites that represent the major biogeographic gradient in the Sierra Nevada. We will locate one site in the northern half of the Sierra Nevada and one in the southern half. Between these two sites, we will look for consistent responses to SPLATs. In collaboration with our MOU partners, we identified 11 criteria for selecting our research sites. These criteria were unranked and represent management and policy priorities of the MOU partner agencies as well as ecological criteria that support the objectives of this study (Table 2). Statistically, our goal in the final site selection was to choose sites that were not outliers with respect to key ecological and management parameters (Table 1). The treatments in our management experiments will be the implementation of strategic fuel reductions within a small fireshed as outlined in the SNFPA (2004) and as implemented by the National Forests. Thus we anticipate treatments in approximately 30% of a fireshed distributed as patches across the entire landscape (Bahro and Barber 2004).

To control for the potential confounding factors and to isolate the ecosystem impacts related to the forest management operation, we propose to use a Before After Control Impact (BACI) design. BACI compensates for the sparse replication (2 sites) and the non-random assignment of the treatments by providing robust longitudinal controls (Stewart-Oaten et al. 1986). BACI design defines two treatments, a control and an impact. In our case, we will subdivide our experimental unit into two subfiresheds. One subfireshed (on the order of 40 km^2 or 10,000 acres in size) will receive SPLATs and be defined as the impact site. The other subfireshed will be the control. Here we define control as a comparable subfireshed in terms of forest type, size, management history, fire history, and terrain features. Since these two sites are subfiresheds, they will also be in close spatial proximity. In terms of management, we expect that currently permitted use in the control fireshed will continue but there will be no major management intervention during the course of the study.

As Stewart-Oaten and Bence (2001) noted, the control site in the BACI design is not a true control but rather a measure of the existing natural variation in the ecosystem. The “before” measurements are crucial in that they provide a means to quantify the differences in ecosystem function between the control and impact sites NOT related to the management impact since these measurements occur before the imposition of any activity. We use the “after” measurements to estimate the effect of the management treatment at the impact site based on the divergence between the control and impact sites.

We propose a 2-2-1-2 schedule of research (total = 7-year research program). We plan and budget for 2 years of pre-treatment measurements. As described above, these before measurements are critical to the success of the research design. An optimistic estimate from forest managers is that the treatments would be implemented during the course of 2 years to be followed by 1 year of ecosystem recovery. Finally, we acquire 2 years of after measurements to measure the effect of the management activity. This research schedule will result in an intense initial effort as we establish baseline conditions (i.e., before measurements) and install sensor clusters (years 1 and 2); a period of reduced activity as we analyze/summarize baseline processes and monitor forest responses during SPLAT implementation (years 3, 4, and 5), and then another concentrated effort at the end (year 6 and 7) to quantify the trade-offs of the management regime in terms of public perception, fire and forest health, wildlife, and water quantity and quality.

In a recent paper, Johnson (2002b) argued for meta-replication. His view is that the best way to ensure credible results for management oriented research is to replicate the studies with different teams who make different sets of assumptions and use independent approaches. Holl et al. (2003) made a similar recommendation for studies on landscape restoration. They recommended a creative combination of data from multiple sources. The possibility for meta-replication already exists in the Sierra Nevada for several of the questions we are charged to address. The Pacific Southwest Research Station (PSW) and Forest Service have ongoing studies across the Sierra Nevada that are producing relevant information (for examples, see PSW Sierra Nevada Research Center 2006). There are also a number of participatory management programs being implemented in the Sierra. These opportunities for meta-replication present an excellent opportunity to extend the limited inferential implications for our two study sites to other sites in the Sierra Nevada.

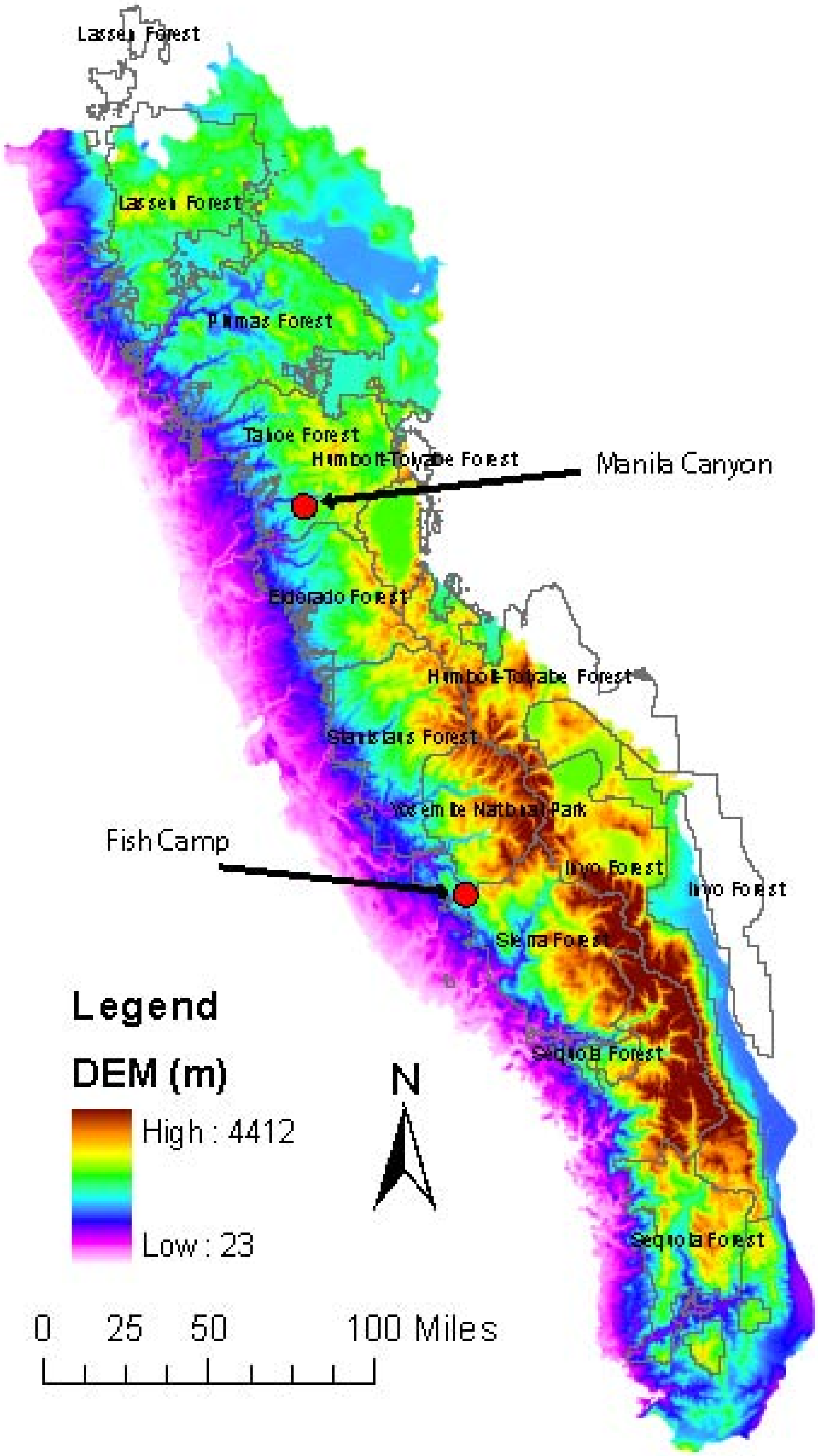
Given an acknowledged need for the UC Team to mesh their efforts with ongoing adaptive management and participatory processes research conducted by the Forest Service and PSW, we will make creating and pursuing opportunities for meta-replication a priority. One way to think about the challenge is that meta-replication approach is a pro-active form of meta-analysis. There may be design or analytical changes that can be made while the studies are ongoing to improve the ability to draw more general conclusions.

