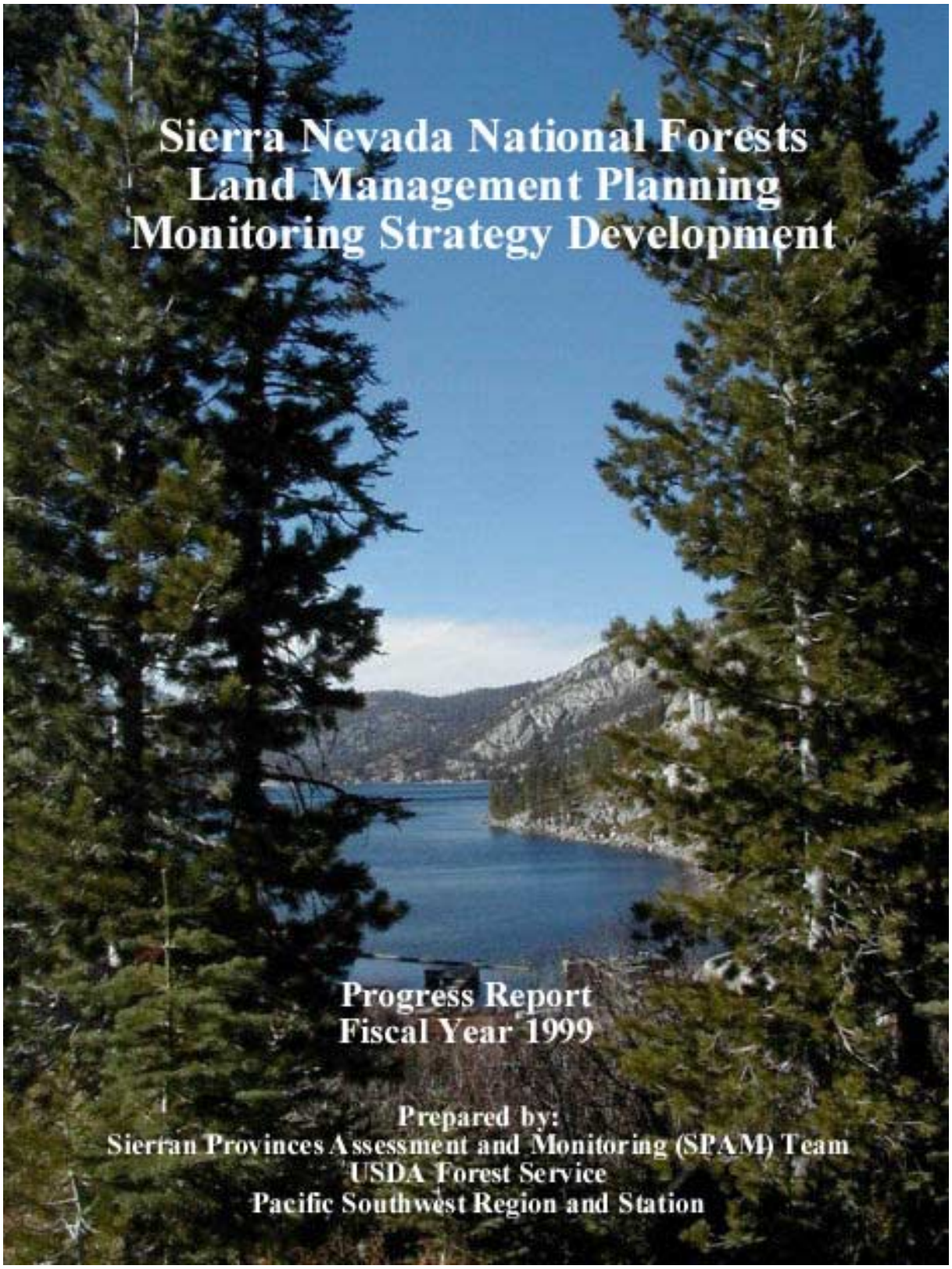

Sierra Nevada National Forests Land Management Planning Monitoring Strategy Development

Progress Report
Fiscal Year 1999

Prepared by:
Sierran Provinces Assessment and Monitoring (SPAM) Team
USDA Forest Service
Pacific Southwest Region and Station

Acronyms

EIS – Environmental Impact Statement
EPA – Environmental Protection Agency
EPC – Ecosystem Process Conceptual Model
FIA – Forest Inventory and Analysis
FHM – Forest Health Monitoring
GIS – Geographic Information System
LIDAR – Laser Altimetry
LVIS – Laser Vegetation Imaging Sensor
LRMP – Land and Resource Management Plan
LTBMU – Lake Tahoe Basin Management Unit
MIS – Management Indicator Species
NASA – National Aeronautics and Space Administration
NF – National Forest
NOI – Notice of Intent
PSW – Pacific Southwest
RD – Ranger District
SAR – Synthetic Aperture Radar
SASI – Sierran All Species Information
SNEP – Sierra Nevada Ecosystem Project
SNFP – Sierra Nevada Framework Project
SPAM – Sierran Provinces Assessment Monitoring Team
TM – Thematic Mapper
USDA – US Department of Agriculture
VCL – Vegetation Canopy Lidar
VG – Vulnerability Status Groups

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CHAPTER 1
INTRODUCTION

The purpose of this progress report is to update and describe the work of the Sierran Provinces Assessment and Monitoring (SPAM) Team in Fiscal Year 1999. For the past three years, the team has been developing a strategic monitoring framework for the 10 Region 5 National Forests within the Sierra Nevada mountain range. The goals of the monitoring strategy have been to provide a cost-effective, scientifically based mechanism for monitoring ecosystems, provide a mechanism for incorporation of findings into future decisions and actions (i.e., adaptive management), and meet Land and Resource Management Plan (LRMP) monitoring requirements and information needs for plan amendments.

Recognizing the existing work of the SPAM Team in the development of the Ecosystem Process Conceptual (EPC) Model (Manley et al. in press) and capitalizing on their efforts, the Sierra Nevada Framework for Conservation Collaboration asked the SPAM Team to develop a strategic monitoring plan for the Sierra Nevada Framework Project (SNFP) Draft Environmental Impact Statement (EIS). Thus, Fiscal Year 1999 was devoted to directly addressing the needs of the SNFP by serving as the monitoring team for the EIS. In this capacity, the SPAM Team is relying on the conceptual foundation they have built over the past 2 years of work. The EIS represents a more narrow array of monitoring questions and information needs than all the questions associated with the 11[1] National Forest LRMP monitoring needs. To the extent possible, the SPAM Team will develop the EIS monitoring plan to best meet the needs of the EIS as well as the LRMP monitoring needs already identified by existing LRMP monitoring plans.

