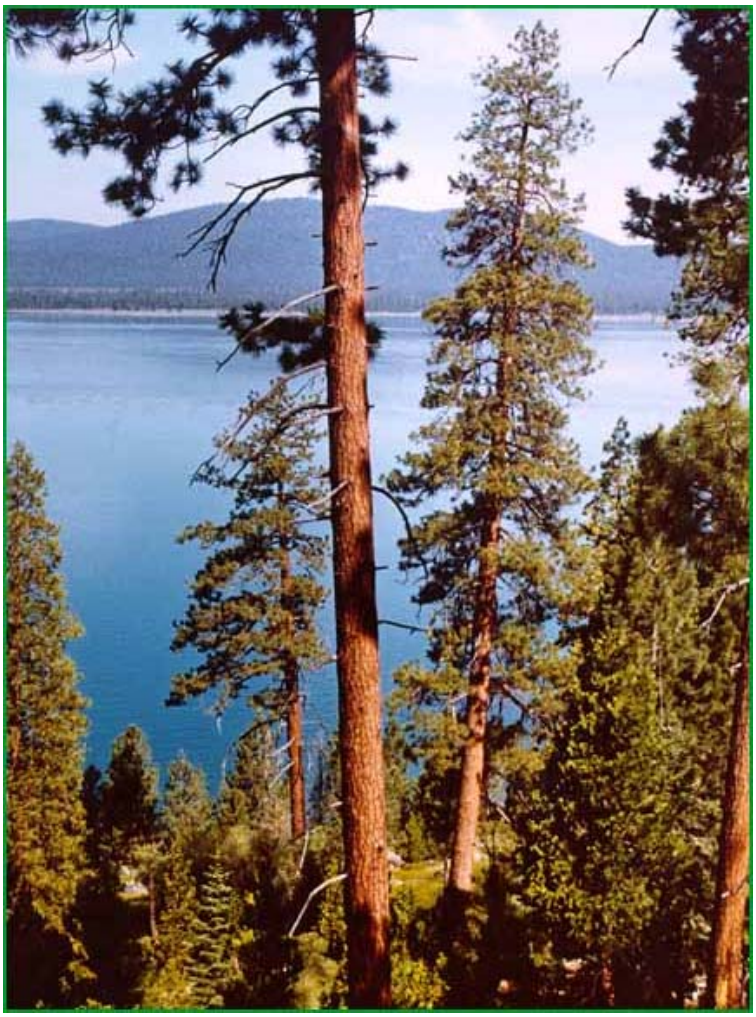
Risk and Uncertainty in Management of the Sierra Nevada National Forests



October 9, 2003

http://gunston.doit.gmu.edu/snfpa_risk/

Risk and Uncertainty in Management of the Sierra Nevada National Forests

Report

submitted to

Jack Blackwell, Regional Forester
USDA Forest Service, Pacific Southwest Region

By

Lawrence C. Walters, Ph. D.
Peter J. Balint, Ph. D.*
Anand Desai, Ph. D.
Ronald E. Stewart, Ph. D.

With research assistance from

Beena Chundevalel
Yija Jing
Nancy Kanbar
Melissa Milne
David E. Phillips

*Corresponding author: Peter Balint, pbalint@gmu.edu
Mailing address: 4400 University Drive, MSN 3F4, Fairfax, VA 22030
Website: http://gunston.doit.gmu.edu/snfpa_risk/

ABOUT THE AUTHORS

Lawrence C. Walters, Ph.D., is Associate Professor and Director of the MPA Program in the Department of Public and International Affairs at George Mason University.

Peter J. Balint, Ph.D., is Assistant Professor with a joint appointment in the Department of Public and International Affairs and the Department of Environmental Science and Policy at George Mason University.

Anand Desai, Ph.D., is Associate Professor in the School of Public Policy and Management at The Ohio State University.

Ronald E. Stewart, Ph.D., is Visiting Associate Professor and Graduate Coordinator in the Department of Environmental Science and Policy at George Mason University.

Beena Chundevalel, Nancy Kanbar, Melissa Milne, and David Phillips are graduate students at George Mason University, and Yija Jing is a graduate student at The Ohio State University.

TABLE OF CONTENTS

INTRODUCTION

This report presents results of the activities of the risk and uncertainty panel. The charge to the panel was to inform the Regional Forester, and others interested in the management of the Sierra Nevada national forests, about the nature of decision-making in a policy environment characterized by multiple and conflicting risks and uncertainties.

In our work, we reviewed the relevant academic and professional literature and offered three workshops for participants in the Sierra Nevada decision process—two for external stakeholders and one for the Interagency Team. At the workshops, we provided information on risk and uncertainty and conducted two exercises to elicit participant preferences with regard to policy choices and outcomes in the Sierra Nevada case. Using this review of the literature and insights gained from the workshops, we evaluated the treatment and communication of risk and uncertainty in the Sierra Nevada Forest Plan Amendment (SNFPA) process. Our assessment, carried out in conjunction with the Regional Forester's review of the January 2001 Final Environmental Impact Statement (FEIS) and Record of Decision (ROD), covered both the development of the 2001 ROD and the review process up through the time we held our workshops in March 2003.

This summary report includes:

1. **A characterization of the decision problem facing the Pacific Southwest Region in the Sierra Nevada planning process.**
2. **A discussion of our findings, including:**
    a. **a consideration of uncertainty, risk, and risk communication in the Sierra Nevada management problem, and our assessment that the decision dilemma in the Sierra Nevada case is a "wicked" problem;**
    b. **a review of approaches to addressing wicked problems: including the precautionary principle, adaptive management, and participatory policy analysis;**
    c. **an evaluation of the use of the precautionary principle, adaptive management, and public participation in the SNFPA process to date; and**
    d. **a summary of results from our work to elicit stakeholder attitudes and preferences.**
3. **A set of design considerations for incorporating risk, uncertainty and stakeholder preferences into future planning for the Sierra Nevada national forests.**

THE NATURE OF THE SIERRA NEVADA MANAGEMENT DECISION PROBLEM

In characterizing the decision environment the Forest Service faces in the Sierra Nevada case, we find three main drivers influencing forest ecosystems over time. These are (1) external human factors, associated with both neighboring communities and the broader interested public; (2) natural events and processes largely beyond the control of the agency—including for example

lightning strikes, droughts, plant community succession, and long-term climatic changes; and (3) Forest Service management strategies and practices (Figure 1).

These three inputs affect ecological conditions in the field. These ecological effects are then translated into outcomes, such as wildfire acres burned, old-growth habitat gained or lost, and timber volume produced. In turn, these ecological effects and outcomes, both observed and projected, influence stakeholder acceptance of and reaction to Forest Service management activities. But stakeholders do and will evaluate Forest Service management decisions on factors other than ecological outcomes. Whether because of uncertainty, lack of trust, or some other reason, stakeholders also scrutinize and evaluate the Forest Service based on the management choices made and the processes used to arrive at those choices.

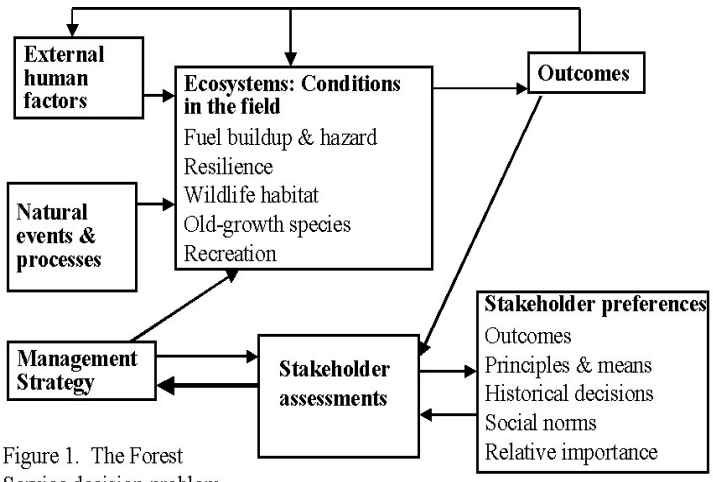


Figure 1. The Forest Service decision problem

In addition to holding varying preferences regarding processes and outcomes, stakeholders diverge in their understanding of—and aversion to or tolerance for—the range of risks and uncertainties associated with forest management in the Sierra Nevada case. Stakeholders, acting on their preferences and levels of risk aversion or tolerance, influence the Forest Service's management strategies and practices through various mechanisms. These include participating in public meetings and other opportunities for public comment, bringing political influence to bear, and initiating formal appeals and legal challenges.

FINDINGS SECTION I: A Consideration of Uncertainty and Risk in the Sierra Nevada Case

Regarding uncertainty and risk as they apply to the Sierra Nevada case, we find that:

1. Uncertainty is a neutral analytical property of an event, relationship, phenomenon, or other important consideration that may be reduced through better science, but generally cannot be eliminated.
2. Defining risk is fundamentally an expression of the values of those framing the decision problem.
3. The important short-term risks facing the Forest Service are related to decision processes, not ecological outcomes.
4. Communicating risk and uncertainty to stakeholders generally occurs in the form of one-way or two-way communication activities, but recent literature suggests that more participatory forms of risk communication may often be necessary.
5. The Sierra Nevada management decision is a wicked problem.

Discussion

1. **Uncertainty is a neutral analytical property of an event, relationship, phenomenon, or other important consideration that may be reduced through better science, but generally cannot be eliminated.**

In this context, we mean by uncertainty the likelihood of the occurrence of an event, relationship, phenomenon, or other important consideration. This likelihood of occurrence may be unknown, or may have a distribution of possible values, but it is not under the immediate control of Forest Service decision makers. In describing uncertainty as value neutral, we wish to highlight two important points:

- Uncertainty is used to describe probabilistic events, whether or not it is possible to quantify those probabilities. For example, the distribution of naturally occurring fire events may be calculable and therefore the probability of fire during a specific time interval estimable. The likelihood of important budget changes as a result of shifts in national public policy priorities during the next 50 years may not be estimable. In both cases, however, "uncertain" is the analytical term used to describe the events.
- Uncertainty does not inherently involve a value position on the part of the analyst or decision maker. The probability of a lightning strike, for example, is independent of attitudes toward fire hazard, owl habitat, or any other value position. In this sense, uncertainty is a neutral concept.

There are three broad categories of uncertainty in the decision context facing the Forest Service: scientific, administrative (or implementation), and stochastic.