In our formal estimates of management impact we intend to take a likelihood approach to evaluating our results (Edwards 1992). Instead of the traditional hypothesis testing, we will measure the support in the data for our a priori expectations (i.e., models). An advantage of this approach is the greater relevance of the information gained by evaluating the effect size with estimates of uncertainty rather than a test of null hypotheses. For example, rather than testing the null hypothesis: Do SPLATs reduce the fire spread rates in the treated firesheds? We plan to report the difference in the rates of fire spread and quantify the uncertainty in these estimates. This approach is more conducive to an adaptive management framework (Johnson 2002b, Hobbs 2003, Bennett and Adams 2004). For cases where we have competing models to explain the observed responses, we will use information theoretics (e.g., Akaike's information criterion, AIC) to quantify the strength of evidence for alternative models (Burnham and Anderson 1998).

6.0 SITE DESCRIPTIONS

The site we are considering in the northern half of the Sierra Nevada is located in the upper Manila Canyon (39°10'31"N, 120°32'23" W) between the north and middle fork of American River in the Tahoe National Forest. The southern site is near Fish Camp (37°28'44" N, 119°38'19" W) in the upper Merced and Fresno River basins, in the Sierra National Forest (Figure 1). Both sites are accessible by forest roads. Other areas were screened, including in the Ruby area of the Tahoe National Forest, areas east of Blodgett Forest in the El Dorado National Forest, the Kings River Project in the Sierra National Forest, and Ponderosa area in the Sequoia National forest. Our process of site evaluations involved extensive consultation with Forest Service managers from all four National Forests. Manila Canyon and Fish Camp were identified

Figure 1. General location map of prospective research sites. Detailed maps are available at https://ucmeng.net/people/rbales/SNammp/Maps.



as areas where there was active planning for fuels management and adequate institutional capacity to implement the treatments in a timely fashion.

Two treatment projects are under planning in the Manila Canyon and Secret Canyon area, the Manila and Whiskey projects. Together they involve 10-15 km^2 (2,400-3,600 acres) of mechanical treatment with mastication, plus thinning by tractor and helicopter. Elevations are about 1,500-2,000 m in the areas proposed for treatment. There are at least 3 options for adjacent subfiresheds (similar to 1st-order CalWater watersheds) that could serve as treatment and control areas, each with areas on the order of 30-40 km^2 (7,500-10,000 acres). While there is some private land in the area, most is under Forest Service ownership.

The Fish Camp area is in the proposed Fresno River treatment project along the Highway 41 corridor south of Yosemite National Park. Near Fish Camp and Sugar Pine, elevations are in the 1,500-1,800 m range for areas proposed for treatment. A few km south, in the Cedervall area, treatment areas are in the 1,100-1,500 m elevation range. Together they involve 10-15 km^2 (2,400-3,600 acres) of area identified for treatment. There are multiple options for subfiresheds that could serve as treatment and control areas.

Based on existing spatial data, there is approximately 4,100 km^2 of potential study area (mixed conifer forests) in the Tahoe (westside only) and El Dorado National Forests. In the Sierra and Sequoia National Forests, the combined mixed conifer forest type covered 2,500 km^2. In regard to the selection criteria (Table 2), the Manila Canyon area meets at least 7 of the 11 criteria. The Fish Camp area meets at least 8 of the 11 criteria. The major difference between the sites is that Fish Camp includes more wildland urban interface in the fireshed while the Manila Canyon area is more remote. The results from our outlier analysis (Table 1) indicate that the candidate sites are within the range of variation present in their respective regions. In other words, they are not statistical outliers. The exception is the close proximity of Fish Camp to urban areas and its lower mean elevation (Table 1). It was intentionally chosen (selection criteria in Table 2) to include wildland urban interface.

7.0 SPECIFIC RESEARCH PLANS

7.1 **Fire and forest ecosystem health**

Both sites that we have selected for study have an accumulation of forest fuels that has created a severe risk of catastrophic wildfire. The primary goal of this component of the study is to evaluate the effectiveness of SPLATs in reducing potential fire behavior and improving forest health. Our approach is first to build a field-parameterized version of the fire behavior model, FARSITE, and simulate SPLAT fuel management designs. The performance of this management technique will be evaluated in terms of slowing fire spread and reducing fire intensity and subsequent tree mortality. The data needed to develop the map layers for FARSITE will be obtained from a network of geo-referenced field plots where we will measure the fire-relevant attributes of the vegetation and the surface fuels. Since these attributes are not only heterogeneous but also resistant to measurement by satellite remote sensing, we will explore innovative, efficient field methods for assessing fuel loads. For example, we have developed protocols to rapidly assess ladder fuel continuity and to estimate ground fuels. We also plan on

Table 1. Outlier analysis of top ranked candidate sites in the northern Sierra Nevada (Tahoe/El Dorado NF) and the southern Sierra Nevada (Sierra/Sequoia NF). Results based on GIS data layers provided by the USFS. For the quantitative variables (elevation, slope, and distance from urban areas), the means are reported with the standard deviation in parentheses. For the categorical variables, the top two ranked categories are reported followed by their fractional importance in parentheses. Majority categories are reported for the candidate sites.