The SPAM Team in Fiscal Year 1999 was comprised of District, Forest, Regional Office, and Pacific Southwest Research Station employees. These dedicated individuals, representing a broad spectrum of interests, worked hard to move this effort forward and their contributions were invaluable. Organization of the team following the design of the EPC Model is noted in Table 1.1. (See Appendix A for team member biographies.)

The Team budget of $1.1 million was allocated through SNFP. This allocation funded employees on 11 national forests, 3 research stations, the regional office, enterprise teams, and several expertise contracts. The work funded in Fiscal Year 1999, poised the SNFP and the SPAM Team to complete a monitoring strategy for the Sierra Nevada National Forests in Fiscal Year 2000.

[1] The Humboldt-Toyiabe National Forest has been included in the Draft SNFP EIS

Table 1.1. The Sierran Provinces Assessment and Monitoring Team (SPAM) – Fiscal Year 1999.

Group	Name	Office Location	Team Role
Executive	Pat Manley	Lake Tahoe Basin Mgmt. Unit	SPAM Team Leader
	Peggy O'Connell	Eldorado NF	Asst. Team Leader
Atmosphere	Beth Plymale	Los Padres NF	Atmosphere Team Leader
	Suraj Ahuja	Mendocino NF	Air Resource Specialist
	Mike Arbaugh	PSW / Fresno	Statistician
	Trent Procter	Sequoia NF	Air Resource Specialist
Biosphere	Vacant		Biosphere Team Leader
	Anne Bradley	Regional Office	Botanist
	Linnea Hanson	Plumas NF	Botanist
	Erik Holst	Eldorado NF	Wildlife Biologist
	John Keane	Stanislaus	Wildlife Biologist
	Michelle McKenzie	PSW/ Redwood Science Lab	Wildlife Biologist
	Rema Sadak	Six Rivers NF	Wildlife Biologist
	Matt Schlesinger	Lake Tahoe Basin Mgmt. Unit	Wildlife Biologist
	Bill Zielinski	PSW / Redwood Science Lab	Wildlife Biologist
Hydrosphere[1]	Cathy Brown[2]	PSW / Albany	Hydrosphere Team Leader
	Jim Frazier	Stanislaus NF	Hydrologist
	Carolyn Hunsaker	PSW / Fresno	Landscape Ecologist
	Amy Lind	PSW / Redwood Science Lab	Wildlife Biologist
	Ken Roby	Plumas	Fisheries Biologist
Lithosphere	Carolyn Napper	Lassen NF	Lithosphere Team Leader
	Alan Gallegos	Sierra NF	Geologist
	Gary Schmitt	Sierra NF	Soil Scientist
Sociocultural	Claudia Stuart	Mendocino NF	Sociocultural Co-Team Leader
	Wally Woolfenden	Mountain Heritage Associates	Heritage Resources
	Linda Reynolds	Inyo NF	Archeologist / Tribal Relations
Data Mgmt.	Vacant		Data Mgmt. Team Leader
	Aaron Bilyeu	Eldorado NF	Wildlife Data Analyst
	Sylvia Mori	PSW/Albany	Statistician

[1] All members of Hydrosphere group are also part of the Biosphere group.
[2] Cathy Brown served as Data Management Team leader for most of Fiscal Year 1999.

CHAPTER 2
ADAPTIVE MANAGEMENT AND MONITORING

The SPAM Team's work accomplishments fall into two main categories of work. The first category, "Completed Work," mainly consists of the deliverables for the SNFP Draft EIS. The foremost accomplishment of the Team in this regard was the finalization of the EPC Model. The Model was developed as a basis for building a monitoring strategy for the Sierra Nevada and foundation for attribute selection for the Draft EIS. In concert with the EPC Model finalization and Draft EIS considerations, the SPAM Team developed a scientific approach to prioritize terrestrial vertebrates for conservation and monitoring. We also held a statistical workshop to explore the possibilities of forming a statistical advisory group and develop partnerships between statisticians involved in monitoring programs.

To assist in the development of our monitoring strategy, the SPAM Team entered into several agreements with enterprise teams and expertise consultants. These consultants were primarily affiliated with several universities.

It should be mentioned that some accomplishments noted as completed work will continue into Fiscal Year 2000 in support of the SNFP EIS. This includes refinements to the Sierran All Species Information database, which was designed in Fiscal Year 1998, to assist in identifying species of concern. Presently this database is being used to assist in the selection of species to be monitored for the EIS.

Currently over 40 separate datasets have been identified and compiled in the amphibian database. However, as with the Sierran All Species Information database, further refinements will occur in Fiscal Year 2000.

Other on-going work for the Framework includes the completion of the draft prospectuses' for ecosystem processes associated with the Draft EIS topic areas. The prospectuses' describe our view and understanding of the operation and dynamics of ecosystem processes, and identification of attributes for analysis and monitoring. Along with the identification of these attributes, the SPAM Team continues to be instrumental in the development of a monitoring strategy for the EIS and to participate in the development of an adaptive management strategy.

Coordination and collaboration is on-going with the American Indian Tribes and communities within the Sierra Nevada bioregion.

"Fiscal Year 2000 Work," is the second category of work and includes two subsections – "Next Steps" and "Special Projects." Projects were developed to explore new ways and tools to clarify or enhance our understanding of ecosystems to guide both monitoring and research in the near future. Two remote sensing projects have been initiated to address forest structure; these projects were an outcome of a landscape workshop held in 1998. Also, a collaborative effort with the California Air Resources Board is underway to build a predictive model of ozone levels for the Sierra Nevada. Once built, the Sierra Nevada model could be used as a monitoring tool for air quality and damage to sensitive vegetation across the Sierra Nevada. Another modeling effort is almost completed that evaluates the efficiency of different experimental design options for monitoring change in the abundance and spatial distribution of species that based on their spatial

extent and pattern, local abundance and detectability. Finally, the SPAM Team is evaluating the usefulness of NetWeaver as a decision support tool. NetWeaver is a knowledge based software that enables the user to model a body of knowledge showing relationships and dependencies among network components.

included: technical merits (e.g., ability to measure, sensitivity to management, representativeness of system conditions), operational constraints (e.g., the amount of money to be allocated to monitoring, the temporal duration of the commitment for funding), and administrative priorities (e.g., value of the information to our agency, and other agencies, our partners). Interaction diagrams and other decision support techniques may be used to assist this important step. Additional information is available through the SNFP Draft EIS project record. This work will continue into Fiscal Year 2000.