To say that something is *scientifically uncertain* within the context of the Sierra Nevada decision problem is to acknowledge that forests are complex systems and that our knowledge of them is incomplete. As a result, no one can state with certainty the long-term outcome of any given management strategy, including maintaining the status quo. Examples of key areas of scientific uncertainty include:

- the acreages of old-growth forest and old-growth forest habitat determined under the various alternatives as projected by vegetation models;
- the population of old-growth dependent species associated with these projected acreages and the resulting probabilities of viability as projected by the California Wildlife Habitat Relations Model and viability models; and
- the annual or decadal acreages burned and severity of burn as projected by such models as FLAMMAP, SPECTRUM, and FARSITE.

Scientific uncertainty is often expressed as a calculated or estimated confidence interval around a predicted value or outcome.

Administrative or implementation uncertainty refers to the vagaries of managing in a political environment in which public goals and priorities, societal needs and conditions, and organizational capacities change over time. Finally, *stochastic uncertainty* refers to those events that are largely random, unpredictable, and uncontrollable, such as lightning-caused ignitions or random changes in species populations.

Each of the factors identified in Figure 1 above is associated with specific uncertainties. In addition, the assessment of outcomes by stakeholders also involves uncertainties, as stakeholder perceptions, values, and priorities may shift over time. Some examples of the multiple uncertainties in this decision are presented in Table 1.

Table 1: Uncertainties in the Sierra Nevada management decision

	Scientific	**Administrative or Implementation**	**Stochastic**
Ecosystem	-Representativeness of sample inventory.	-Sampling and inventory implementation.	-Measurement error in the initial inventory.
Natural events and processes	-Climate change.	-Lack of access to affected areas. -Lack of understanding of the interaction between administrative action and naturally occurring stressors.	-Number, size, and location of ignition events. -Drought conditions and related disease and insect-produced stresses.
External human factors	-Incidence of invasive species.	-Adjacent development in surrounding areas.	-Changing societal needs and priorities.
Management or strategic	-Externalities (e.g., air quality, economic impacts). -Long-term effects.	-Funding levels and timing. -Institutional capacity (e.g., data, models, expertise, organization). -Public perceptions.	-Short-term resource availability (e.g., firefighters from other jurisdictions).
Stakeholder assessment	-Understanding of scientific explanations and logic.	-Representativeness of stakeholder groups. -Desired and minimum acceptable outcome levels and the relative importance of each. -Stability of stakeholder preferences over time. -Willingness of stakeholders to compromise.	-Changing societal needs and priorities.

Obviously, there is much that is uncertain and largely uncontrollable in this decision environment. While it is true that some uncertainties can be reduced over time through better science and organizational learning, many if not most uncertainties cannot be eliminated altogether.

The uncertainty dilemma

In describing and representing the scientific and stochastic uncertainties inherent in the Sierra Nevada management decision, analysts face a dilemma. On one hand, simple and accessible characterizations of the multiple uncertainties are likely to be misleading, biased, or wrong. One example may serve to make this point. Recent graphs generated by the SNFPA Review Team depict likely outcome trajectories of different management strategies over the next 140 years as lines. Objections were raised that such depictions may be misleading because they suggest that these trajectories are or can be known with certainty, or at the very least that depicted differences are real and meaningful. Those objecting argued that confidence intervals should be placed around each line, and that doing so would likely show that depicted differences in expected

outcomes are significantly more uncertain than the initial graphs suggest. Whether or not the objection is valid, the point remains that lack of detail was seen to be at least misleading, likely biased, and perhaps even wrong.

But the alternative poses its own challenges. Detailed characterizations of uncertainty are likely to be difficult to understand and present, and consequently may not be useful to the public or to decision makers. There is no scientific or technical solution for this dilemma. The resolution focuses on the decision processes employed. To be effective, such processes must tightly integrate analysis and broader deliberation, and should allow all participants to understand where scientists agree, where they disagree, and where their relative certainty ends (Stern and Fineberg 1996).

2. **Defining risk is fundamentally an expression of the values of those framing the decision problem.**

Risk is a concept with a long pedigree in a variety of disciplines, but in virtually all technical discussions, risk is represented as having three components:

- one or more potential stressors (sometimes called hazards);
- a probability that these stressors will occur (often called exposure); and
- the likely adverse effect that will result if the stressors do occur.

It is common to compare risks based on the product of the magnitude of the loss that will occur and the probability of its occurrence. Such calculations are referred to as "expected values." In one recent example produced by the National Academy of Public Administration (Fairbanks, Gardner et al. 2001), the NAPA panel finds that many federal risk assessment methods consider mostly the magnitude of hazards. The panel argues that it is necessary to develop methods that clearly include all three components of risk:

- *Hazard*: e.g., an area's fuel loading and dryness conditions;
- *Risk or exposure*: e.g., the probability of ignition; and
- *Value*: e.g., the physical, social, and economic costs of the potential damage.

An important observation regarding the role of value judgments in assessing risk is also made by Slovic (2000) and is incorporated in a recent study by the National Research Council (NRC) (Stern and Fineberg 1996). In any characterization of risk, these studies argue, two critical value judgments are at least implicit. First, there is the judgment that a particular process or outcome merits serious attention. The decision to focus on wildland fire hazards or old-forest owl habitat, rather than, say, the economic vitality of adjacent communities or the potential harms to black oaks, is a value judgment made by key actors. Because of the influence of those key actors, one set of values prevails in characterizing the risks in a given decision. Other actors at different times could have made, and have made, different judgments.

Second, there is the judgment about what constitutes an unacceptable level on the outcome dimension. To say that some number of acres of stand-destroying fires is unacceptable reflects again the values of the decision makers. Between these two judgments, there is much room for analysis in modeling, measuring, and calculating, but these important analytical efforts should not obscure the central observation that focusing on some outcomes and not others, and on some outcome levels and not others, is a reflection of the value judgments and priorities of those

making the decision. Again, which perceptions prevail in determining acceptable threshold levels of risk is a function of the influence of key actors. Our point is simply that these choices are neither objective nor purely scientific, nor could they be.

3. **The important short-term risks facing the Forest Service are related to decision processes, not ecological outcomes.**

The NAPA discussion is useful in helping to characterize the risks facing the Forest Service in the Sierra Nevada, which are broader than fire management.

- *Long-term risk*: given observed ecosystem conditions, existing external human factors, and future natural events and processes, the probability that any particular adopted management strategy will result in a preponderance of outcomes judged undesirable by the majority of stakeholders over the long term (beyond 10 years).

But in addition to long-term risk, the Forest Service faces important short-term risks as well.

- *Short-term risk*: given observed ecosystem conditions, existing external human factors, and future natural events and processes, the probability that any particular adopted management strategy will be seen as undesirable by the majority of stakeholders over the near term (10 years) because:
    - it results in a preponderance of undesirable outcomes; or
    - it violates accepted historical precedents; or
    - it violates widely held principles and standards of practice; or
    - it violates broadly held social preferences.

What emerges from this characterization is the observation that short-term risks involve much more than just concern about uncertain outcomes or the products of the decision. While stakeholders are certainly concerned with ecological outcomes, many are willing to accept modest short-term habitat losses if potential long-term gains are great enough (see Findings Section IV for a discussion of this point). Further, in the short run, none of the vegetation models or fire projections shows a significant difference in ecological outcomes. If it is true both that stakeholders are willing to consider short-term tradeoffs, and that alternatives under consideration are indistinguishable in their short-run outcomes, then the focus of short-term risks must shift to concerns with the decision process. Attention must be paid to process, or the decision maker runs the risk of failing to garner public support in the short term even though the likelihood of desirable long-term outcomes is enhanced. And this makes the "risk dilemma" all the more relevant.

The risk dilemma

How people perceive risk depends on:

- what they value;
- how the risk is framed; and
- their level of trust in the responsible organization or institution.

It is well known, for example, that there is an inverse relationship between perceived risk and perceived benefit, and the relationship is linked to an individual's general affective evaluation of

a hazard. If an activity is "liked" people tend to judge its benefits as high and its risks as low. If the activity is "disliked" the judgments are the opposite—benefits tend to be perceived as low while risks are perceived as high (Slovic 2000).

Further, and perhaps even more important, every way of presenting risk information is a "frame" that can shape the judgments of participants in a risk decision. If the issue is framed in a positive light, people are more likely to dwell on the positive aspects of the decision, and vice versa. One often cited example is the observation that summarizing medical risks in terms of mortality rates yields very different perceptions compared to when the same information is presented in terms of survival rates. If a given treatment is described as having a mortality rate of 10 percent, for example, it is perceived very differently than if the same treatment is said to have a survival rate of 90 percent. The evidence also shows that experts are not immune to these framing effects. The effect is as strong when subjects are physicians as when they are lay people. As the NRC report concludes:

> Numerous research studies have demonstrated that different but logically equivalent ways of summarizing the same risk information can lead to different understandings and different preferences for decisions (Stern and Fineberg 1996, p. 57).

It should be noted that this is not an issue that can be resolved with better science. There is no scientific way to determine that one summary of risk is more accurate or less biased than another when both accurately reflect the data. Consequently, the problem of generating a single unbiased summary of risk information to meet the needs of participants in a risk decision has no purely technical solution.

As with uncertainty, the resolution of this dilemma focuses on the decision processes employed. In this light, it is also important to note a corollary to the affective evaluation principle mentioned above: if participants trust the organization presenting the risk information, they are more likely to accept the characterization. And the level of trust is a byproduct of the decision process (Shindler and Toman 2003). Experience in a variety of settings suggests that such trust is easily damaged and difficult to restore.

4. **Communicating risk and uncertainty to stakeholders generally occurs in the form of one-way or two-way communication activities, but recent literature suggests that more participatory forms of risk communication may often be necessary.**

Risk communication activities include but are not limited to public meetings, workshops, field trips, press releases, and other risk messages between the agency and any and all interested and affected parties. The agency implementing these types of activities usually has the goals of clarifying and defining risks, educating and informing stakeholders with the best available knowledge surrounding a risk decision, or seeking to legitimize an agency decision. In each instance, increasing confidence and trust in the agency risk decision is an important objective (National Research Council 1989).

There are typically two risk communication responses employed by agencies to meet these goals. The first is to utilize one-way risk communication activities that inform interested and affected parties of the nature of the scientific analysis used to support a risk decision. Underlying one-way communication is the assumption that the agency, with access to the best science, is *the* best

informed and therefore the best suited to make risk decisions. The resulting risk communications are typically releases of probabilistic risk statements from agency experts to affected parties. Once non-experts are provided with the risk information, the agency experts then assume that the non-experts will understand and accept the justification for the agency decision.