Region Site	Elevation (m)	Slope (°)	Distance from urban area (km)	Aspect (N, E, S, W)		Canopy cover class (%)		Tree size distribution (size class)	
				1st Rank	2nd Rank	1st Rank	2nd Rank	1st Rank	2nd Rank
Tahoe/El Dorado National Forests	1511 (393)	5.5 (2.5)	21.4 (8.6)	W (0.36)	S (0.28)	>59 (0.40)	40-59 (0.30)	Small (0.44)	Medium (0.36)
Manila Canyon	1589 (260)	6.6 (3.6)	27.3 (3.5)	Majority: W		Majority: 40-59		Majority: Medium	
Sierra/Sequoia National Forests	2007 (311)	8.1 (3.3)	31.6 (12.9)	W (0.31)	S (0.27)	>59 (0.42)	40-59 (0.24)	Small (0.70)	Medium (0.17)
Fish Camp	1368 (316)	6.2 (2.8)	5.9 (3.1)	Majority: W		Majority: 40-59		Majority: Small	

Table 2. Criteria for site selection and evaluation of candidate sites with regard to these criteria. Note criteria were unranked.

Criteria	Manila Canyon (northern)	Fish Camp (southern)
Old forest habitat for species at risk	Yes	Yes
Potential for recruiting large tree structure	Yes	Yes
Proximity to wildland urban interface	No	Yes
Adjacent to significant amounts of private land eligible for State grants	Yes	Potential
Large enough to support fireshed scale research	Yes	Yes
Representative of typical Sierran landscape (i.e., not outliers)	Yes (see Table 2)	Yes (see Table 2)
Sufficient organizational capacity of National Forest to implement treatments	Yes	Yes
Presence of existing data/studies/infrastructure	Spotted owl study; Nearby watershed studies	Limited
History of land and resource management agencies involving community interest in forest management	To be determined	To be determined
Potential for positive and detectable changes leading to desired forest conditions	Yes	Yes
Costs of development and implementation of treatments	More remote; potentially more expensive	Yes. Extensive infrastructure available

linking intensive, field-based, forest and fuel inventory techniques to remotely sensed data to allow us to populate the needed GIS data layers to perform the SPLAT simulations. We will repeat the field measurements and fire behavior analysis after the treatments have been completed. The differences in modeled fire behavior between the control and treated firesheds will provide the necessary information to quantify the efficacy of the SPLAT approach.

This module will be integrated with the water module by providing tree canopy cover and bare mineral soil exposure (percent) on a 30 x 30-m GIS grid after simulated wildfires for the entire area of interest. This information will be used in estimating perturbations to the hydrologic cycle after wildfires. We will use archived ignition locations for the last 25 years to determine where "simulated" wildfires will begin. Eightieth, 90th, and 97.5th percentile fire weather, representing moderate, severe, and extreme fire weather conditions, will be computed from archived data from RAW's weather stations located near the study sites (http://www.wrcc.dri.edu). This fire weather information will include maximum and minimum temperatures and humidity's, wind speeds, wind direction, 1, 10, and 100-hour fuel moistures, and herbaceous and live woody fuel moistures that will be used in the wildfire simulations. Linkages to the wildlife component of this study will occur by providing pre and post simulated wildfire effects on forest canopy cover, large woody debris, tree structure, and ground fuels on the 30 x 30 m grid. Linkages to the social component of this study will occur as we learn how the public perceives and reacts to one of the first implementations of a SPLAT strategy in any forested ecosystem. Input from stakeholders on what are the most important characteristics to determine the effects of SPLATs on potential fire behavior and forest health is also encouraged.

The increased fire risk in the Sierra Nevada is related to fundamental changes in the structure and composition of the mixed conifer forest. As a result of relative increases in the density of shade-tolerant tree species (mostly white fir and to a lesser extent incense cedar), the forest is more homogeneous in terms of species distribution (Ansley and Battles 1998, Roy and Vankat 1999). Also, net increases in understory tree density have been reported in the literature (Kilgore 1973, Parsons and DeBenedetti 1979, Ansley and Battles 1998) and noted on forest health assessments conducted by the USFS. As a result, many trees are experiencing increased competition for resources that in turn reduces the vigor of individual trees. Under these circumstances, forest pests and pathogens spread faster and with more virulence (Maloney and Rizzo 2002). The biological-driven feedback between competition and predation further acerbates hazardous fuel conditions by creating a large cohort of dead and dying stems. These changes have raised concerns about potential for increases in tree morbidity and mortality.

Radial stem growth in trees has proven to be a reliable indicator of mortality risk (e.g., Pacala et al. 1996). Typically, growth-mortality functions are based on the most recent five years of growth (Kobe et al. 1995, Wycoff and Clark 2000). However, recent work has documented a relationship between longer term growth characteristics and tree decline, including lifetime growth rates, long term growth trends, and abrupt changes in growth (Pedersen 1998; Cherubini et al. 2002; Suarez et al. 2004). Das et al. (In review) have demonstrated that incorporating these additional growth characteristics significantly improves the predictions of mortality for white fir and sugar pine trees in the Sierran mixed conifer forests. For example, internal validations of the growth mortality models had a correct classification rate of 81.6% for white fir and 81.6% for sugar pine.

These validated growth-mortality models can be used to develop robust forest-wide assessments of health for target species. For every tree sampled, a probability of mortality can be predicted. These predictions are then summarized in vulnerability profiles. These vulnerability profiles provide a general measure of tree vigor in the target population.

Reducing understory tree density is one of the objectives of the strategic fuel modifications. Thus there will be areas in the fireshed were density is locally reduced. Our expectation is that reductions in tree density will lead to increases in growth and thus increase tree survivability. However, we are less certain of the impact beyond the borders of the treated areas. The implementation of SPLATs across the landscape will create a substantial amount of edge areas. Thus it is critical to know the extent of the impact of the individual SPLAT into the surrounding untreated forest.

We propose to use white fir and sugar pine as indicator species of tree health in the experimental firesheds. These two species represent the gradient in life-history strategies employed by the dominant tree species in the mixed conifer forests. White fir is a shade-tolerant, fire-sensitive species while sugar pine is less shade-tolerant but more resistant to fire damage (Burns and Honkala 1990). We will use stratified random sampling within the firesheds with the strata initially defined by areas in and out of SPLATs to gather an unbiased sample of trees. We will collect samples before treatments are imposed (years 1 and 2) and after the treatments are in place (years 6 and 7). To estimate the probability of mortality, we extract an increment core near the base of the tree and measure the relevant growth parameters. We will construct vulnerability profiles by species and strata and then compare the changes in the distributions that occur with the treatments. We also will collect comparable data from the control watershed to measure changes in tree mortality not associated with the management activity. Given the size of the firesheds, we anticipate sampling 250 trees per species and strata. These trees will be tagged and geolocated so they can be resampled after the treatments are in place. We will also monitor the firesheds during the field sampling for evidence of major pest and pathogen occurrence.