The SPAM Team is continuing to identify high priority attributes to be monitored in association with each of the problem areas and alternatives identified in the draft and final EIS. The attributes identified for monitoring may be a larger, smaller, or slightly different set of attributes than those used in the analysis of issues by the EIS team. Differences in attributes used in each application would be the result of data available for EIS analysis, as well as technical, operational, or administrative considerations. This work will continue in Fiscal Year 2000.

MONITORING STRATEGY FOR THE EIS

The SPAM Team continues to develop a monitoring strategy for the selected alternatives, including sampling and analysis procedures. The monitoring strategy will be responsive to the needs of individual issues and alternatives in terms of the extensiveness, detail, and intensity of monitoring proposed. The SPAM Team will, to the extent possible, construct the monitoring strategy such that additional monitoring needs (re: other LRMP monitoring) can be readily added to the strategy without the need for significant alteration of the overall strategy. This work will continue in Fiscal Year 2000.

The Design Team or Forest Supervisors may decide that some issues not addressed in the EIS should be addressed through monitoring. Any such additional monitoring needs will be integrated into a coordinated monitoring approach. This work will continue into Fiscal Year 2000.

ADAPTIVE MANAGEMENT STRATEGY

The SPAM Team will continue to participate in the development of the overall adaptive management strategy and construct the monitoring to best accommodate the needs of the adaptive management strategy. This work will continue in Fiscal Year 2000.

PRIORITIZING VERTEBRATE SPECIES FOR CONSERVATION AND MONITORING

Bioregional conservation planning requires the development of tools and methods for prioritizing conservation needs in light of limited funding and the complexity of bioregional scale systems. For the Sierra Nevada, we needed an objective, defensible approach to prioritizing terrestrial vertebrates for conservation and monitoring. We assessed the vulnerability status of 427 native species based on estimates of population size, population trend, and change in distribution between pre-European and current time periods using both summary scores to produce a linear ranking and cluster analysis and decision tree-based models to determine the components of vulnerability status groups – high, moderate, and low vulnerability. Forty-two species were classified as highly venerable and were characterized by declining population trends and $\geq$50% range contractions. The Moderate VG group was comprised of 168 species characterized by declining population trends and <49% range contraction to stable ranges. The remaining 217 species with stable or increasing population trends and ranges were classified in the Low VG. The High VG species were unevenly distributed among the high priority environments identified as problem areas in the Draft EIS. Only one of the 42 species was hypothesized to be dependent on late-seral/old-growth forests, 10 species were dependent on

western foothills, and 21 species were dependent on riparian/meadow environments. The results of our analysis provide an objective basis for identifying priority species, and associated priority environments, for conservation that can serve to focus funding for research and monitoring on those species at greatest risk of extinction or extirpation from the Sierra Nevada Bioregion. Further details of the analysis are located in the Appendices of the Sierra Nevada Framework Project Draft Environmental Impact Statement.

SIERRAN ALL SPECIES INFORMATION DATABASE

The Sierran All Species Information (SASI) Database is a database designed to assist the monitoring team in selecting species to be monitored for Biosphere processes. The database was also designed to facilitate information sharing with other agencies and partners. It contains a separate data table for each of several taxonomic groups and it has been completed for 4 groups of terrestrial vertebrates (amphibians, reptiles, mammals, and birds) and fish. It contains taxonomic and life history data as well as current Federal and State management status information. Compilation and entry of basic taxonomy, life history, and management status data for vascular plants has also been completed; however, some additional proposed data fields remain to be filled for these species.

In addition to the database, updates have been made to vertebrate species range maps. For terrestrial vertebrates, the California Wildlife Habitat Relationships species range maps were distributed to species experts to evaluate them in both a historic and current context. Changes made to these maps were then translated onto the electronic version, resulting in revised maps showing historic and current species ranges in the Sierra Nevada. The same was done for fish using the University of California at Davis, Information Center for the Environment coverages.

AMPHIBIAN DATABASE

The amphibian database project is an attempt to pull together into a single place and common format, all amphibian sighting and survey data for the Sierra Nevada. Currently over 40 separate datasets have been identified and compiled. Most of the data is from the Forest Service, with additional data from the National Parks, California Department of Fish and Game, and private researchers. Originally, roughly half the data was in some sort of electronic format with half in hard copy only. All together, there are over 6,000 records. To date, all the datasets have been converted to a common format and have been combined into a single common database. Two additional projects were recently initiated: (1) a pilot effort with the Lassen National Forest to convert this data from its current format (Microsoft Access) to Oracle, and (2) spatially referencing all the records. Spatial referencing involves converting legal or descriptive species locality information to latitude/longitude values so that the localities can be easily mapped and analyzed using a G.I.S. system. This spatial referencing project is a joint effort among the Sierra Nevada Monitoring Team, California Department of Fish and Game, and U.C. Davis.

MONITORING STRATEGY STATISTICAL WORKSHOP

The Sierra Nevada Framework Project Monitoring Team sponsored the “Monitoring Strategy Statistical Workshop” in June of 1999. The purpose of the workshop was to share information between statisticians involved in various national survey and monitoring programs; to explore the possibilities of forming a statistical advisory group; to develop partnerships between statisticians involved in monitoring programs; to discuss issues related to funding and scale of sampling; and, to investigate marketing strategies designed to help decision makers distinguish among the levels of monitoring.

In addition to the SPAM Team and SNFP leaders, workshop attendees included statisticians from PSW, the Inventory and Monitoring Institute (Ft. Collins, Colorado), the National Monitoring and Evaluation Coordinator (Forest Service, Washington Office), Environmental Protection Agency, Bureau of Land Management, National Park Service, Natural Resource Conservation Service, and United States Geological Survey. Comments by the various attendees indicated an underlying need to institutionalize monitoring, set data standards, and maintain credibility. Additionally, attendees noted the need to bridge the gap between management and science. (A more detailed account of the workshop discussions can be found in Appendix B.)