One-way risk communication has serious shortcomings relating directly to the value judgments inherent in risk characterization as well as to the risk and uncertainty dilemmas described above. One-way risk communication practice by its very nature precludes the involvement of interested and affected parties in determining acceptable levels on outcome dimensions as well as in determining which outcomes merit attention in the first place. Even if an agency manages to incorporate the value judgments that are most important to interested and affected parties into its one-way risk communications, stakeholders will often have perceptions of risk and responses to uncertainty that are quite different from those of the agency experts responsible for the risk decision. The misunderstandings that arise between agency experts and interested and affected non-experts resulting from the failure to acknowledge differing values and perceptions of risk and uncertainty often lead to distrust of one-way risk communication practice and consequently also of agency risk decisions.

The second risk communication response, often in reaction to the failure of one-way risk communication to increase trust or adequately inform interested and affected parties, utilizes a two-way risk communication process. Here, non-expert feedback is garnered to actively involve stakeholders in the risk decision process and to ensure understanding of agency risk communications. In the former case, two-way communication is facilitated by the agency to aid in the identification of hazards in the risk assessment process and to aid in the selection of regulatory options and evaluation of administrative, political, and social realities in the risk management process. In the latter case, two-way interaction is facilitated by the agency to ensure that non-experts not only receive risk messages regarding risk decisions, but that the risk messages are understood.

While two-way risk communication efforts are often made in a sincere attempt to more effectively involve interested parties in risk decisions that directly affect their lives, these efforts are often not enough to address the inherent difficulties present in the risk and uncertainty dilemmas. Because the risk characterization and ultimate risk decision is left exclusively to the agency, interested and affected non-expert parties who were actively involved in a two-way process may become distrusting of the agency if it reaches a decision that misrepresents or excludes their views (National Research Council 1989; Chess, Salome et al. 1995). The uncertainty surrounding the characterization and the differing perceptions of risk are still present.

In sum, regardless of the number of one-way and two-way risk communication activities utilized, one-way and two-way risk communication processes that exclude non-experts from the risk characterization and the final risk decision will often come up short in building trust and in inspiring stakeholder confidence that the final risk decision has been informed by the best available knowledge.

A third and less often employed risk communication response to the shortcomings of one- and two-way risk communication practice is participatory risk communication. In participatory risk communication there is an explicit acknowledgement that experts operating within the confines of a positivist risk decision process may not have all of the necessary answers to a complex risk decision, regardless of the amount of public feedback received. In participatory risk communication there is a paradigm shift from a focus on expert/non-expert communications to a focus on broad-based deliberation and communication among all affected and interested parties—experts and non-experts are viewed as equal partners. This paradigm shift does not just impact risk communication, but also the entire risk decision process. Participatory risk communication relies on an "analytic-deliberative" risk decision process that emphasizes the integration of risk assessment and risk management (Stern and Fineberg 1996). We discuss this process in greater detail below.

Slovic suggests that to restore trust, risk decision processes

> "…may require a degree of openness and involvement with the public that goes far beyond public relations and *'two-way communication'* to encompass levels of power sharing and public participation in decision making that have rarely been attempted" (Slovic 1993, p. 680, emphasis added).

To meet the goals of adequately informing stakeholders with the best available knowledge and increasing trust, risk communication practice, like the uncertainty dilemma and risk dilemma, has a resolution that revolves around the decision processes employed.

5. The Sierra Nevada management decision is a wicked problem.

Clearly, some public problems are more difficult to resolve than others. Renn (1995) suggests that environmental debates operate on three levels, and that ecological risk assessment has *decreasing utility* as an input into policymaking as levels of complexity and conflict increase. For straightforward problems, scientific analysis can serve as a basis for policymaking with little controversy. At a medium level of complexity, public trust in the implementing institutions and their technical expertise is required. At the highest level of complexity and conflict, profound social and cultural values come into play, and stakeholder involvement is essential. In these most complex cases, the processes of defining shared values, common goals, desirable outcomes, and acceptable risks become political. Consequently, technical analyses alone, which do not integrate social values and deliberation, cannot provide an adequate decision-support framework.

To make this point more clearly, it is helpful to consider two dimensions of any decision: the state of necessary knowledge and the level of agreement on guiding values (Table 2, adapted from Committee of Scientists 1999, p. 131). Given these characteristics of a decision environment, there are four possible scenarios. If the knowledge base underpinning an issue is well understood and generally accepted,

Table 2: The nature of issues and wicked problems

State of knowledge	Agreement on values	
	High	**Low**
Well developed	Routine analysis with periodic stakeholder and expert review. *Decisions are easy*	Emphasis on stakeholder deliberation with periodic expert review
Tentative/gaps/ disagreements/ research needed	Emphasis on expert deliberation with periodic stakeholder review	Emphasis on both stakeholder and expert deliberation. *Wicked problems!*

and the agreement on values among stakeholders is high, then decision-making is easy and stakeholders may be comfortable with an agency-expert or authoritative strategy.
If agreement on values is low, but the science is well understood, then the focus is on dialogue among the stakeholders, guided by the science, to try to understand and resolve the value differences. When the science is uncertain and there are important gaps in the knowledge base, but the stakeholder agreement on values is high, then the focus is on getting the science issues resolved with oversight and engagement by the stakeholders when needed to assure that their values are being reflected in the science and decision-making. But when both the science is uncertain and the agreement on values is low, then the issue becomes a wicked problem, and significant dialogue among scientists, stakeholders, and decision makers is needed.

Some of the key characteristics of wicked problems are (Allen and Gould 1986):

- The definition of the problem is in the "eye of the beholder"; that is, each stakeholder defines the problem differently and therefore there is no single correct formulation of the problem.
- Outcomes are not scientifically predictable.
- The decision maker cannot know when all feasible and desirable solutions have been explored.
- The resources of ecosystems, communities of interest, funds, organizational capabilities, etc., combine with stakeholder demands in idiosyncratic ways; therefore, any solution is likely to be "one-shot" and unique.
- Solutions are generally better or worse, rather than true or false.

It is our firm belief—based on the risks and uncertainties associated with all aspects of the decision framework and the lack of a clear consensus on public values and perceptions of risk—that the Sierra Nevada planning effort is a classic wicked problem. This means that there is no single correct response, only some responses that are better than others, and that the Pacific Southwest Region must cope with the complexities and ambiguities associated with wicked problems.

FINDINGS SECTION II: Approaches to Addressing Wicked Problems

Approaches frequently used in the public arena to address wicked problems include the precautionary principle, adaptive management, and participatory policy analysis. Regarding these approaches, we find that:

1. Although the precautionary principle may make positive contributions to general considerations of scientific uncertainty, it does not provide useful, practical guidance for decision-makers as they address wicked problems.
2. Adaptive management can be described as an incremental approach to learning by doing that entails cycles of implementation, experimentation, monitoring, feedback, and revised implementation. In the academic and professional literature, the concept of adaptive management is now being expanded to address social and political, as well as scientific, uncertainties.
3. Participatory policy analysis is an approach that engages all stakeholders in long-term processes of analysis and deliberation with the objectives of educating participants, informing decisions, and reaching consensus responses to complex policy dilemmas.

Although attractive in principle, participatory policy analysis is difficult to implement successfully in practice.

Discussion

1. **Although the precautionary principle may make positive contributions to general considerations of scientific uncertainty, it does not provide useful, practical guidance for decision-makers as they address wicked problems.**

The precautionary principle is formulated in various ways in the environmental policy and other literatures. In all forms, however, the central idea is that if consequences of a proposed activity are uncertain and potentially harmful, the activity should not be undertaken until further research clarifies the risks. Under the precautionary principle, therefore, uncertainty about possible adverse outcomes cannot be used to justify going forward with potentially risky treatments, technologies, or management strategies. Moreover, the burden of proof on safety shifts from the regulator to the developer of the novel technology, product, or activity.

The precautionary principle, as analyzed in the literature, is seen to have both strengths and weaknesses as a response to scientific uncertainty. On the positive side, the precautionary principle requires public managers to address important safety-first considerations, acknowledge the limitations of standard analytic decision-support mechanisms, and consider economic, ethical, and political—as well as technical—aspects of the problem (deFur and Kaszuba 2002). On the negative side, the precautionary principle is not an effective tool for decision-making in the case of wicked problems, which have multiple uncertainties affecting all policy choices including the status quo. In these cases, application of the precautionary principle may lead to contradictory recommendations when applied to separate components of the problem and to decision-making paralysis when applied at a wider, more dynamic, systems-based level (Sunstein 2003).

In the context of wicked problems, the precautionary principle has common-sense appeal and is easy to grasp; yet, it is frequently impossible to implement when interpreted literally. Moreover, with its risk-averse foundation, the precautionary principle limits flexibility in policy choices and thus conflicts with adaptive management.

2. **Adaptive management can be described as an incremental approach to learning by doing that entails cycles of implementation, experimentation, monitoring, feedback, and revised implementation. In the academic and professional literature, the concept of adaptive management is now being expanded to address social and political, as well as scientific, uncertainties.**

Borrowing from both operations research and management science, adaptive management relies on systematic use of the scientific method and mathematical models to help managers make decisions in the face of complexity, changing conditions, and uncertainty about system dynamics (McLain and Lee 1996). Adaptive management, while acknowledging that policies must satisfy social objectives, is based on the idea that management strategies must be flexible and subject to continuous modification to adapt to unexpected outcomes (Gunderson 1999). Adaptive management assumes that decision makers should structure interventions to take advantage of uncertainty as a tool for learning rather than simply working to avoid or react to the inevitable

surprises bound to arise during efforts to control complex systems (Timmerman 1986). Thus, adaptive management is a scientific approach that views policies as hypotheses and management actions as experiments.

In a nutshell, adaptive management is a structured process of "learning by doing" that involves more than just improved ecological monitoring and strengthened responses to expected management impacts (Walters 1997). A common form of adaptive management that the Forest Service used in the past, for example, involved monitoring results of implemented strategies to determine whether outcomes were as expected. In current versions, however, adaptive management includes both trial-and-error approaches to ecosystem management and more formal experimental methods in which hypotheses regarding system responses to various interventions are developed and tested in the field with scientific rigor (Stankey, Bormann et al. 2003).

The original concept of adaptive ecological management and assessment (Holling 1978) has matured since its initial application to natural resources as a science-driven process with some stakeholder involvement. Now referred to as adaptive collaborative management (Buck, Geisler et al. 2001), adaptive management has evolved into a stakeholder-driven process with scientist involvement in a facilitated process to achieve stakeholder networks that learn and adapt together. However, the experimentation that underlies adaptive management remains expensive, time consuming, and sometimes difficult to implement due to legal and social constraints. Adaptive management for example cannot function effectively without extensive monitoring; yet managers may not have funding that is sufficient, or reliable enough, to maintain the minimum necessary levels of monitoring.