The collection and processing of tree cores provides an exceptional educational and public participation opportunity. With minimal training and supervision, the community can help collect the cores. Immediate inspection of the cores provides an insight into the growth history of the individual tree. Comparing just a few cores will illustrate the variability among trees in a firesheds. Events in the core (e.g., low growth due to drought, high growth due to death of neighbor) tangibly demonstrate the processes that effect the growth and survival of trees and thus help to build the necessary common understanding of how these ecosystems function.

We will supplement this detailed tree vulnerability approach with a mortality assessment based on remotely sensed images of the entire fireshed. Before treatments, the team plans to obtain a set of high-resolution satellite-based photographs. A recent application in the tropics (Clark et al. 2005) has demonstrated the potential of using remotely sensed images to measure tree mortality across large regions. We will develop this approach for the challenges of conifer dominated forests. Our field based plots and vulnerability trees will provide the necessary ground-truthing to refine the detection routines. With a second, post-treatment set of images, we will be able to measure changes in the magnitude and distribution of tree mortality across the fireshed and relate any changes to the intensity and proximity of fuel modifications areas.

7.2 **Participatory Processes**

Throughout the planning process, our work in participatory processes has been informed by research indicating that efforts at improving risk communication and community relations must come from within an organization as a whole (Chess et al. 1994). Organizational learning should occur at different levels, so the UC team operating as a neutral third party (MOU 2005), has facilitated this learning within the UC Team and MOU Partners, as well as with those participating community stakeholders. We propose to build a program that will offer improved communication options to the agencies and build environmental credibility by defining, testing, and measuring the participatory process as it proceeds.

Using comparative case studies, we will develop and evaluate methodologies that have been understudied in the risk communication field (Chess et al. 1995). We plan to compare the impact of two suites of participatory adaptive management approaches. One suite will center on a ‘community of learning’ approach that emphasizes engaging stakeholders in learning about the tradeoffs of each management option, and the other on a ‘community of collaboration’ approach that emphasizes the shared expertise of all participants. These approaches rely on different models of risk communication, but both are equally expected to achieve some degree of success in the case study areas. Seven tasks are involved in the participatory process research.

Defining a participatory adaptive management model. Recent studies have suggested that adaptive management provides a useful framework for engaging stakeholder participation because of its emphasis on deliberate experimentation, potential for incorporating stakeholder knowledge, and flexibility in responding to changes in goals and knowledge (McDaniels and Gregory 2002; Clark 2002). Among the potential benefits of investing in public participation as a part of the adaptive management process in the Sierra Nevada are: the opportunity to meet the public’s increased expectation for having a voice in governance (Allen 1998; Baldassare 1994; Bishop and Davis 2002); the opportunity to foster relationships that will endure beyond the specific project focused on (Shindler and Cheek 1999); increased ownership and satisfaction with the outcomes of the adaptive management process (Margerum 1999; Shindler & Cheek 1999); increased trust of the managing agencies among the affected publics (Shindler & Cheek, 1999); an

Box 2. Essential factors for participatory adaptive management model

1. Stakeholders should be involved as early as possible in the process and information should be developed drawing on stakeholder knowledge and ideas. Part of this involvement will be development of local histories for each site.
2. A spectrum of people, including those not usually at the table, should be involved.
3. A transparent process should be maintained.
4. Competing interests should be recognized and acknowledged.
5. Tradeoffs should be identified, and stakeholders should understand the consequences of different decisions.
6. The information needs of participants should be established early. Scientific information should be provided in ways that enable stakeholder participation and build credibility by presenting a balanced view of management options.
7. The adaptive management framework should encourage scientists, managers, and stakeholders to work together.
8. Feedback to scientists and managers should be provided.
9. Feedback should be used, so there has to be enough flexibility for meaningful input. If feedback is not used, an explanation should be provided.

established tendency to move towards collaboration and engagement in place of conflict (Innes & Booher 1999); and improved bio/physical outcomes (Selin, Schuett & Carr 2000).

Adaptive management incorporates stakeholder participation in order to improve the amount and breadth of information for decision-making and to make higher quality decisions. We realize that participation takes time, and does not necessarily reduce conflict, but successful participation should create meaningful engagement and build mutual understanding, learning, and trust. Based on previous research (Arvai et al. 2004) and experience, we posit that nine factors are essential to a successful model (Box 2).

Facilitating researcher, stakeholder, and public meetings. Using a collaborative process the UC Team has developed a workplan that includes general agreement between the UC researchers and MOU partners, and incorporates preliminary public input. This process has involved numerous researcher meetings, two MOU partner meetings, one public meeting with more than 50 people in attendance, weekly UC researcher and MOU partner phone conferences, and interviews with key informants and interested parties. Meeting notes have been posted on the public website. The goal was to build MOU Partner and UC Team commitment to the collaborative process, and we saw an increase in meeting attendance over the course of the workplan development phase as well as many agreements on operating principles and the scientific focus of the research. We plan to continue this collaborative approach.

Development of Interactive Website. This adaptive management effort must address the challenge of how dynamic communities with changing needs, aspirations, and technologies can maintain a non-destructive relationship (Geyer 1994, Meredith et al. 2002). Any adaptive process that tackles this challenge will require the sharing and discussion of information about the human and natural components of the system being managed (Walters and Holling 1990; Haklay 2003).

We seek to answer the question: Can web-based tools help facilitate public participation in a natural resource adaptive management setting? Specifically, we want to incorporate place-based data access and content acquisition into the comment and response dialogue. A geographically enabled web-based commenting system can greatly enhance the public's ability to participate in the development of spatially relevant policy. The ability to easily incorporate maps depicting topics of discussion can help participants visualize the locations and scenarios under debate. The inclusion of spatial data used in the formation of policy, such as ecological or fire modeling results, will allow stakeholders to see precisely how the policy under discussion might affect their specific locations of concern. Additionally, a web-based map can be the interface to a commenting system. Instead of a traditional bulletin board-like interface, where each comment follows another in a chronological list and discussion threads are divided by subject matter, a spatial interface organizes discussions geographically. A user starts by viewing a map with icons indicating locations under discussion, then clicks on a location to view all the discussion threads relating to that place. In addition, mixed media (maps, photos, and comments) can be uploaded and linked to specific locations.