TRIBAL RELATIONS

There are more than 50 American Indian Tribes and communities in the greater Sierra Nevada bioregion. As a follow-up to the Tribal Summit Meeting held at Lake Tahoe in 1998 to discuss the Sierra Nevada Framework Project, including the monitoring plan, a second Tribal Summit was held in May, 1999 at the Mooretown Rancheria outside Oroville. Additionally, an Eastside Summit was held in Bishop in August 1999; subregional meetings have been held in Bishop, Clovis, Placerville, Oroville, and Susanville.

EXPERTISE CONSULTATION

Enterprise Teams

The SPAM Team entered into a service agreement with the Mountain Heritage Resources, enterprise team. Mountain Heritage collaborates with the SPAM Team to develop an integrated strategy to monitor ecosystems, including sociocultural systems, that may affect or be affected by Forest Service Management in the Sierra Nevada physiographic region.
Adaptive Management Services worked as an agent of SPAM on NASA projects (see Work Accomplishments – Remote Sensing & NASA Projects).

Consultants

M. Everett Brown, a data analyst, contracted work for entry of disturbance data for the Sierran Province Aquatic Monitoring pilot study.

Jim Pushnik was contracted to write a prospectus addressing the attributes for general condition and expected change for photosynthesis/respiration processes. (Department Biology, California State University, Chico)

Amy Merrill wrote the prospectus for portions of the nutrient cycling metaprocess model. (Department of ESPM, University of California, Berkeley)

Sonja Manor provided the modeling, programming and statistical expertise to design simulations to estimate the confidence of frequency of occurrence and distribution data. (Department of Mathematics, Humboldt State University)

FISCAL YEAR 2000 WORK

WORKING ARRANGEMENT

Pat Manley and Peggy O'Connell will continue to serve as the primary SPAM Team representatives interacting on a regular basis with the EIS and Science Integration Teams. They will facilitate communication and interactions between the EIS, Science Integration, and SPAM Teams to ensure that products are integrated and complementary. SPAM Team members will participate in meetings, discussions, and working groups as frequently as possible and as needed. Sierra Nevada

NEXT STEPS

Monitoring Plan Design for the EIS

The next major step in the development of the monitoring plan is to design data analysis and data collection schemes. Data analysis schemes entail detailing how attributes will be analyzed to answer attribute specific questions (statistical analysis) as well as how overarching questions and goals will be assessed based on the results of monitoring (decision-support models). One or more work sessions will be organized to assess and develop design options.

The development of a data collection scheme involves multiple steps. First, data sharing across questions and topic areas needs to be assessed to maximize benefits from data collection efforts. Then, a variety of analysis techniques will be used to assess the most effective and efficient integrated data collection scheme possible. Considerations for meeting the individual data collection objectives of each topic area will require additional, perhaps prior, evaluation. For example, sampling options for detecting trends in the distributions of many species are in the process of being evaluated through a simulation modeling exercise. The results of this analysis will be used to evaluate the ability of integrated design options to meet the information needs of many questions. Finally, design options will need to be evaluated and developed for data collection efforts that fall outside the optimal integrated design selected.

Monitoring Plan Field Testing for the EIS

A number of field trials and pilot data collection efforts have been identified for Fiscal Year 2000. The team identified efforts that will contribute significantly to reducing uncertainty about the design and success of the proposed monitoring plan, and that are feasible to implement and will yield results quickly such that they can be incorporated into the monitoring strategy by the end of the fiscal year.

SPECIAL PROJECTS

Remote Sensing & National Aeronautics and Space Administration (NASA) Projects

The landscape working group of the SPAM Team sponsored a workshop, "Integrated Strategy for Measuring Forest Structure Using Ground, Photography, and Satellite Data." The purpose was to explore new opportunities and guide both monitoring and research directions during the next five years. The SPAM Team focused the objective of the workshop on capturing the strengths and weakness of current and emerging remote sensing technologies as they pertain to the measurement of forest structure. The workshop generated a paper; the full paper is in press as a Government Technical Report.

As an outcome of the workshop, the following projects were developed.

The USDA Forest Service currently has several key management and research questions that focus on wildlife habitat, forest condition, fuels and old growth. Many of the key forest structural attributes that ecologists consider important to answer these questions are not available or not sufficiently accurate over large regions. These attributes include canopy cover, life form, large tree density, tree size, biomass, crown volume, height to live crown and vertical foliar diversity. Given the wealth of existing and planned NASA remote sensing data during the Earth Observing System-era, the Forest Service has targeted new initiatives that apply remote sensing data and techniques to the routine retrieval of forest characteristics for forest mapping, monitoring and inventory.

Project 1

Forest Characterization and Inventory Using Airborne and Space-based Lidar – University of Maryland, Department of Geography

Of particular interest is lidar remote sensing using both airborne platforms and data from NASA's Vegetation Canopy Lidar (VCL)

mission, the latter providing the first global sampling of canopy vertical and horizontal spatial structure.

The overall goal of this work is to develop the use of lidar (laser altimetry) remote sensing for the recovery of forest structural attributes crucial for forest management. The results of this project will help the monitoring portion of the Sierra Nevada Conservation Framework determine if forest structure can be monitored for the Sierra Nevada using soon-to-be-available air-borne or satellite sensors. A collaboration among VCL scientists and USDA Forest Service scientists, the pilot project has three main objectives:

1. Apply and validate techniques for the direct retrieval of important forest structural characteristics from lidar remote sensing over National Forest and National Parks in the southern Sierra Nevada of California.
2. Initiate work to model or infer other important forest and habitat characteristics for the Sierra Nevada region from lidar and fusion with other remotely sensed data.
3. If results are favorable, discuss what type of infrastructure would be necessary for the operational use of VCL and air-borne lidar data to monitor forest structure across the Sierra Nevada.

Project 2

Forest Structure From Multispectral Fusion – University of Michigan, Engineering and Computer Science Department

The monitoring portion of the Sierra Nevada Conservation Framework is interested in three-dimensional structural characterizations of trees as these attributes are critical to forest management needs with regard to late-seral old-growth status, wildlife habitat analysis, and fire fuels characterization. This work is a pilot effort to evaluate the extent that remotely sensed data can be used in a multistage sampling scheme to provide laterally extensive, spatially explicit and accurate attribute estimates for forest structure. The results of this 3-year project will help the Framework determine if forest structure can be monitored for the Sierra Nevada using remote sensing.