3. **Participatory policy analysis is an approach that engages all stakeholders in long-term processes of analysis and deliberation with the objectives of educating participants, informing decisions, and reaching consensus responses to complex policy dilemmas. Although attractive in principle, participatory policy analysis is difficult to implement successfully in practice.**

According to participatory theory, resolution of complex problems in practice requires approaches that are acceptable to all stakeholders, practical to implement, technically feasible, economically sustainable, and politically achievable. A committee of the National Research Council suggests that when confronting complex, multi-stakeholder social or environmental problems, scientific risk assessment and risk characterization should be combined with broad social participation in an iterative, "analytic-deliberative" process (Stern and Fineberg 1996). Under this approach, stakeholders, including experts and non-experts, work together to characterize and determine appropriate responses to risk by integrating scientific, social, ethical, and political inputs to decision-making.

Participatory processes generally lead to development of temporary, ad hoc associations of stakeholders that come together to address specific issues. Yet attaining the necessary levels of trust and understanding to confront complex policy dilemmas requires sustained attention and involvement from the earliest stages. To establish this essential participatory infrastructure, the approach proposed by the NRC committee relies on development of "learning networks" (Senge 1990; Stubbs and Lemon 2001) of stakeholders to create a cooperative decision-making

environment in which trust, understanding, and mutual reliance develop over time (Stern and Fineberg 1996).

The learning network process is one in which analysis and deliberation build on each other in iterative cycles. This analytic-deliberative approach requires the engagement of both scientists and public stakeholders. The process is driven by a "feed-forward" mechanism in which stakeholders determine what is socially relevant or acceptable given the best science, and science helps strengthen stakeholders' grasp of technical issues. Analysis allows participants to develop and draw from a common, scientific knowledge base that informs deliberations. Deliberation in turn allows a policy consensus to emerge that is both socially and scientifically acceptable.

Unfortunately this process is not a panacea. Since participatory policy analysis is democratic in its integration of various types of information, including quantitative and qualitative, analytical and perceptual, and objective and subjective, it can be highly demanding of social resources, including time, money, and stakeholder commitment. The literature seems to suggest that it is quite easy for such processes to get derailed and that there are many more instances of failed processes than of successful ones.

In the context of wicked problems, therefore, the search for an optimal solution should give way to efforts that strive more realistically for mutual "satisficing." In contrasting optimizing behavior with satisficing behavior, Simon states:

> A decision maker who chooses the best available alternative according to some criteria is said to optimize; one who chooses an alternative that meets or exceeds specified criteria, but that is not guaranteed to be either unique or in any sense the best, is said to satisfice (Simon 1997, p. 295).

Thus "satisficing" is the search for broadly acceptable and implementable solutions, rather than for optimal solutions that may be difficult to implement. Indeed, optimal solutions generally do not exist for wicked problems.

FINDINGS SECTION III: An Evaluation of the Use of the Precautionary Principle, Adaptive Management, and Public Participation in the SNFPA Process

To varying degrees, the Forest Service has integrated the precautionary principle, adaptive management, and public participation into the SNFPA decision-making process. Following our review of the FEIS, ROD, and Review Team report and our discussions with stakeholders and agency team members, we find that:

1. The precautionary principle influenced the selection of Modified Alternative 8, and the development of related standards and guidelines, and contributed to subsequent problems with implementation.
2. Adaptive management, as applied in the Sierra Nevada case to date, is necessary but not sufficient to assure success.
3. Opportunities for public participation in the SNFPA process have been unprecedented. Nevertheless, possibilities remain for further expansion of public engagement as the Forest Service looks beyond the current process to future forest management decision-making.

Discussion

1. **The precautionary principle influenced the selection of Modified Alternative 8, and the development of related standards and guidelines, and contributed to subsequent problems with implementation.**

The precautionary approach appears to have influenced both public attitudes and Forest Service decisions in the Sierra Nevada case. Although key documents related to the SNFPA project—including the FEIS, ROD, and Review Team report—do not explicitly cite the precautionary principle, they do contain precautionary language. Moreover, management decisions in the SNFPA case, and the outcomes of those decisions, have reflected some of the difficulties predicted to occur when the precautionary principle is applied to wicked problems.

FEIS

In the SNFPA case, managers face risks and uncertainties relating to, among other central concerns, fire management and old-growth forest habitat protection. In some cases, however, a cautious approach designed to reduce risk of adverse outcomes in one of these two areas may increase risk in the other. The FEIS acknowledges this dilemma in its discussions of potential conflicts between fuels treatment strategies and protection of California spotted owl activity centers (PACs). Alternative 8, for example, explicitly incorporates a cautious approach to fuels treatment in PACs, even in wildland-urban intermix zones (WUIs), while recognizing that the risk of fire in these areas may be increased as a result (USDA Forest Service Pacific Southwest Region 2001a, vol. 1, ch. 2, pp. 54 & 65). Following the logic of the precautionary principle, Alternative 8 calls for more research to reduce uncertainty surrounding risks to owl habitat from various management strategies.

Alternative 5 in the FEIS also includes precautionary language (USDA Forest Service Pacific Southwest Region 2001a, vol. 1, ch. 2, p. 113). This alternative includes prescriptive standards and guidelines that limit management options under the assumption that interventions—even those designed to promote forest health—may actually increase the risk of ecological degradation.

ROD

In selecting Modified Alternative 8 in the Record of Decision, the Regional Forester attempted to balance the often conflicting strategies of caution and flexibility. Modified Alternative 8, for example, takes a precautionary approach to fire management within the WUIs and a precautionary approach to preservation of PACs outside these zones. Yet the ROD also recognizes that neither management strategies nor forest ecosystems remain static and that adaptive management is essential (USDA Forest Service Pacific Southwest Region 2001b, pp. 2, 6, & 12).

Review Team Report

In its report to the Regional Forester discussing concerns that arose after the ROD was issued, the Review Team argues that the effort to balance caution and flexibility embodied in Modified Alternative 8 does not appear workable in practice (USDA Forest Service Pacific Southwest Region 2003, p. 12). In particular, the team finds that prescriptive standards and guidelines

added to the ROD as precautionary measures may actually reduce the likelihood that the broadly accepted goals expressed in the ROD could be achieved (USDA Forest Service Pacific Southwest Region 2003, pp. 12-13). For example, limits to mechanical fuels treatment in PACs—imposed to minimize damage to owl habitat—may increase the risk of stand-destroying fires and thus heighten the danger to the habitat that the restrictions are intended to protect.

The Review Team report also raises a second issue that matches theory regarding potential problems linked to the precautionary approach: constraints on the ability to take advantage of opportunities to tradeoff short-term losses for long-term gains (USDA Forest Service Pacific Southwest Region 2003, p. 37). If ecological models reveal, for example, that certain forest management and fuels treatment strategies are likely to cause modest losses in owl habitat over the short term but significant gains in owl habitat over the longer term, application of the precautionary principle would preclude or severely restrict implementation of such actions.

Finally, the Review Team notes that precautionary language in the ROD limits options for adaptive management—particularly in the Herger-Feinstein Quincy Library Group (HFQLG) pilot project area, where policy experiments and adaptive management form the core of the project's strategy and mission (USDA Forest Service Pacific Southwest Region 2003, pp. 6 & 52).

2. **Adaptive management, as applied in the Sierra Nevada case to date, is necessary but not sufficient to assure success.**

The FEIS, ROD, and Review Team report all describe adaptive management as an essential mechanism for dealing with uncertainty in the Sierra Nevada case.

FEIS

Appendix E of the FEIS discusses adaptive management in detail, describing it primarily as an experimental, scientific process. Key components of the approach are identified as follows: Forest Service personnel develop a management strategy, implement the strategy, monitor effects in the field, and provide feedback so that the strategy can be modified and improved (Figure 2). Appendix E also emphasizes the critical importance of monitoring and research. The document lists three types of monitoring essential for success: implementation monitoring, status-and-change monitoring, and cause-and-effect monitoring. The authors note that without effective monitoring and feedback on all three levels, adaptive management collapses (USDA Forest Service Pacific Southwest Region 2001a, Appendix E, pp. 4, 14-17).

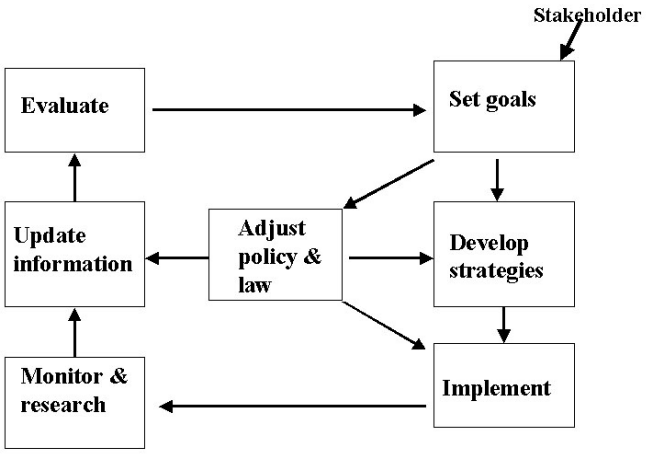


Figure 2. Sierra Nevada Forest Plan Amendment adaptive management process (FEIS, Appendix E)

The FEIS recognizes that although adaptive management is in principle a scientific enterprise, it is not conducted entirely in isolation from the broader social and political decision-making arena. The model of adaptive management included in Appendix E (Figure 2 above) shows a link to public stakeholders, particularly in the goal-setting process. The model also acknowledges the requirement that administrators go through a transparent public process as they modify management strategies in response to new information. Despite these peripheral connections to the public arena, however, adaptive management as described in the FEIS remains fundamentally a scientific undertaking that does not incorporate stakeholder involvement at all stages.

ROD

The Record of Decision also emphasizes the importance of adaptive management (USDA Forest Service Pacific Southwest Region 2001b, pp. 15-16). In the ROD, the Regional Forester stated:

> Adaptive management will allow the Forest Service to test new and innovative management techniques as part of formal research projects. To accomplish this, I will allow for variances from the standards and guidelines in Appendix A to test hypotheses in a scientifically structured manner (USDA Forest Service Pacific Southwest Region 2001b, p. 15).

A key objective of adaptive management in the Sierra Nevada case is to test silvicultural practices that mimic natural heterogeneity of forest landscapes:

> Basic forest ecological principles will be employed to design such conditions, consistent with the size and intensity of natural disturbance agents. This study will test the hypothesis that California spotted owls will not be directly, or indirectly, affected by limited levels of silvicultural treatments that mimic natural disturbance processes (USDA Forest Service Pacific Southwest Region 2001b, p. 16).