Developing tools to gather new information, optimize the use of available information, and ensure that all parties can effectively participate in the decision-making process are critical components of a natural resource adaptive management process (Meredith et al. 2002). Modern tools such as Internet message boarding, "counter-mapping" and Geographic Information Systems (GIS) have been used often separately as information gathering and sharing tools (Aberley 1993; Leitner et al. 2002; Sieber 2002; Crampton and Stewart 2004); and the combination of these tools, often called webGIS, are also increasingly being used for public participation and community monitoring. WebGIS systems, a hybrid of GIS and Internet technologies, are a promising option for entering and storing heterogeneous datasets, indexed by location, and making them widely available in a visual, dynamic, and interactive format (Kearns et al. 2003).

If successful, these tools can be replicated and scaled-up to meet the needs of a larger clientele and stakeholder group. Success will be evaluated using annual stakeholder surveys to determine how the Internet-GIS component of the public participation compares to the range of other participation options. The incorporation of the interactive website into a suite of collaborative opportunities helps broaden the range and modes of participation of various stakeholders and ensures that review notes and progress updates are easily accessible to a broad public.

Establish UC Cooperative Extension in collaborative management positions. In order to have the full participation of UC in the implementation and facilitation of a participatory adaptive management process, we propose creating two UC Extension Specialist positions, one for each case study area, that will: (a) conduct, coordinate, and participate in research on participatory methods, (b) work with researchers and stakeholders to facilitate stakeholder participation in research, monitoring, and interpretation of results, (c) make sure stakeholder input and feedback is incorporated into the adaptive management process, and (d) increase opportunities for local stakeholders to engage with the process.

Case study research approach. Researchers investigating collaborative processes in natural resource management have conducted numerous case studies over the last decade, yet attempts to introduce a more "experimental" approach are rare (Arvai et al. 2004) because of a lack of opportunities and resources to conduct simultaneous processes in similar communities. This adaptive management project offers an opportunity to introduce more controls than are usually possible into the study of collaborative processes. Because the program will implement the same forest management strategies at the same time in two different areas of the Sierra Nevada, it is possible to compare approaches and responses. We propose to implement two models of participatory adaptive management in the communities surrounding the two study areas. While distinctly different approaches are proposed, both are informed by the best science available, and both are equally expected to lead to success. Selection of the specific approaches used in each suite will be done, in part, by the publics to be engaged in the process, thereby facilitating their ownership of the final approach. In addition, communities at both case study areas will have access to the interactive web program and regional-level public meetings of the type already implemented in development of this workplan. The transparent decision-making process will avoid issues of social exclusion (Barnes, Newman, Knops & Sullivan 2003; Cleaver 1999). The two collaborative approaches are outlined by Arvai et al. (2004):

First will be the information-based community or the '**community of learning**'**.** In this study area we will employ a suite of approaches that focus on illuminating the scientific and technical information underlying the adaptive management process. As a community of learners (Brown and Camione 1994), participants will explore underlying assumptions, tradeoffs, and knowledge gaps, as well as management choices developed by the UC Science Team and MOU partners (Lawson, 1985; Eliason, 1996; Arambula-Greenfield, 1997). Through this effort the engaged publics are expected to gain a rich understanding of the adaptive management process, the decisions underlying it, and the values implicit in management choices. This model is especially useful where decisions are driven by factors external to the engaged community. It works from the assumption that engaging the community will have many benefits including informed advocacy, an environment of trust, increased capacity to share information between the community and the involved agencies in the future, and improved understanding of and satisfaction with the management approaches taken.

Second will be the '**community of collaboration**'. The focus of these approaches will be engaging community members as experts in their own right (Fisher 1993). Treatment of lay knowledge as holding significant value in risk-related decisions underlies this approach and will incorporate local understandings of environment (Eden 1996; Kerr, Cunningham-Burely & Amos 1998) into the decision-making process. Key to this approach is the expectation that community members will be contributors of innovative ideas, novel aspects of analysis, and new bits of information not otherwise available through other processes (Beierle & Cayford, 2002). From the outset, attention is given to learning the scientific, technical, and value-based aspects of the decisions being made to ensure that input is not from a position of being 'ill-informed' (James & Blamey 1999). Critical reflections methods (Mezirow et al, 1990; Heath, 1999), that provide 1) a process to connect the development of scientific knowledge with expert knowledge from a community, and 2) a way to match a communities' readiness to address complex ecological themes with the current scientific issues and data (Heath, 1999) might be included in this approach.

To compare the effectiveness of these two approaches, they will be evaluated with measures that gauge both process and outcome, i.e. 'indicators of success'. Among those measures we intend to include: 1) all engaged parties' satisfaction with the process, 2) the perceived fairness of the process, 3) overall trust and confidence in the agencies held by the 'engaged' publics in the two communities as well as trust and confidence in the specific management approaches utilized under SPLAT (Beierle 1998; Halvorsen 2003), 4) perceived levels of risk both to the ecosystem and to the communities (Beierle 1998), 5) ability to move forward with treatments even if all aspects of the treatments are not fully approved of or agreed upon by all parties (Halvorsen 2003), 6) the creation of networks and relationships (social capital), and 7) indicators developed by stakeholders, including number and type of appeals to the Forest Plan. We will also draw on categories of evaluation proposed by Arvai et al. (2003) that allow researchers to determine which components of the process need revision or improvement. These measures will be a central focus of our early work with both communities, and both communities will have input into the selection of final measures to be used.

7.3 **Water quality and quantity**

The Sierra Nevada Framework identifies at least nine water issues of concern that motivated development of this component of the research plan (SNFPA 2004, Box 3). Within this context, we expect the proposed fuel management treatments to have a measurable impact on at least six key features of the forest water cycle and associated aquatic ecosystems:

1. Treatment will alter soil moisture patterns in the areas treated, with effects dropping off in riparian areas and in untreated forest, and potentially in drier areas.
2. Treatment will affect the timing, duration, and magnitude of rainstorm and snowmelt flow in headwater streams. These responses will be linked to changes in soil moisture patterns, to canopy attenuation of rainfall/snowmelt, and to changes in the surface energy balance after thinning.
3. Stream turbidity and transport of suspended material will increase following treatment, but effects will diminish with subsequent runoff events. These effects will be reflected in stream macroinvertebrates.
4. Treatments will have a small, positive effect on summer stream baseflow, depending in part on proximity of treatments to streams; the first fall storms may induce a greater response in streamflow. These responses will be linked to changes in soil moisture and evapotranspiration.
5. Effects of treatments will be more significant in first and second order streams that drain treated headwater catchments (up to a few km^2) and will have modest, if any, effects on higher order streams that drain a mix of treated and untreated area.
6. In the context of the physiographic and hydroclimatic regimes, it will be possible to define thresholds linking area treated with both aquatic effects and impacts on the forest water cycle.