The project will create a number of prototype information products for evaluation by the Forest Service and potential use by the monitoring team of the Framework. Archival and new remotely sensed data will be acquired for two pilot study transects, one each in the northern and southern Sierra Nevada. These data sets (optical multispectral scanner such as Landsat TM, airborne laser altimetry (lidar) such as SLICER and LVIS, orbital synthetic aperture radar such as SIR-C/X-SAR, ERS-1/2, JERS-1, Radarsat; and airborne synthetic aperture radar such as the JPL AirSAR) will be orthorectified into Universal Transverse Mercator coordinates and coregistered. Two fusion approaches will be tested. In the first, optical and SAR image data sets will be used to independently generate initial products (such as land-cover classification, vegetation structure and biophysical retrievals), and fusion of these products will be accomplished using a knowledge-based decision tree or neural network. In the second approach, fusion of the orthorectified image data will be used to generate the output products directly using combined algorithms. Accuracy assessments, based on independent data, will be applied to the results of both approaches in order to evaluate the merits and limitations of each approach.

University of Maryland and NASA Goddard Space Flight Center flew Lidar imagery under their Earth Observing Satellite program over the Sierra National Forest in October 1999. Plans have been made for one graduate student from each university to work in California on these and related projects for the next few years.

PSW is in the process of providing existing ground-based data such as FIA/FHM plot data,

other vegetation data on permanent plots such as the Sierra National Forest has, and other ancillary data that may be of use in working with the LIDAR or radar projects, Digital Elevation Models, classified Landsat TM imagery, etc.

Design Options for Monitoring Vertebrate Species Biodiversity

The National Forest Management Act requires that the Forest Service maintain viable populations of all native species of plants and animals. Understanding the conditions that foster long-term persistence of populations and species requires field and analytical methods that are only recently being developed and are not necessarily agreed upon (Groom and Pascual 1998). The estimation of population size is usually considered essential to this process. Estimates/indices of population size and growth with a satisfactory level of statistical precision are very difficult and expensive to attain, even for a few species (Thompson et al. 1998; White et al. 1982; Zielinski and Stauffer 1996, Forsman et al. 1996). Adherence to stringent assumptions is inescapable and the resulting cost is substantial. Although this approach may be necessary to monitor a few particularly vulnerable or imperiled species (e.g., under 'Expected Change' monitoring module as defined by the Monitoring Team of the Sierra Nevada Framework Project, United States Department of Agriculture [USDA] 2000), it is difficult to achieve for more than a few species. For this reason, the Monitoring Team has decided that monitoring the change in *geographic distribution* of the greatest number of species possible provides a strong proxy for the sizes of their populations. Change in the spatial extent of distribution is considered by Temple and Wiens (1989) as a 'secondary population parameter'. This approach (referred to by the Monitoring Team as the 'General Condition' monitoring module for the 'Species and Population Dynamics' process) is presumed to provide a safety net of baseline information about the status of many of the Sierranspecies.

Although the number of individuals of a species can vary without changing its geographic distribution, it is unlikely that significant population increase or decrease can occur without some change in the proportion of range that is occupied. In fact, some have argued that the proportional occupancy of 'sink' versus 'source' regions or habitats is a viable method of monitoring change in abundance (Bowers 1996, Manor 1998). Furthermore, 'atlas' monitoring approaches that report only the presence or absence of a species in a sampling block can be as effective in detecting population decline under some circumstances as measures of abundance (e.g. Bart and Kloeisewski 1989, Robbins et al. 1989). The pattern of change in abundance, however, can strongly influence the ability to detect the change (McKelvey et al. 1998).

The purpose of this project is to evaluate the efficiency of a systematic array of survey points – at which presence/absence data are collected for multiple species – to detect change in the abundance and spatial distribution of species that differ in their spatial extent and pattern, local abundance and detectability. A Monte Carlo simulation model of presence/absence monitoring (technically detection/non-detection monitoring) is used to determine how survey grid dimensions affect the ability to detect changes in spatial distribution for classes of species that vary in their patterns of distribution, abundance and their detectability. Statistical hypothesis testing will be used to evaluate the power of various grid dimensions to distinguish change in geographic distribution and to determine the magnitude of decline in occupancy that is required before a reliable change in distribution can be declared. The modeling and statistical evaluations will aid in the consideration of a survey grid to maximize the ability to detect change for as many species as possible. Conversely, this exercise will also help inform decisions about which types of species – in terms of the spatial extent and pattern of distribution and abundance – are *unlikely* to be sampled at sufficient intensity to monitor change in their geographic distributions.

The first set of simulations are complete and the final report is in review and will be available for distribution early in 2000.

Ozone Assessment

The Sierra Nevada Conservation Framework monitoring program has identified several management and research needs associated with air pollutant concentrations, distributions, and associated biological effects. One of the key pollutants affecting vegetation throughout the Sierras is the phytotoxic compound ozone. An effort is underway to characterize current ambient ozone exposure and ozone injury patterns, and to develop a method for estimating potential future risks to sensitive vegetation throughout the Sierra bioregion.

Ambient Ozone Patterns and Ozone Injury Risk to Ponderosa and Jeffrey pines in the Sierra Nevada.

Passive ozone filters were installed and changed at 85 locations throughout the Sierra Nevada every two weeks by a group of about 20 Forest Service and Park Service employees between May 15 and October 1, 1999. Exposed filters were mailed to the Riverside Fire Laboratory and stored in a –18°C freezer. Chemical analysis of filters is underway, and preliminary ambient ozone surfaces for the Sierra Nevada Bioregion are now available (Figure 2.1). Foliar evaluation has been completed at 26 foliar injury plot locations along the westside of the Sierra Nevada.

In addition, a work group has been formed to conduct the data analysis, model development and Risk Assessment work that will be conducted over the next year. This group consists of Mike Arbaugh, Andrzej Bytnerowicz, Haiganoush Preistler (PSW Statistician), Trent Procter, Jenny Rechel (Geographical Information Systems expert), Susan Schilling (Programmer) and Rocio Alonso Del Amo (visiting Fulbright Scholar). Other groups will be examining the data using different techniques. These groups presently include William Hogsett (Environmental Protection Agency, Corvallis) and ESRI. Other groups have also expressed interest.

Smoothed 24 hr average summer ambient ozone distribution over the Sierra Nevada Bioregion between May and October 1999. Red colors indicate high ozone concentrations, and blue colors indicate areas of low concentrations. Notice that in addition to high concentrations in the southern Sierra Nevada, an additional area of high ozone concentration exist extending from the San Francisco-Sacramento area to the Lake Tahoe Basin. Numbers indicate average points of low and high ozone concentrations in ppb.