Thus, the ROD, reiterating the characterization of adaptive management presented in the FEIS, envisions a scientific process of inquiry driven by the concerns of scientists rather than stakeholders. Further, in keeping with the precautionary approach described earlier, the ROD limits the extent and objectives of experimentation in the field. These restrictions are particularly significant in the case of the HFQLG pilot project, which is founded on the idea of experimentation in management practices. In this regard, the approach articulated in the ROD is similar to that adopted in the Northwest Forest Plan and may lead to many of the same problems (Stankey, Bormann et al. 2003; Thomas 2003).

While the ROD clearly recognizes the importance of adaptive management in dealing with risk and uncertainty, its approach to implementation suffers from several potential flaws. First, it provides little opportunity for stakeholder involvement in the adaptive management process. Second, it may not reflect stakeholder preferences and priorities. Third, it appears to rely on large-scale (and expensive) experimentation that may increase short-term ecological risk. Finally, its application may be limited by the very standards and guidelines that adaptive management is supposed to test.

Review Team Report

The Review Team report reiterates the importance of adaptive management and addresses several of the weaknesses mentioned above. The Review Team, for example, reinforces the central role of monitoring and feedback, urging both a stronger emphasis on cause-and-effect monitoring and a greater effort to provide rapid, real-time feedback to managers (USDA Forest Service Pacific Southwest Region 2003, pp. 96-98). The Team also recognizes the need for greater public participation to help build trust in the adaptive management process, recommending for example that stakeholders be involved in evaluating the results of monitoring (USDA Forest Service Pacific Southwest Region 2003, p. 99).

The Review Team also discusses constraints the ROD placed on application of adaptive management in the HFQLG pilot project area. In response, the Team recommends that the SNFPA ROD be modified so that within the pilot project area standards and guidelines conform to those contained in the HFQLG ROD of 1999 (USDA Forest Service Pacific Southwest Region 2003, p. 111).

Despite the Review Team's efforts to address weaknesses in the adaptive management process outlined in the SNFPA ROD, significant problems remain. First, as the Review Team acknowledges, budget constraints are likely to limit monitoring (USDA Forest Service Pacific Southwest Region 2003, p. 97); yet, without effective monitoring, adaptive management cannot succeed. Second, opportunities for public participation are still modest. Third, the process remains primarily a means to address scientific questions, with no attempt to integrate administrative, social, and political uncertainties or to build a consensus for dealing with risk.

3. **Opportunities for public participation in the SNFPA process have been unprecedented. Nevertheless, possibilities remain for further expansion of public engagement as the Forest Service looks beyond the current process to future forest management decision-making.**

The SNFPA process has incorporated numerous opportunities for public engagement. These have included both public meetings and formal periods established for public comment. Public participation in the Sierra Nevada case shows marked improvement over the situation in many past government decision-making processes. During development of the FEIS, for example, stakeholder groups had the opportunity to develop alternative management strategies that were considered in detail. Moreover, SNFPA documents repeatedly make reference to the importance of transparency and public involvement. For example, the recent Review Team report states:

> The year-long review has been an open, transparent and highly collaborative process by local Forest Service employees working with a host of key stakeholders, including elected officials, tribes, interest groups and other government agencies. Insight was obtained from dozens of public meetings, workshops and field trips held with employees, interest groups, scientists, other government agencies, journalists and others. Biweekly updates were given to key stakeholders (USDA Forest Service Pacific Southwest Region 2003, Executive Summary).

Over the past ten years, the Pacific Southwest Region has significantly expanded the boundaries of public participation. While retaining ultimate decision-making responsibility as required by law, Forest Service administrators have strengthened opportunities for concerned citizens and

stakeholder groups to participate in the development of alternative forest management plans and to comment on those under consideration. We find the Region's past efforts commendable.

As the Region looks to the future, it is worth noting that recent trends in the literature call for still richer public engagement in environmental management, particularly in the case of wicked problems. Both the third-stage risk communication strategy and the analytic-deliberative decision model described above are examples of the new approaches to public participation and deliberation being proposed. Once the SNFPA process is concluded, we recommend that the Forest Service consider these and other options for engaging the public in confronting future decision-making dilemmas.

FINDINGS SECTION IV: Participant Attitudes and Preferences

Based on analysis of data collected during our workshops, we find that:

1. The majority of participants do not feel the SNFPA decision process, subsequent to issuing the ROD, has been satisfactory.
2. While participants recognize that there are multiple risks and that individuals value them differently, they are willing to consider tradeoffs among these competing risks.
3. Participants feel that adaptive management involving experimentation and learning is a preferred approach to managing the forests. There is considerable willingness among individuals who subscribe to one value position to consider other values and the tradeoffs implied in the different perspectives.
4. Three factors are most important in determining individual preferences and tradeoffs. They are amount of timber harvesting, potential long-term changes in habitat, and potential changes in the incidence of wildfires.

It should be noted that while we did have a broad representation of perspectives in these workshops, our findings are based on a total of 75 individual responses. A larger sample of responses would allow us to place greater confidence in these findings.

Discussion

In early March 2003, we held three meetings to elicit opinions on the experiences of individuals who had been actively engaged in the decision-making processes related to management of the Sierra Nevada national forests. Two of the meetings were held with external stakeholders that included many individuals from forest industry, forest user groups, environmental organizations, local community representatives, and some local government officials and employees (stakeholders group). The Forest Service provided us a list of 55 individuals from this group who had been actively involved in the development of the Final Environmental Impact Statement and Record of Decision. We mailed letters to these individuals inviting them to attend either one of the two meetings offered for external stakeholders. The same agenda and content were covered at both meetings. The meetings were also advertised on the Forest Service SNFPA website and in the newspapers of the affected communities. Forest Service officials indicated to us that at the start of the Sierra Nevada planning process (approximately 1994-1996), there were as many as 250 stakeholders actively engaged in the process.

The third workshop was held in conjunction with a meeting of the Interagency Team that consisted of federal and state land management and regulatory agencies, wildlife and forest scientists, and key Forest Service line (Regional Forester, Assistant Regional Foresters, Forest Supervisors) and staff officers (those responsible for forest planning, wildlife, forest management, etc.). A total of 143 invitations were sent to this group. Invitations were also sent to the Executive Committee, which consisted of 12 local heads of federal and state agencies.

Seventy-seven individuals from the 210 invited attended one of the meetings. At all three workshops we provided an overview of the concepts of the Forest Service decision problem, the nature of wicked problems, risk and uncertainty, and the participatory process. We then asked participants to complete two activities to help us measure their attitudes: a survey and a card-sort exercise. Two individuals chose not to participate in the survey and card-sort exercise.

The survey was designed to help us identify attitudes toward, and preferences for:

- decision-making processes;
- risks and tradeoffs;
- management strategies and tradeoffs;
- management philosophy;
- the Forest Service as a management institution; and
- management priorities for the Sierra Nevada national forests.

The card-sort exercise was designed to help us determine through conjoint analysis (Green and Srinivasan 1978) which factors influenced participant attitudes toward decisions regarding management of the forests. In this context we focused on management strategies and practices, the locations in which these strategies and practices would be implemented, and potential outcomes.

The findings presented in this section are derived from our meetings with external stakeholders and the Interagency Team and their responses to the two exercises. We stress that we collected data only from a total of 75 people, a sample too small to support definitive conclusions. Nonetheless, virtually all of the participants were either directly involved in the SNFPA review process or were citizens and government officials with long-term engagement in the Sierra Nevada decision processes. As such, their views are important indicators of the views and values that may be held by interested parties in general.

Because of the sample size, we grouped respondents to our questionnaire into three categories based on their self-identified organizational affiliation. The groupings are as follows.

- The public (47%):
    - members of private-sector or business-related organizations;
    - members of environmental or other nongovernmental organizations;
    - individual concerned citizens; and
    - all others not elsewhere classified.
- Government agency employees, other than the Forest Service (21%):
    - municipal or county government employees;
    - state government employees; and
    - federal government employees, other than the Forest Service.

- Forest Service employees (32%).

Given that as many as 250 individuals were originally involved in the planning process from the stakeholder group alone, there is a logical concern about the representativeness of those remaining in the process. Further, the Forest Service retains a mailing list of several thousand people who have indicated an interest in the Sierra Nevada Framework. We cannot say, based on the nature of our sample, how this larger group might respond to our survey.

1. **According to participants, the SNFPA decision process, subsequent to issuing the ROD, has not increased trust in the Forest Service, increased consensus among stakeholders, or provided adequate opportunity for public involvement and deliberation.**

One consistent finding across all groups was a general pessimism about the potential for finding a consensus agreement for managing the Sierra Nevada. Asked to evaluate the statement, "A consensus agreement is possible that would satisfy all participants concerned about management of the Sierra Nevada forests," 79 percent to 83 percent of all three groups disagree or strongly disagree with the statement.

Nearly half of all participants do not feel that their most important concerns have been adequately incorporated in the process (Table 3, next page). This is also true for a strong minority of Forest Service employees. (During the first meeting with stakeholders, it was noted that the instructions for the exercise did not clearly state the time period to be considered in answering the questions. At this meeting and at both other workshops, we clarified that in our instruments "the SNFPA decision process" referred to the time period from November 2001 to the time of the workshops in March 2003.)

What is less clear is whether the dissatisfaction with the process is due to disagreement with the outcome or frustration with the process itself. A majority of Forest Service employees and a plurality of the public disagree that the process has afforded adequate opportunity for public involvement. Among those who feel their most important concerns were not adequately incorporated in the process, 65 percent also feel that the opportunity for public involvement was inadequate. Clearly, these participants could be rejecting a process that yielded what is for them an unacceptable result. On the other hand, among those who feel their views were adequately incorporated in the decision process, 50 percent do not agree with the statement that public involvement and deliberation opportunities were adequate.

A majority of public participants and a substantial minority of Forest Service employees also disagree that their trust in the Forest Service has increased as a result of the process. Again, this erosion of trust seems strongest among those who do not feel their important concerns were adequately incorporated in the process (71 percent). But among those who are either neutral or agree that their concerns were incorporated, 58 percent do not agree with the statement that their trust in the Forest Service has increased.

Regardless of their attitudes toward the decision outcomes, the majority of participants feel that their personal contributions have made a difference and that the process has been valuable in educating the public. It would certainly not be a surprise to find that those who object to the

decision outcome may find fault with the decision process. It is worth noting however that at least for a large minority of participants, the SNFPA process needs further improvement.