Box 3. Water issues identified in SNFPA

Water quality: Clean Water Act & Safe Drinking Water Act
Species viability: habitat, native & invasive species
Plant & animal community diversity: riparian areas, wetlands & meadows
Special habitats: Maintain & restore special aquatic habitats
Watershed connectivity: within and between watersheds
Floodplains & water tables: connections to distribute flood flows & sustain habitats
Watershed condition: infiltration characteristics, vegetative cover & stream flows
Streamflow patterns & sediment regimes: in-stream flows, sediment regimes, conditions of riparian, aquatic, wetland & meadow habitats
Stream banks & shorelines: physical structure & condition of stream banks & shorelines

Research will consist of intensive field measurements in areas subject to treatment, data analysis, modeling to interpret observed watershed response, and spatial scaling to estimate responses across larger areas.

Field measurements and interpretation. Each of the four field study sites (two each, treatment and control) will include an instrument cluster within the study fireshed. Working with the fire and forest ecosystem health science team members, we will develop complementary, and if possible coincident, definitions for firesheds and watersheds in each of the study areas. For measuring stream impacts it will be important to choose areas where the entire watershed (fireshed) drains to a stream. Thus we expect to locate on higher order streams. In each of the two forests one instrument cluster will be in a catchment subject to treatment and the second in an untreated control catchment. As noted in section 5.0, this sampling regime provides both a before and after set of measurements and a parallel control set of measurements. Each instrument cluster will have about a 1-km^2 footprint, will include a stream reach, and will consist of both aquatic and terrestrial measurements. It is desirable to choose a response reach of the stream, one that is not too steep and is subject to sediment deposition and scour.

Autonomous stream water quality measurements will include stream stage, temperature, electrical conductivity, and turbidity. A single, self-logging instrument package (Seabird SBE 52-MP) provides the first three. We will also evaluate continuous measurement of dissolved oxygen. For these continuous measurements we will choose a stream section with shallow bedrock so that most of the water flow is in the stream rather than subsurface. If feasible, we will install a control section (weir or flume) in the stream to enable making more accurate discharge measurements for both the higher flow events and the smallest flows. Otherwise, stream stage will be related to discharge by developing a site-specific rating curve. Temperature and electrical conductivity, together with discharge, will provide indications of stream response to runoff events, and facilitate inter-site comparisons. Measurable responses for turbidity will most likely be limited to periods during and immediately after storms, with interstorm periods having values below the detection limit.

Stream macroinvertebrates will be measured bi-annually at multiple sections along the response reach, following protocols in use in the Sierra Nevada (e.g. Herbst and Kane, 2005). The biological integrity of stream environments can be estimated from an enumeration of the inhabitant organisms. Aquatic insects and other invertebrates are central to the functioning of stream ecosystems, consuming organic matter and algae, and providing food to fish and birds. Invertebrates also tolerate disturbance to varying degrees and integrate the impacts of disturbance. Their community composition can indicate water quality and habitat conditions. Monitoring relative to reference sites (having little or no impact but similar physical setting), and over time, permits impact problems to be estimated (Rosenberg and Resh 1993, Davis and Simon 1995, Karr and Chu 1999).

Sediment scour and deposition will be measured in the same reaches using autonomous, continuously recording scour pans (Hamblen, 2003; Hamblen et al., in preparation) set into the bed of the stream. These will be limited to reaches with small-grained sediments in their beds and relatively flat slopes. A second indication of sediment scour and deposition will come from seasonal surveys of the stream profile and bed material (Bunte and Abt, 2001). These latter data will link well with existing operational measurements by the Sierra Nevada Forests. Erosion will be measured by selecting a sensitive reach – “a reach that is likely to show change that relates to the monitoring objective and is uniform in terms of channel and valley form characteristics” (USFS Region 5 SCI Protocol) of 100-200 m in length. In this sensitive reach, a detailed longitudinal profile, riffle and pool cross sections, and Wolman particle size distribution measurements will be taken (we propose to count more than 100 particles, as per Bunte and Abt, 2001). The longitudinal profile and cross sections will show erosion related changes in channel-form and bed-form due to scour and deposition. The particle size distribution will measure embeddedness of the channel substrate, and show changes in the deposition of fine particles associated with erosion. These measurements will be done multiple times during the year, with the goal of showing change due to precipitation and snowmelt patterns, and will be conducted before and after treatments.

We will evaluate two ways of measuring hillslope erosion. However, it is expected that a large rain/runoff event will be needed to elicit a measurable response. First, erosion pins will be placed across a hillside to measure the soil loss over the site. Alternatively, silt fences installed along the contour of a hillslope will collect eroded material and measure the amount of soil transported off the hillside (e.g. Benavides-Solorio, J. and L. H. MacDonald, 2005). These measurements will need to be done several times a year (in response to precipitation pattern variations – i.e. thunderstorms vs. snowmelt). In more rain-dominated areas, sediment fences will be cleaned out following large storms in order to get sediment production on a storm basis rather than annually; this will help generate and test more useful predictive models.

Soil moisture response to the stream will be measured using an embedded sensor network, which is a single “instrument” consisting of 10-15 nodes distributed over the landscape (Rice et al., 2005). These nodes will be placed to capture the physiographic and canopy variability across the site (Bales et al., submitted). Each node will be equipped with 3 levels of soil moisture/temperature (Decagon and Watermark), snow depth (Judd Communications), solar radiation, temperature, and relative humidity (built into wireless pods). A weather station providing precipitation, wind, and long-wave radiation will be integrated into each cluster. All measurements will be continuous over the study period, with each cluster being self logging (Bales et al., 2005). By using autonomous instruments, we can limit field visits to short visits for routine maintenance and downloading of data, and periodic visits for making sediment measurements. We also propose to add telemetry to the instruments, which will provide a real-time indication of operation and problems. Three options that have been used in other locations in the Sierra Nevada will be evaluated once sites are selected: 1) telemetry via Forest Service radio, 2) GOES satellite link, and 3) cellular phone link (ground or satellite).

Modeling and scaling of watershed response. Results from the hillslope-to-catchment scale field sites, supplemented with other ongoing measurements in the region, will be scaled up to the larger watershed and forest scales in order to evaluate the broader impacts of treatments. As most effects of treatments will be more significant in higher-order than lower-order streams it is planned to focus most hydrologic and water-quality modeling on headwater catchments on the order of 1 km^2. Effects of treatments on water yield will be investigated at larger watershed scales, based on responses measured at the smaller scales, and using hydrologic models explicitly designed to use satellite remote sensing and other spatial inputs (Dressler et al., 2006; Molotch et al., 2004).