Figure 2.1 Ambient Ozone Patterns for the Sierra Nevada: Preliminary Summer 1999 Ozone Distribution

NetWeaver

The SPAM Team is currently evaluating the usefulness of the NetWeaver knowledge base software package for the monitoring program. NetWeaver is a decision support tool based on fuzzy logic that enables the user to model a body of knowledge showing relationships and dependencies among network components leading to interpretation and evaluation of information. NetWeaver can integrate a wide variety of qualitative and quantitative data of varying detail and confidence levels. In our application, such a model can be used to evaluate long-term monitoring data with regards to management activities. The SPAM Team plans to evaluate the usefulness of NetWeaver as a needs assessment tool, and ultimately, as a tool to model and evaluate monitoring data for use in making adaptive management decisions.

The team is presently testing NetWeaver as a data needs-assessment tool. Status and Change monitoring questions and proposed attributes for answering those questions were entered into NetWeaver for each of the monitoring topic areas (old forests, lower westside hardwoods, aquatic/riparian/meadow ecosystems, fire/fuels, noxious weeds, soil productivity, air quality, and sociocultural conditions). Data entry for the sociocultural conditions topic area is still in progress. This Status and Change knowledge base will aid team members in determining the usefulness of various attributes, as well as allow the team to maintain consistency of attributes across topic areas.

CHAPTER 3
KEY PROCESSES & THEIR PROSPECTUSES: FURTHER DEVELOPMENT OF THE EPC MODEL

BACKGROUND

The EPC Model (Manley et al. in press) serves as the scientific basis and ecological foundation of the monitoring plan. The monitoring plan is designed to be responsive to changing information needs by providing a clear set of questions to answer, a specified time frame to answer each question, and the ability to add and delete questions without redesigning the conceptual foundation or experimental design of the plan. This adaptability achieves the goal of a monitoring plan with long-term usefulness.

The conceptual model is centered on ecosystem processes and considers humans as part of ecosystems. The conceptual model also provides an objective, broad-based, and structured framework by which we can select specific indicators, or attributes to monitor and adjust to monitoring needs over time. It can also assist in identifying gaps in current knowledge.

The EPC Model has a hierarchical structure that consists of three levels: the ecosystem model, the sphere model, and the process model. The ecosystem model consists of the basic components that make up an ecosystem, and the interactions between them. It includes five spheres: Atmosphere, Lithosphere, Hydrosphere, Biosphere, and Sociocultural Sphere. The five spheres are defined by a unique set of functions, components and structures, which are highly interactive. The second level of the model, the sphere model, describes the key processes within each sphere. The third level of the model, the process models, describes the mechanics of each of the key processes. These models serve many purposes including the selection of attributes to monitor – attributes that best reflect the operation and integrity of that key process.

The Process Prospectuses are intended to serve as documentation of our view and understanding of the operation and dynamics of the ecosystem processes. They serve as a guide for selecting strong attributes that can be accurately measured and easily interpreted[2].

Each ecosystem process contains two parts: (1) essential elements and outcomes, and (2) the influence of affectors on the process. Essential elements are the components required for the process to occur or influence its rate of occurrence. Outcomes represent what the process produces. Affectors are actions, primarily human activities, which change some aspect of a process. The affectors identified in the process models are specific to the Sierra Nevada and National Forest System lands. Thus, it is at this stage where the Model becomes specific to the particular area for which a monitoring plan is being developed. Consequences are the results of the affectors acting on the process, and represent potential focal areas for assessment and monitoring.

[2] Key processes are documented in detail. Copies of these prospectuses can be obtained from Ms. Peggy O'Connell, Eldorado National Forest, Placerville, California.

Attributes generally consist of a set of specific measures that reflect one or more aspects of the process through direct measures, or measures of its elements, outcomes, or affector consequences. The candidate attributes identified need to address three complementary approaches to monitoring: (1) attributes that reflect the general condition of the process over time, (2) attributes that reflect expected changes over time resulting from key affectors operating in the ecosystem, and (3) attributes that reflect the key affectors. Criteria for identifying candidate attributes differ for general condition, expected change, and key affector attributes. General condition attributes are ideally direct measures of the process, but are often measures of the outcomes and essential elements of the process models. Expected change attributes are primarily measures of the consequences identified in the process model. Affector attributes are derived by careful consideration of the cause-effect relationships of the greatest interest.

KEY PROCESSES

The key processes identified in each of the five spheres of ecosystems are listed below. Each Process Prospectus contains a description of the process and its dynamics at the bioregional scale. The prospectuses contain a list of candidate attributes to monitor for the general condition of the process, and for the changes expected to occur to the process as a result of affectors (i.e. Management activities, climatological change, etc.). The approach and rationale for choosing the candidate attributes is described, as well as a quantitative analysis, and the required metrics. A discussion of identified research needs is also included. The description of the process and the general condition attributes are applicable to any monitoring project. The prospectuses become specific to a particular planning area with the expected change attributes and key affectors.

Sphere	**Key Processes**
Atmosphere	Chemical Reactions Hydrodynamics Radiative Transfer Transport and Dispersion
Biosphere	Photosynthesis and Respiration Individual Vitality Individual Behavior Species and Population Dynamics Interspecific Interactions Community Dynamics Trophic Dynamics Evolution and Genetic Dynamics
Hydrosphere	Infiltration Evapotranspiration Surface Water Movement and Storage Groundwater Water Movement and Storage Surface Water Chemical Reactions Groundwater Water Chemical Reactions Surface Water Thermal Dynamics Cyrologic Dynamics
Lithosphere	Erosion and Sediment Dynamics Physical and Chemical Weathering Volcanism Tectonics
Sociocultural	Land and Resource Transactions Human and Population Dynamics Economic Activity Technological Innovation and Diffusion Human Social Structure Dynamics Human Communication Dynamics of Attitudes, Beliefs, Values and Behaviors

ATMOSPHERE

The **Chemical Reactions** process is the thermal and photochemical decomposition, recombination, and exchange of atoms and molecules in the atmosphere, which can be heterogeneous or homogenous in character. This key process includes the interactions among different gaseous and particulate chemical components, and determines their

relative concentrations and distributions. The atmosphere is composed primarily of nitrogen, oxygen, and argon, whose proportions have remained relatively constant over geologic time. Trace gases comprise the remaining 1 percent of atmospheric gases, and their concentrations vary within ecological time scales, primarily as a result of human activities (Seinfeld and Pandis 1998). Although their proportions are small, trace gases are extremely important in atmospheric chemistry. They react to create many major atmospheric phenomena, such as smog, acid deposition, stratospheric ozone depletion, and anthropogenically forced climate change (Seinfeld and Pandis 1998). Examples of consequences resulting from affectors acting on Chemical Reactions include changes in visibility, climate, and stratospheric ozone.