Table 3: SNFPA decision process

	Public		Other government employee		Forest Service employee	
Statement	**SD/D**	**A/SA**	**SD/D**	**A/SA**	**SD/D**	**A/SA**
The issues and concerns that I believe are most important are adequately incorporated in the SNFPA decision process.	60%	20%	43%	50%	35%	43%
The SNFPA decision process affords adequate opportunity for public involvement and deliberation in determining the final management goals and priorities.	46%	30%	13%	53%	50%	41%
The SNFPA decision process has resulted in increased agreement among most parties on what the most important issues and goals should be.	68%	8%	50%	36%	50%	27%
My trust in the US Forest Service and its management of the Sierra Nevada has increased as a result of the SNFPA decision process.	62%	19%	27%	47%	36%	36%
The SNFPA decision process is helpful in educating and informing the public on key decision issues.	35%	41%	13%	60%	18%	59%
On balance, I believe that my participation in the SNFPA decision process has improved the quality of the final decision.	28%	53%	7%	73%	9%	77%

SD=Strongly disagree; D=Disagree; A=Agree; SA=Strongly agree. In all cells, the "neither agree nor disagree" category has been omitted.

Table 4 reports attitudes toward the Forest Service and its capacity to manage the Sierra Nevada. By and large, most participants feel that the Forest Service has or can obtain the technical skills necessary to manage the forests. However, the majority of respondents outside the Forest Service do not agree that the Forest Service has a good fire management record. Moreover, there is disagreement about whether the Forest Service can be trusted to protect and restore owl habitat. Thus, while most participants see the agency as competent (or at least potentially competent), outsiders have concerns about both the record of accomplishments to date and the Forest Service's priorities for the future.

Table 4: Forest Service capacity

	Public		Other government employee		Forest Service employee	
Statement	**SD/D**	**A/SA**	**SD/D**	**A/SA**	**SD/D**	**A/SA**
The Forest Service has, or can develop, the skills and information necessary for effective medium- to long-range ecological risk management in the Sierra Nevada forests.	8%	67%	14%	71%	22%	70%
The Forest Service has a good fire management record in the Sierra Nevada.	54%	19%	57%	14%	13%	70%
Forest Service personnel can be trusted to protect and restore essential habitat for the California spotted owl and other old forest species.	38%	32%	14%	57%	17%	74%
Unexpected outcomes from management actions are the result of agency failings.	59%	11%	57%	7%	87%	4%

SD=Strongly disagree; D=Disagree; A=Agree; SA=Strongly agree. In all cells, the "neither agree nor disagree" category has been omitted.

Views on the appropriate decision processes to follow in managing the Sierra Nevada national forests are ambivalent. As shown in Table 5, most participants do not feel that the general public has the expertise necessary to manage the forests. At the same time, there is substantial disagreement over the role of experts. Over half of all participants disagree with the statement that expert plans are more feasible and balanced than those developed by local participants, and 65 percent of Forest Service employees take this position. In addition, a strong majority of all participant groups disagree that management decisions should be guided solely by science and expert opinion.

With regard to the role for public values and participatory processes, while most groups agree that these are important, support is strongest among Forest Service employees. On balance, it appears that most participants—while recognizing that citizens must be educated and informed if they are to participate effectively—remain skeptical of claimed expertise and continue to value local stakeholder views and engagement.

Table 5: Decision process

	Public		Other government employee		Forest Service employee	
Statement	**SD/D**	**A/SA**	**SD/D**	**A/SA**	**SD/D**	**A/SA**
The general public lacks the specialized knowledge necessary to guide management decisions in the Sierra Nevada.	30%	59%	13%	73%	27%	55%
Forest management plans developed by experts are generally more feasible and balanced than plans developed by local participants.	46%	38%	40%	53%	65%	22%
Management decisions in the Sierra Nevada should be guided solely by science and expert opinion.	72%	8%	67%	13%	86%	5%
Broadly held public values should guide management decisions in the Sierra Nevada.	27%	51%	33%	20%	23%	64%
Democratic, participatory processes generally lead to better forest management decisions than processes dominated by experts.	24%	49%	20%	67%	0%	83%

SD=Strongly disagree; D=Disagree; A=Agree; SA=Strongly agree. In all cells, the "neither agree nor disagree" category has been omitted.

2. **While participants recognize that there are multiple risks and that individuals value them differently, they are willing to consider tradeoffs among these competing risks.**

Responses to questions regarding risks and tradeoffs inherent in management decisions indicate a sophisticated understanding of underlying issues. Participants acknowledge that management practices that require timber harvesting in the forests will be integral parts of any management decision. They also both acknowledge and demonstrate the willingness to confront tradeoffs, between for example the likelihood of catastrophic fires and damage to old-growth forest habitat.

While all tradeoffs offered to workshop participants are not shown, Table 6 (next page) does indicate that participants seem most willing to tradeoff short-term losses in old-growth forest habitat for a likelihood of long-term gains, but they appear relatively less willing to incur short-

term losses in habitat for potential economic gains or fire-safety benefits. Participants also demonstrate a slight preference (not shown in the table) for the location of fuels treatments, preferring that treatments occur in the defense and threat zones, or WUIs (i.e., within 1.5 miles of residences and other improvements), rather than elsewhere. Participants clearly recognize the uncertain nature of outcomes, and yet in general they appear willing to tradeoff short-term losses for potential long-term gains. This finding is at odds with a general impression that certain interest groups might be unwilling to make such tradeoffs. Given the wide range of interest groups represented in our sample, we believe this finding to be defensible. However, a larger sample would allow us to place greater confidence in these findings.

Table 6: Tradeoffs

	Public		Other government employee		Forest Service employee	
Statement	**SD/D**	**A/SA**	**SD/D**	**A/SA**	**SD/D**	**A/SA**
A 3 percent short-term reduction in old forest habitat acreage is acceptable if there is a good chance that over the long-term at least a 10 percent gain in habitat acreage will result.	27%	61%	0%	93%	14%	86%
A 3 percent short-term reduction in old forest habitat acreage is acceptable if there is a good chance that long-term economic benefits to adjacent communities will result.	36%	48%	14%	57%	14%	76%
A 3 percent short-term reduction in old forest habitat acreage is acceptable if there is a good chance that over the long-term safety benefits to adjacent communities from reduced fire hazard will result.	33%	61%	0%	79%	10%	86%
Providing fuels treatments on 1.5 to 2 percent of the forest each year (roughly 150,000 acres) is acceptable if there is a good chance the average number of acres burned will be reduced by 5 to 10 percent per year.	22%	69%	15%	77%	5%	95%
A 3 percent short-term decline in spotted owl nesting habitat is acceptable if there is a good chance the average number of acres burned will be reduced by 5 to 10 percent per year.	31%	56%	23%	54%	13%	74%
A 3 percent short-term decline in spotted owl nesting habitat is acceptable if there is a good chance the average acres in lethal or stand replacing fires will be reduced by 10 to 30 percent per year.	25%	63%	8%	77%	9%	87%
The creation of small openings or gaps in the forest canopy is acceptable if there is a good chance that the long-term effects on forest regeneration and health are positive.	15%	82%	7%	93%	13%	87%

SD=Strongly disagree; D=Disagree; A=Agree; SA=Strongly agree. In all cells, the "neither agree nor disagree" category has been omitted.

3. **Participants believe that adaptive management involving experimentation and learning is a preferred approach to managing the forests. There is considerable willingness among individuals who subscribe to one value position to consider other values and the tradeoffs implied in the different perspectives.**

Participants believe that given the underlying uncertainties, some form of adaptive management of the forests may be the best approach to managing the forests (Table 7, next page). They are willing to accept some adverse outcomes resulting from experimentation with different strategies in order to learn more about the consequences of implementing such strategies. They also

believe that some costs of managing the forests should be recoverable through harvesting of trees and other uses of natural resources. There is general agreement that there are tradeoffs to be made, and most participants appear willing to consider recommendations regarding the nature and extent of these tradeoffs.

Responses to the first and third statements listed in Table 7 show that workshop participants do not favor strict application of the precautionary principle. In fact, they appear willing to tolerate some risk of harm in order to learn from experimentation. Responses to the second question show broad approval for the idea of adaptive management.

Table 7: Management philosophy

	Public		Other government employee		Forest Service employee	
Statement	**SD/D**	**A/SA**	**SD/D**	**A/SA**	**SD/D**	**A/SA**
When outcomes of management decisions are uncertain, the safest course is to take no action.	88%	9%	85%	8%	96%	4%
When outcomes of management decisions are uncertain, adaptive management is the most responsible approach.	12%	70%	0%	77%	13%	70%
If a management or research "experiment" may damage some habitat for an old-growth forest dependent species, then the experiment should not be allowed.	61%	27%	85%	0%	91%	4%

SD=Strongly disagree; D=Disagree; A=Agree; SA=Strongly agree. In all cells, the "neither agree nor disagree" category has been omitted.

4. **Three factors are most important in determining individual preferences and tradeoffs: amount of timber harvesting, potential long-term changes in habitat, and potential changes in the incidence of wildfires.**

The large majority of participants demonstrate concern for three broad value foci:

- natural resource production and utilization;
- conservation of old-growth forest species and habitat; and
- responsiveness to legal requirements and popular will.

We stress, however, that in general these are not mutually exclusive or independent concerns. Relatively few individuals single-mindedly commit to only one set of values. For most participants, these three sets of values are jointly held and competing concerns. Moreover, people are willing to consider tradeoffs above identifiable thresholds.

Participants' top priorities for the Sierra Nevada national forests are (number in parentheses represents the percent of respondents ranking this option either first or second in importance):

- complying with all environmental and legal requirements (64%);
- following a decision process that is open and fair (63%);
- avoiding catastrophic fire losses in communities (63%);
- protecting threatened and endangered species (59%);
- promoting good air quality (55%);
- enhancing healthy and abundant old forest habitat (54%); and
- avoiding catastrophic fire losses in old forests (52%).

When we asked participants to compare specific alternatives involving relative treatment amounts, treatment locations, and potential outcomes, we found that three factors are most important in determining individual preferences and attitudes toward tradeoffs:

- *Amount of timber harvesting*. Few people are adamantly opposed to all timber harvesting. But based on conversations and questions we heard, we found that an extremely important aspect of this issue is the maximum diameter of trees to be cut.
- *Potential long-term changes in habitat*. Most participants are willing to accept strategies that would lead to modest short-term habitat losses in return for significant long-term habitat gains.
- *Potential changes in the incidence of wildfires.* Most participants are not willing to compromise on the goal of reducing the long-term incidence of wildfires. Respondents appear strongly supportive of efforts to reduce fire risk.