Spatial data. Each of the science teams will require detailed maps of the study area in order to understand processes at the site scale, and to upscale results to the forest scale in order to evaluate the broader impacts of treatments. Because spatial variability of vegetation and terrain features greatly influences forest health, wildlife habitat, water cycling, and fire behavior over a range of scales, we plan to extract the topography and vegetation information from numerous available existing and remotely sensed geodatasets augmented with field measures acquired using GPS, leaf area meters, and laser rangefinders. First, we propose to acquire high-resolution remote sensing images (e.g. IKONOS) and LiDAR data to map in detail the vegetation and topography of the sites, the change of the crown closure, and leaf area index before and after the treatments. Those spatial data will aid in the better understanding of spatial relationships between canopy and forest characteristics with habitat, fire, and hydrologic responses (e.g. soil moisture and thus stream response). We also plan on scaling up these relationships from the catchment to the forest level using coarser resolution remotely sensed imagery (e.g. Landsat TM) and topography (e.g. NextMap Radar product at 5-m spatial resolution).

Public participation. The interested public can participate in the water research either through participation in field measurements or use of data and information produced from the research (or both). Over the past ten years, under the international GLOBE program (www.globe.gov) we have directly engaged dozens of schools in making water quality measurements, including aquatic macroinvertebrates, and have supported measurement protocols and quality control for thousands of more schools. We have also published papers using volunteer (GLOBE) data (Morrill et al., 2005). We will continue to engage volunteer groups under this project. We plan to make our data available via the internet, as described below, including analyses of results. Another aspect will be stakeholder partnerships. Since our data should also be of interest to water managers and other groups, we will pursue leveraging and partnerships to enhance the data and track field measurements.

7.4 **Wildlife**

Criteria for refining wildlife question. With unlimited financial resources we would argue for detailed monitoring of vital rates of each of the over 400 terrestrial vertebrates occurring in the Sierra Nevada bioregion as a fundamental component of good resource management. However, given that the cost of monitoring just the presence-absence of all terrestrial vertebrate wildlife, not to mention aquatic and invertebrate wildlife, would be beyond any conceivable budget available, the first decision must be to prioritize the species to be studied. Hence, we support Multiple Species Inventory and Monitoring (Manley et al. 2005) in general. However, a primary goal of adaptive management is to focus monitoring and research effort on one or a few critical topics. Prioritization is a difficult but critical first step determining *why* funds will be spent on monitoring and research (Walters 1986, Hanley 1994, Tear et al. 2005).

We used the following criteria to prioritize the wildlife species to be studied in this adaptive management program: 1) The species has a history of impeding forest management activities because of insufficient knowledge of its ecology, resulting in a lack of public trust in the Forest Service's ability to insure its viability during and after forest manipulations; 2) The species is suspected of responding negatively to the proposed forest management practices; 3) The species must be present in detectable numbers in at least one study area; and 4) The species is expected to exhibit a relatively high “signal-to-noise-ratio” in that its negative response will be detectable despite considerable natural variability due to weather and other environmental factors unrelated to forest manipulations.

Prioritization. We considered two approaches to systematically review all 427 native vertebrate species that currently occur or previously occurred prior to European colonization of the Sierra Nevada bioregion. The first approach was that used by the Forest Service for its first Sierra Nevada Framework EIS (2001, Volume 4, Appendix R-1). Specific criteria used in this analysis emphasized extinction risk and included population size, population trend, and range change. The reliability of this information was not considered. Forty-two species were classified as “high vulnerability" species, including six species now likely to be extinct. Twenty-one of the high vulnerability species depend on riparian, meadow, or aquatic habitats that are important but quite restricted in their distribution, and therefore less likely to be directly affected by strategic fuel management. Thirteen of the high vulnerability species are dependent on western foothill (hardwood) environments, and therefore also less likely to be affected by management activity in mixed conifer stands. Only the fisher (*Martes pennanti*) was considered a high vulnerability species dependent on late seral (dense canopy) conifer forest habitat. Thus, this approach clearly places the fisher at the top of the priority list for this adaptive management program because the fisher also satisfies all of the remaining criteria listed above. We note that this approach would list the following moderate vulnerability species in decreasing priority: northern goshawk (*Accipiter gentilis*), spotted owl (*Strix occidentalis*), marten (*Martes americana*), and northern flying squirrel (*Glaucomys sabrinus*).

The second approach to prioritizing species used the California Wildlife Habitat Relationships (CWHR) System (Airola 1988, Mayer and Laudenslayer 1988). The CWHR System was developed as a result of a Memorandum of Understanding signed in 1980 by all state and federal agencies with responsibilities for wildlife or wildlife habitat in California. It is now maintained by the California Department of Fish and Game. It represents the "best available science" as it is kept up to date based on published research. We queried the CWHR database (Version 8.0) to consider the relative response of wildlife to a change in forest structure from a dense (>60% canopy closure), small tree (quadratic mean diameter at breast height 11-24 in) Sierra Mixed Conifer (SMC 4D) stand to an open cover (25-39% canopy closure), medium/large tree (quadratic mean diameter >24 in) stand (SMC 5P). We focused on Sierra Mixed Conifer Habitat because this type is consistent with the focus of the study (see section 5.0 RESEARCH DESIGN). This approach indicates that of the 221 species potentially inhabiting Sierra Mixed Conifer Habitat in the Sierra bioregion, 121 (55%) would find habitat value increased, 65 (29%) would find habitat value unchanged, and 35 (16%) would find habitat value decreased. Of the later group, only the fisher and marten would find generally suitable habitat decreased to a low suitability, suggesting that the manipulated habitat would become a "sink" for these species. That is, the low quality habitat may allow individuals to survive there, but reproduction would not be sufficient to maintain population size without immigration from neighboring "source" habitat (i.e., habitat rated moderate to high suitability). Northern goshawk and spotted owl would be expected to have reduced habitat quality, but not to the extent indicated for fisher.

The results of both these approaches are similar in that the fisher is clearly the most important species for consideration in any adaptive management program that includes a wildlife species in its monitoring scheme. Therefore, the fisher should receive first priority. If additional funds are available, the northern goshawk and the spotted owl should be considered. Unfortunately, the influx of barred owls may cause such disruption to the spotted owl that it could be difficult or impossible to disentangle the effects of this factor from those of habitat modification (Olson 2005).