The second process, **Hydrodynamics**, includes the interactions of water, in its liquid, solid and gaseous states, with other chemical and physical factors. Hydrodynamics is specifically defined here the condensatory processes leading to the formation of water particles, whether liquid or solid, some of which fall from the atmosphere and reach the ground (modified from Huschke 1959). Although the atmosphere contains only about 0.001 percent of the Earth's water, atmospheric moisture is a primary factor in atmosphere chemical reactions, radiation transfer, and atmospheric dynamics (Seinfeld and Pandis 1998). Water vapor influences the global heat balance by retaining much of the infrared radiation emitted by the Earth's surface, and by the reflection of incoming solar radiation by clouds. Energy is circulated within the atmosphere as water undergoes transitions from gas to liquid to solid. Cloud and fog drops are the site of aqueous phase chemical reactions that are important producers of secondary species. Examples of the consequences resulting from affectors acting on Hydrodynamics process include: changes in precipitation distribution and changes in cloud cover and thickness.

Radiative Transfer is the process that includes the interception and absorption of solar energy (Seinfeld and Pandis 1998) and the transmission and transformation of electromagnetic energy within the atmosphere (modified from Manahan 1991). The atmosphere provides a crucial role in the maintenance of the global heat budget by governing radiative exchange. As solar energy enters the atmosphere, a proportion is reflected to space by atmospheric gases, clouds, particles, and by the earth's surface. The remainder is

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Photosynthesis and Respiration are a unique and essential set of processes that, because they are conducted by living organisms, reside within the biosphere. Because the product of photosynthesis (carbohydrate) is the primary reactant for respiration, we treated these two reactions together in a single process. Moreover, the result of photosynthesis, and the net balance between photosynthesis and respiration, are accounted for by similar

measures: gross and net primary productivity and secondary productivity (Odum 1971). Examples of consequences resulting from affectors acting on Photosynthesis and Respiration include: changes in ratio of productivity/biomass, changes in phytomass, and changes in trophic structure.

The next six processes include a continuum from the level of individuals to communities. Although we realize that some of the processes are nested subsets (population and species dynamics are affected, for example, by the vitality and behavior of individuals) we identified multiple processes at the individual level to better differentiate processes operating at various temporal and spatial scales.

Individual Vitality addresses the integrity of those functions essential to the existence and reproductive success of an organism. This includes all the physiological processes necessary to sustain somatic and reproductive function in animals, plants and fungi. Examples of consequences resulting from affectors acting on Individual Vitality include: changes in disease resistance, changes in individual growth rate, and changes in morbidity.

Individual Behavior is the process that describes the array of actions and reactions demonstrated by an organism, and includes behaviors related to habitat selection (foraging and resting), parental care, communication and reproduction (Alcock 1984, Begon et al. 1990). Variation in the spatial and temporal (circadian and seasonal) distribution of behavior is an integral component of this process as well. This process applies exclusively to animals, and examples of consequences resulting from affectors acting on Individual Behavior include: changes in temporal distribution of behavior (e.g., daily movements), changes in diet, and changes in habitat use and selection.

Species and Population Dynamics include all the essential elements that account for spatial and temporal variation in the size, density and distribution of species and recognizable populations within species (Begon et al. 1990). This includes elements that account for variation in composition (age structure and sex ratio), growth rate, and persistence of populations—or metapopulations—over space and time (Hanski and Gilpin 1991, Boyce 1992, Hanski et al. 1996, Beissinger and Westphal 1998). Examples of consequences resulting from affectors acting on Species and Population Dynamics include: changes in demographic structure, changes in habitat use, and changes in geographic range.

Interspecific Interactions are a set of processes including competition, predation, parasitism, mutualism and commensalism (Begon et al. 1990). Because of the large number of interactions among species, we limit our interpretation of Interspecific Interactions to well known and strongly dependent or interdependent interactions between two (or relatively few) species or functional groups. Interactions may be between a prey species and a specialist predator species, or simply between two groups of organisms (e.g., conifers and mychorrizal fungi). Examples of consequences resulting from affectors acting on Interspecific Interactions include: changes in species composition, changes in trophic structure, and changes in population growth rate.

A community is an assemblage of species that occur together in the same space and time (Odum 1971). Biotic communities result from interactions among individuals, populations and species; their collective properties include species diversity, biomass and productivity. Vegetation communities tend to be identified on the basis of their dominant plant species and described by the species composition and developmental stage (seral stage) of the assemblage (e.g., Sawyer and Keeler-Wolf 1995). Aspects of the field of Landscape Ecology address the distribution and composition of community types over large areas (Turner 1989). Fire, often characterized as a disturbance, is also a process and is considered here as an integral part of the **Community Dynamics** process. The succession of plant and animal change that follows fire is an important component of Community Dynamics. Examples of consequences resulting from affectors acting on Community Dynamics include: changes in

species richness, changes in proportion of age classes, and changes in gradients of structural conditions.

Trophic Dynamics is the flow of energy within and among trophic levels (producer, primary consumer, secondary consumer, etc.) within a community or larger unit of organization. Trophic Dynamics reflect species behavior and activities in an ecosystem, and therefore, the number of species performing participating in particular activities can serve as an index of the flow of energy within and among trophic levels. The proportion of species in different trophic levels can be used to assess the energy base and the trophic dynamics of the biota (Karr and Dudley 1981), especially because more direct measures of productivity can be ambiguous (Schindler 1987). The loss of secondary or tertiary consumers can have important effects on ecosystems (Estes 1995, Power et al. 1996). Examples of consequences resulting from affectors acting on Trophic Dynamics include: changes in species richness within trophic level or functional group, changes in food-web structure, and changes in secondary productivity.