A recent analysis of focus groups from Clay County, Florida, Marin and Tuolumne Counties, California, and Oscoda County, Michigan found that four common factors affect the acceptance of three fuels management practices (prescribed fire, mechanical treatment, and defensible space requirements): beliefs about the outcomes of fuels management, personal importance of fuel management, situational specificity (residents assess the acceptability in the context of situation- and site-specific considerations), and agency trust (Winter, Vogt et al. 2002). It seems reasonable to assume that these factors also influence the acceptability of fuels treatments in the Sierra Nevada.

SUMMARY

In summary, our findings are:

- Uncertainty is a neutral analytical property expressing the likelihood that an event, relationship, phenomenon, or other important consideration will occur. Some uncertainties may be reduced through better science, but generally most cannot be completely eliminated.
- Risk is fundamentally an expression of the values of those framing the decision problem. Characterizing the risks inherent in a given decision requires selecting both the outcomes on which to focus attention and the levels deemed acceptable by decision makers. These decisions, based in scientific and analytical information, are driven by the values of those involved.
- The important short-term risks facing the Forest Service are related to decision processes, not ecological outcomes.
- The Forest Service must confront two difficult dilemmas in framing its strategies and communicating with stakeholders:
    - The uncertainty dilemma: On one hand, simple and accessible characterizations of the multiple uncertainties involved in these complex systems are likely to be misleading, biased, or wrong. On the other hand, detailed characterizations of uncertainty are likely to be difficult to understand and present, and consequently may not be useful to the public or to decision makers.
    - The risk dilemma: Every way of presenting risk information is a "frame" that shapes the judgments of participants in a decision involving risk. Numerous research studies have demonstrated that different but logically equivalent ways of

summarizing the same risk information can lead to different understandings and different preferences for decisions.

Neither of these dilemmas can be resolved with better science. In both cases, the resolution depends on the decision processes employed. To be effective, such processes must tightly integrate analysis and broad deliberation.

- Risk communication activities include but are not limited to public meetings, workshops, field trips, press releases, and other risk messages between the agency and any and all interested and affected parties. Communicating risk and uncertainty to stakeholders generally occurs in the form of one-way or two-way communication activities, but recent literature suggests that more participatory forms of risk communication may often be necessary.
- Because of the high levels of scientific uncertainty, the profound public disagreement both over the characterization of associated risks and over desired outcomes, and the requirement that despite these unresolved difficulties the Forest Service must act, the Sierra Nevada management decision falls into the technical category of "wicked" problems. As such, it should be acknowledged by all involved that there is no single best answer for managing the Sierra Nevada.
- The use of the precautionary approach in the ROD and in related standards and guidelines has made it difficult in the short term for forest managers to implement the decision effectively in the field. Moreover, both in theory and in practice, the precautionary approach may conflict with efforts to apply adaptive management over the longer term. Participants recognize these limitations of the precautionary approach: over 85 percent of the public employees and stakeholders we surveyed disagree with the statement that no action is the safest course when faced with uncertainty.
- The FEIS, ROD, and Review Team report recommend and rely on scientific adaptive management as the primary means for dealing with uncertainty in the Sierra Nevada case. Adaptive management is supported by over 70 percent of our questionnaire respondents. However, many professional and academic proponents of adaptive management have now moved away from a narrow scientific focus to explore more explicitly collaborative forms that incorporate administrative, social, and political uncertainties and attempt to foster shared views of the central risks involved in environmental management.
- The SNFPA decision process has included significant opportunities for stakeholder participation through informal input, public meetings, and public comment periods. However, based on our sample, 50 percent of Forest Service employees and 46 percent of the members of the public who participated in our workshops do not agree that the process has afforded adequate opportunity for public involvement. Moreover, 36 percent of Forest Service employees and 62 percent of the public do not agree that their trust in Forest Service management has increased as a result of the process.
- While the public employees and other stakeholders we talked to recognize that there are multiple risks and differ in their assessment of the importance of those risks, these participants are willing to consider tradeoffs among competing risks. In particular, they are open to timber harvesting, but do not agree on the maximum size of trees to be harvested.
- Three factors are most important in determining individual preferences and tradeoffs: the amount of timber harvesting; the potential long-term changes in habitat; and potential changes in the incidence of wildfires.

LOOKING TO THE FUTURE

It is clear that the Forest Service has used extensive public engagement and state-of-the-art practice in the decision-making process involving management of the national forests in the Sierra Nevada. However, review of the most recent literature suggests that in the case of wicked problems, even this may not be enough to assure an implementable decision in the future. Wicked problems are characterized by a high degree of scientific uncertainty (and, therefore, of real and perceived risk) and a lack of public consensus on the solution. Further, the decision-maker must make a decision in such an environment. The literature suggests that the participatory process must be highly collaborative, continuously updated, inclusive, and based on a sharing of authority.

Both the National Environmental Policy Act (NEPA) and the National Forest Management Act (NFMA), key laws affecting the Forest Service decision process, mandate public participation but provide little guidance as to how that participation is to occur and what role the public has in the ultimate decision. Historically, public participation has been interpreted to mean providing opportunities for the public to comment on proposed federal actions that may impact the environment. In the Sierra Nevada case, the Forest Service has gone far beyond this minimal level of public participation. For example, extensive local and regional public meetings were held to educate the public about the state of the science for wildlife, forests, and wildfire in the Sierra Nevada and to obtain feedback from stakeholders. Of the nine alternatives ultimately considered in the FEIS, five were based directly on specific alternatives or concepts offered by outside groups (Alternative 2 by the Sierra Club, Alternative 3 by the Association of Forest Service Employees for Environmental Ethics, Alternative 4 by the forest industry, Alternative 5 by the Sierra Nevada Forest Protection Campaign, and Alternative 7 by the Modoc County Land Use Committee). We believe that at the time this level of public participation was unprecedented in federal land management planning.

NEPA and NFMA do make it clear that it is a federal official who is responsible for making the decision. The decision-maker cannot delegate this authority to any outside individual or group. Further, the decision-maker must balance legal mandates and regulations, budget realities, public desires and expectations, and biological limitations in reaching a decision, guided by the values and risks at stake. This is especially difficult in the case of wicked problems where the science is uncertain and there is no consensus on public desires and values. It is also clear that the personal values of the decision-maker play a role in the final decision. In fact, according to the Forest Service, definition of acceptable risks is part of the job of the manager (USDA Forest Service 1997).

There is a clear dilemma between the legal, historical, and agency cultural decision framework and the findings from the most recent research on public participation, particularly as it applies to wicked problems. One the one hand, the law and precedence require the responsible federal official to make the decision. On the other hand, the literature is suggesting that it may be necessary to share that responsibility with stakeholders in order to assure short- and medium-term success. For example, Shindler and Toman observe:

> Thus effective, inclusive communication strategies must not only provide information but also focus on how people come to understand forest conditions and support policies for fuel reduction (Shindler and Toman 2003, p. 14).

Further, such complex issues as management of the Sierra Nevada national forests will most likely be dealt with over long periods of time. Is it possible to keep a broad and representative segment of the stakeholders actively engaged over such a prolonged period unless they see progress and believe that their involvement leads to better decisions?

We acknowledge the outstanding efforts of the Forest Service in applying state-of-the-art participatory processes and management techniques for dealing with risk and uncertainty. However, the fact that this resulted in 234 formal appeals, strongly suggests that there is still room for improving the process. To be sure, those who disagree with a decision are much more prone to find fault with the process leading to that decision. The management of the Sierra Nevada is a public decision and as such will always be part of a political process. The real question is whether in a decision process as protracted and extensive as the Sierra Nevada, disagreements can be managed and progress made on the ground. The unusually high number of formal appeals suggests that at the very least the Forest Service should continue to seek ways to reduce conflicts and improve the decision process. Two studies from other forest regions help to make this point. In the neighboring Pacific Northwest, studies from forest communities show that citizens recognize that the Forest Service now solicits more public comments but believe that the agency does not use this input in forming management plans (Shindler, Brunson et al. 2002). In a separate longitudinal study of residents in the Blue Mountains of eastern Oregon and Washington, researchers found that despite significant public engagement efforts by the agency, the relationship between the Forest Service and the residents appears to have eroded (Shindler and Toman 2003). Although our sample is small, our own data support these conclusions. Therefore, with hope of providing guidance for the *future* planning effort in the Sierra Nevada, we offer four design considerations.

1. **Recognize the wicked nature of the problem and lack of a single best solution.** Acknowledging that the management of the Sierra Nevada is a wicked problem is important to arriving at an appropriate characterization of the challenges facing the Forest Service in the future. One immediate implication is the recognition that there will be no optimal solution to the problems faced. No amount of scientific or analytical effort will produce a solution that addresses, with sufficient certainty, all the critical ecological and political aspects of the management problem for all stakeholders. Instead, the most productive approach for dealing with wicked problems will be to seek broadly satisfactory, rather than optimal, solutions. A satisfactory solution in this context implies one that is consistent with ecological and legal constraints and is also acceptable to the public. We characterize this approach as "collective satisficing."

2. **Redesign public involvement**. Again, there is no optimal solution to the management problem, and the greatest short-term risks for the Forest Service are related to decision processes rather than ecological outcomes. The SNFPA dilemma is a wicked problem characterized at all levels by multiple risks and uncertainties. Both the scholarly literature and best practice from a number of environmental management arenas indicate that the best approach for dealing with such decisions is to develop a decision process

that tightly integrates the best scientific analysis and the fullest possible public participation and deliberation. Future efforts should continue to focus on and expand public deliberation, informed by the best available science, analysis, and a systematic inclusion of public values.

3. **Refocus the implementation strategies.** Because risks and uncertainties associated with the human and ecological systems that constitute the Sierra Nevada region can never be entirely eliminated, adaptive management should continue to be the preferred implementation strategy. Adaptive management should be conducted at the scale necessary to address the problem. However, large-scale adaptive studies are often expensive and present greater risks. Therefore, they may be difficult to implement. One of the strategies suggested by our work is the development of learning networks. Such networks develop on the basis of stakeholders and agencies working together to solve problems, including the design and monitoring of small-scale adaptive management studies designed to address local concerns. There appears to be significant value in such experiments in educating stakeholders and building trust to move forward. We believe, that while larger-scale studies are needed, some emphasis should shift to a smaller-scale and a more collaborative approach emphasizing:
    a. implementation of a variety of relatively small experimental treatments in the field; and
    b. full integration of adaptive management in an iterative process of public deliberation that addresses sociopolitical as well as ecological uncertainties and strives to build consensus on the important risks.