Monitoring of any of these species (fisher, goshawk, spotted owl, marten) must involve radiotelemetry of all individuals and detailed vital rate analysis since their large home ranges and low density will allow for only a few individuals in any one 30,000-acre study area. No other wildlife species is likely to be as negatively affected by the proposed SPLAT program.

Consequently, if these species are found to be viable in the treated regions, it is unlikely any other species will be eliminated or seriously impacted.

The fisher currently occurs only in the southern Sierra, but historically did occur in the northern Sierra, and could be reintroduced there. Of the sites being considered for study (see section 6.0 SITE DESCRIPTIONS), the fisher is present only in the southern site while the current ranges of the northern goshawk, spotted owl, and marten include both the northern and southern research areas.

Quantifying wildlife response. In an active adaptive management context (Walters and Holling 1990, Lancia et al. 1996), we recommend that the primary wildlife question to be evaluated is that the fisher population in the treatment area will exhibit decreased viability over time as measured by population trend, reproductive performance, survival, and dispersal success as a result of lowered habitat quality. It is essential to go beyond presence-absence monitoring to determine the factor limiting a population (Schlaepfer et al. 2002). If funds allow, the same hypothesis can be applied to the northern goshawk, spotted owl, and marten.

It has been suggested that "wildlife" might be represented in this adaptive management system by species richness or simply by a guild of species indicative of open (thinned) forest. The CWHR analysis described above makes it clear that from a "biodiversity" perspective one can expect more species to respond favorably than not to the proposed treatment. We submit that simply documenting that some species will respond favorably will not solve the management dilemma we are attempting to resolve. The Forest Service is finding itself hampered by public opinion and legal impediments because of a lack of knowledge about certain species that are hypothesized to respond unfavorably to proposed forest manipulations. Not focusing this adaptive management program on a solution to this issue will not solve the current management dilemma.

Initial drafts of two types of models will be constructed prior to field work. First, a fisher habitat relationships model will be applied to each study area to provide testable predictions as to the likely distribution of animal activity. Second, a fisher population dynamics model will be used to suggest a range of likely population trajectories given possible values for population size, reproduction, and age/sex-specific survival/dispersal. The field monitoring will test predictions and allow refinement of the vital rate estimates and their variability with season, year, and habitat condition.

The rationale and basic approach to monitoring any of the four top priority species is similar; therefore, only the fisher methodology will be described in detail. Because there will be so few individual fisher inhabiting any study area, all individuals must be monitored. One can expect about 5 fisher (1 male, 4 females) per 40 km^2 (10,000 acres) of suitable habitat. Thus, the issue of statistical inference for point estimates about the local population does not arise.

We want to make it clear that we support the continued monitoring of presence-absence of fisher and other carnivores throughout the Sierra (Zielinski and Stauffer 1996, Zielinski et al. 2005). Presence-absence data are necessary to detect major changes in the range of these species, but they are insufficient to inform us as to which environmental factors are limiting a population (Stanley and Royle 2005, Vojta 2005).

The entire population in each study area will be monitored. As noted above, we expect to find about five adult fishers per subfireshed. The only feasible way to ensure that all individuals in the study area are monitored daily is to carry out an intensive, year-round, radio-telemetry study (Braun 2005). This will necessitate initial and periodic live-trapping of all members of the population in the study area, and maintaining radio tags on each individual. Radios are likely to remain effective for only 8-10 months; therefore live-trapping must occur at least twice a year. Each tagged individual must be located daily to ensure that the cause of death can be determined if and when mortality occurs. With this intensity of monitoring, reproductive success will be relatively easy to detect. Video camera traps will be used to monitor den sites. Dispersal can also be monitored with this approach assuming aerial support is available. Detecting mortality, quickly locating the carcass, and carrying out a detailed necropsy will be the most difficult but most essential activities.

A radio-telemetry study of this intensity will require at least three teams of two field technicians plus a light plane and pilot on call. With two study areas, we will require a total of six pairs of technicians. A full-time pilot must be able to cover both study areas. Monitoring should be continuous for five to ten years to produce useable results because of the likely high annual variation in vital rates due to weather patterns. This is even more essential for an introduced population.

We take this opportunity to point out that the most elegant and straightforward scientific test for the fisher is to carry out a reintroduction program in a region with SPLATs (to the standards set by many successful fisher reintroductions), and monitor its success in detail. If it is successful, then the issue of how to manage Sierra Mixed Conifer habitat for fisher is resolved, plus we are closer to our goal of rejoining the southern Sierra population with that in northwestern California. If it is not successful, then we should know why as a result of monitoring the causes of death. For example, if fishers are lost to goshawks in open timber stands we might conclude that thinning was too extensive. If fishers are lost to illegal trapping or road kills we might conclude thinning is not the problem.

The interested public can participate in wildlife research in several ways. Incidental observations of species of concern can be provided to researchers using an interactive web site. Selected individuals willing to volunteer for intensive training and substantial time commitments can assist in camera trapping, live trapping, and radio-tracking subject animals. Individuals with special expertise such as veterinarians and aircraft pilots may be able to volunteer for certain jobs.

8.0 PROJECT MANAGEMENT AND ADMINISTRATION

The Center for Forestry at UC Berkeley will be the lead administrative unit for the Sierra Nevada Adaptive Management and Monitoring program. The Center will be responsible for the financial and logistical coordination of the program. Members of the UC Research Team have agreed to communicate results with one voice. Thus the goal for the team is to reach a consensus assessment of the impacts of the prescribed management regime. Uncertainties associated with these impacts will be identified and, to the best of our ability, quantified. If consensus cannot be reached, we will present the competing arguments and their supporting evidence. Project planning and decision making will be the responsibility of the PI and executive committee, involving Co-PI's representing the four research areas.

Field data, spatial data, and other project data will be made available to team members via the Internet, using an existing digital library modified to accept and serve data and metadata from this project. Our goal is to have share data within the team as soon as it is available on our computers, i.e. both raw and processed data. We will make processed data available outside the team in as timely a manner as possible, following basic quality control.

We propose a reporting schedule that includes quarterly updates and annual reports. These updates and reports will be written to make them as relevant as possible to the management questions. As is our practice, these updates and reports will be made available to all parties. We will invite public review and comment with our responses organized and presented in the subsequent communication. In conjunction with the summaries provided by the UC Research Team, groups of researchers will prepare their findings for the peer-reviewed academic literature. In short, we hope to build the organizational infrastructure that improves upon the "strategy of hope" (Rogers 1998) by making reliable scientific information relevant to the challenges faced by managers.

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