4. **Reengineer the decision process**. Incorporating the three design considerations above into the forest management decision process will require that the process be reengineered in an iterative, analytic-deliberative flow. The approach we suggest incorporates the key aspects of the Forest Service's NEPA and forest-planning processes. The planning process is typically driven by identified issues that determine the scale and nature of the analysis and decision. The redesigned process (Figure 3, p. 31) begins with the identification of issues (Step 1), but it also formally seeks at the outset to identify stakeholder values and preferences about these issues (Step 2). The importance and difficulty of Step 2 should not be minimized. Appropriate identification of stakeholder values and preferences will require both sophisticated data collection and measurement techniques and sophisticated modeling. Simply soliciting public input in traditional ways will not accomplish the intended purpose because of the scale and diversity of the management task and the publics involved. Understanding and characterizing public values and priorities with sufficient precision will require the development of new capacities within the Forest Service.

   Information about stakeholder preferences and values once obtained can then be used as an important input in developing a modeled set of alternatives that are environmentally, economically, and technically feasible and also reflect the range of stakeholder preferences and values (Step 3). This step is motivated by the observation that there are generally a very large number of potential solutions that are technically feasible, not just the relatively small number usually displayed in a draft or final environmental impact

statement. Further, since there are no perfect solutions to wicked problems, only those that are more satisfying or more useful than others, it will be important to find solutions that allow the agency to move forward in an adaptive management mode with a broad base of public support. Therefore, the alternatives developed in Step 3 should be analyzed only to the extent that they can be useful to stakeholders in further refining their preferences in Step 4.

Stakeholder reactions to the alternatives might then used in an iterative, analytical process to define a small set of feasible alternatives, perhaps three to five, that best satisfy public preferences and values (Step 5). This set of alternatives could then be fully analyzed and subjected to the NEPA process, and a decision made (Steps 6, 7, and 8). The decision would then be implemented, and a combination of monitoring of results from implementation and small-scale experiments, jointly identified by stakeholders (managers, public interest groups, and scientists) to answer specific questions, could be used to provide feedback (Steps 9 and 10) to identify new issues and opportunities.

The final supplement to this report will include a more complete explication of each of the findings and design considerations listed here, including a more comprehensive documentation of the relevant literature and a more detailed discussion and a demonstration of key elements of this redesigned process.

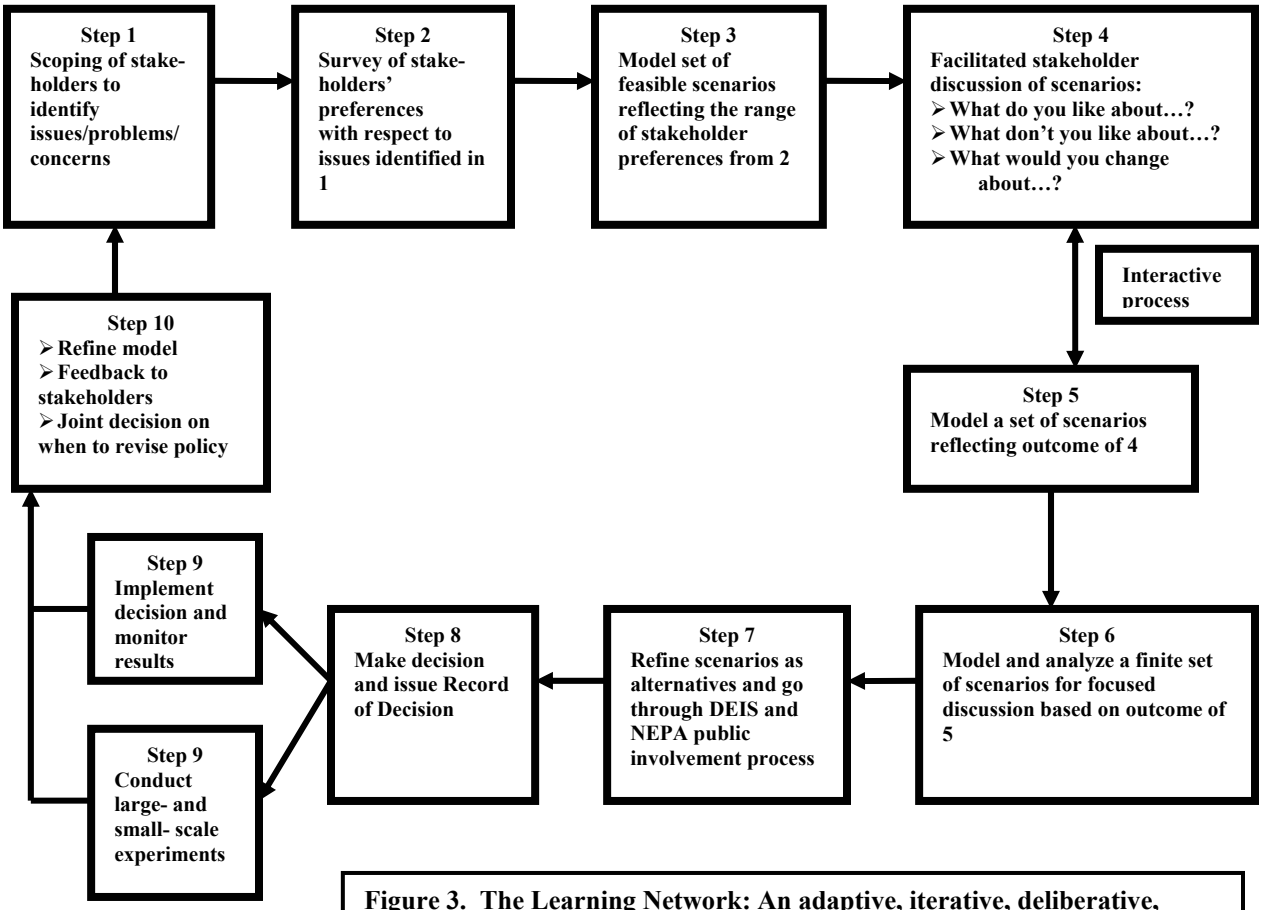


Figure 3. The Learning Network: An adaptive, iterative, deliberative, analytical, participatory process for natural resource decision-making in a wicked problem environment built upon the USDA Forest Service NEPA and NFMA planning process.

REFERENCES

Allen, G. M. and E. Gould, Jr. (1986). "Complexity, wickedness, and public forests." Journal of Forestry **84**(4): 20-23.

Buck, L., C. C. Geisler, et al., Eds. (2001). Biological Diversity: Balancing Interests through Adaptive Collaborative Management. Boca Raton, FL, CRC Press.

Chess, C., K. L. Salome, et al. (1995). "Improving risk communication in government: Research priorities." Risk Analysis **15**(2): 127-135.

Committee of Scientists (1999). Sustaining the People's Lands: Recommendations for Stewardship of the National Forests and Grasslands into the Next Century. Washington, DC, U.S. Department of Agriculture.

deFur, P. L. and M. Kaszuba (2002). "Implementing the precautionary principle." The Science of the Total Environment **288**: 155-165.

Fairbanks, F., H. Gardner, et al. (2001). Managing Wildland Fire: Enhancing Capacity to Implement the Federal Interagency Policy Phase II Report: Study of the Implementation of the Federal Wildland Fire Management Policy. Washington, DC, National Academy of Public Administration.

Green, P. E. and V. Srinivasan (1978). "Conjoint analysis in consumer research: Issues and outlook." Journal of Consumer Research **5**: 102-123.

Gunderson, L. H. (1999). "Resilience, flexibility and adaptive management: Antidotes for spurious certitude?" Conservation Ecology **3**(1): 7.

Holling, C. S. (1978). Adaptive Environmental Assessment and Management. London, John Wiley & Sons.

McLain, R. J. and R. G. Lee (1996). "Adaptive management: Promises and pitfalls." Environmental Management **20**: 437-448.

National Research Council (1989). Improving Risk Communication. Washington, DC, National Academy Press.

Renn, O. (1995). "Style of using scientific expertise: A comparative framework." Science and Public Policy **22**: 147-156.

Senge, P. M. (1990). The Fifth Discipline: The Art and Practice of the Learning Organization. New York, Doubleday.

Shindler, B., M. Brunson, et al. (2002). Social acceptability of forest conditions and management practices: A problem analysis. General Technical Report PNW-GTR-537. Portland, OR, USDA Forest Service, Pacific Northwest Research Station.

Shindler, B. and E. Toman (2003). "Fuel reduction strategies in forest communities: A longitudinal analysis of public support." Journal of Forestry **101**(6): 8-15.

Simon, H. A. (1997). Models of Bounded Rationality, Vol. 3: Empirically Grounded Economic Reason. Cambridge, MA, MIT Press.

Slovic, P. (1993). "Perceived risk, trust and democracy." Risk Analysis **13**(6): 675-682.

Slovic, P. (2000). The Perception of Risk. Sterling, VA, Earthscan Publications.

Stankey, G. H., B. T. Bormann, et al. (2003). "Adaptive management and the Northwest Forest Plan: Rhetoric and reality." Journal of Forestry **101**(1): 40-46.

Stern, P. C. and H. V. Fineberg, Eds. (1996). Understanding Risk: Informing Decisions in a Democratic Society. Washington, DC, National Academy Press.

Stubbs, M. and M. Lemon (2001). "Learning to network and networking to learn: Facilitating the process of adaptive management in a local response to the UK's national air quality strategy." Environmental Management **27**(8): 321-334.
Sunstein, C. (2003). Beyond the Precautionary Principle. Public Law and Legal Theory Working Paper No. 38. Chicago, University of Chicago Law School.
Thomas, J. W. (2003). Application of the Northwest Forest Plan in National Forests in California. Sacramento, CA, USDA Forest Service Pacific Southwest Region.
Timmerman, P. (1986). Mythology and Surprise in the Sustainable Development of the Biosphere. New York, Cambridge University.
USDA Forest Service (1997). Integrating Science and Decision Making: Guidelines for Collaboration among Managers and Researchers in the Forest Service. Washington D.C, USDA Forest Service FS-608.
USDA Forest Service Pacific Southwest Region (2001a). Sierra Nevada Forest Plan Amendment Final Environmental Impact Statement. January 12, 2001.
USDA Forest Service Pacific Southwest Region (2001b). Sierra Nevada Forest Plan Amendment Record of Decision. January 12, 2001.
USDA Forest Service Pacific Southwest Region (2003). Sierra Nevada Forest Plan Amendment Management Review and Recommendations. R5-MB-012.
Walters, C. (1997). "Challenges in adaptive management of riparian and coastal ecosystems." Conservation Ecology **1**(2): 1.
Winter, G. J., C. Vogt, et al. (2002). "Fuel treatments at the wildland-urban interface." Journal of Forestry **100**(1): 15-21.