Evolution is morphological, physiological or behavioral change with continuity in successive generations. Genetic dynamics consists of all the processes that affect the size and composition of the gene pool, and that affect the variation available for natural selection, and the potential for random effects such as genetic drift (Futuyma 1986). The evolutionary process has produced some species that are endemic to the Sierra Nevada (Graber 1996) and species that are not endemic vary in regard to their degree of phylogenetic uniqueness (Vane-Wright et al. 1991, Freitag and Van Jaarsveld 1997). The **Evolution and Genetic Dynamics** process includes the conditions that led to the variation in taxonomic diversity and genetic diversity that exist today, as well as the conditions that permit continued adaptation to change in the future. Examples of consequences resulting from affectors acting on Evolution and Genetic Dynamics include: changes in gene flow/gene migration, changes in demographic structure, and changes in population size.

HYDROSPHERE

Infiltration is the process that governs the rates and amount of water transferred from the atmosphere to ground and surface water. It is the process whereby water enters the soil surface and begins to move downward toward the soil profile. Once beneath the surface, water is available to the roots of plants, as well as soil fauna. When precipitation rates exceed infiltration rates, water runs off surfaces. Change in infiltration may affect both amounts and timing of runoff, and timing and amount of available soil moisture. Activities that change the characteristics of the soil at the surface, or the covering of soil are the primary affectors of this process, and include affectors such as Roads and Landings, Fire, Urbanization, and Domestic livestock grazing. Examples of consequences resulting from affectors acting on Infiltration include: changes in flow regime, changes in soil aeration, and changes in water availability.

Evapotranspiration includes the series of processes and mechanisms through which water is transferred from liquid to atmospheric states. Evaporation occurs from surfaces; transpiration from the pores or through the surface of plants. Transpiration rates are influenced by the capabilities of plants to retain water, by temperature, and by relative humidity. Activities that result in changes to the amount and types of vegetation or to microclimate can affect this process. Examples of consequences resulting from affectors acting on Evaporation include: changes in flow regime, changes in humidity, and changes in microclimate.

In the broad sense, the **Surface Water Movement and Storage** process is the movement and storage of water brought to Earth via precipitation that exceeds infiltration. Movement occurs in easily recognizable drainage features such as streams and rivers, and also across the surface, usually during times of heavy precipitation. Water is stored temporarily in depressions on the surface, and in the longer term in features that are key elements of aquatic

affectors acting on Surface Water Movement and Storage include: changes in flooding timing and duration, changes in flow regime, and changes in surface water storage capacity.

The **Groundwater Movement and Storage** process is the subsurface movement of water through the soil/rock matrix. Movement below the surface is much slower than on the surface because of gravity and pressure differences created by features such as soil and geology. Some ground water surfaces at springs, seeps, and at channels. Examples of consequences resulting from affectors acting on Groundwater Movement and Storage include: changes in water table levels and changes in rate of loss or creation of springs, seeps, and ponds.

The two processes pertaining to chemical reactions, **Surface Water Chemical Reactions** and **Groundwater Chemical Reactions**, represent the chemical properties of water including the exchange of chemicals within the hydrosphere and between the hydrosphere and other spheres (Hynes 1970, Wetzel 1983). Water is an essential component in, and a medium for, many chemical and biochemical reactions and cycles. Oxygen exchange and nutrient cycling (including nitrogen, phosphorus, and micronutrients) are primary processes that occur within surface water, as well as between surface water and the Lithosphere, Atmosphere, and Biosphere (Wetzel 1983). Surface Water Chemical Reactions is the key process that considers the cycling of chemicals and their interactions with biological and physical elements in the surface water environment. Examples of consequences resulting from affectors acting on Surface Water Chemical Reactions include: changes in eutrophication rates, changes in nutrients, and changes in water temperature. Groundwater Chemical Reactions is the cycling and interactions of chemicals with biological and physical elements in the groundwater environment. The quality of groundwater, with its secondary links to surface water and biota, is the primary consequence of change to this process. Other examples of consequences resulting from affectors acting on Groundwater Chemical Reactions include: changes in conductivity and changes in nutrient composition.

The two thermal processes, **Surface Water Thermal Dynamics** and **Cryologic Dynamics**, describe the array of processes representing the heating, cooling, and freezing of water. Surface Water Thermal Dynamics is the exchange of heat within surface water, and between surface water and the atmospheric and terrestrial environments. The thermal dynamics of water are driven by its high specific heat, and are affected by factors such as depth and currents. Stream temperatures typically fluctuate more quickly but over a smaller range than do lake temperatures (Hynes 1970). In stream systems, thermal dynamics are influenced primarily by the following elements: stream discharge, surface area, temperature of groundwater inflow, inputs of solar energy and geothermal conditions (Gordon et al. 1992, Kattelmann 1996). In lake systems, basin topography, inputs of solar energy and wind are the primary factors affecting thermal dynamics (Wetzel 1983, Hauer and Hill 1996). The unique density characteristics of water are a primary factor in thermal stratification and mixing of lakes. Thermal stratification and mixing are processes of thermal dynamics that occur in both streams and lakes, but rates and degrees differ substantially in these two environments (Hynes 1970). Examples of consequences resulting from affectors acting on Surface Water Thermal Dynamics include: changes in thermal stratification, changes in mixing/turnover dynamics, and changes in freeze-over timing and duration.

Cryologic Dynamics, the second thermal key process, is the suite of processes and physical features produced or derived from snow pack, snow avalanches, and glaciers. Features affected or formed by snow pack and snow avalanches are common in the Sierra, but are limited to higher elevations where snow accumulations and condition and topography necessary for their genesis are present. Glaciers had overwhelming influence on Sierra landforms and are still present, but are not currently a predominant force acting on the landscape. Examples of consequences resulting from

affectors acting on Cryologic Dynamics include: changes in snow avalanche rates and changes in glacier size and movement.

LITHOSPHERE

Erosion and Sediment Dynamics includes the sub-processes of erosion, mass wasting, and sediment transport and dispersion. Erosion is the wearing away of the land surface by running water, wind, or ice. Mass wasting is a general term for the dislodgment and downslope transport of soil and rock material under gravitational forces, including slides, flows, and heaves (Carson and Kirby 1972, Bates and Jackson 1995). Sediment transport and dispersion is the suspension, movement, and settling of sediment through water or air (Bates and Jackson 1995). These sub-processes were grouped into one process because they exhibit similar consequences in response to affectors. For example, erosion and mass wasting respond similarly to Roads and Landings in that both produce sediment and result in reduced soil productivity.

Physical and Chemical Weathering is the breakdown of rocks and minerals by chemical activity and physical forces. Climate is the primary modifier of the rate at which weathering occurs. In physical weathering, rocks disintegrate by agents such as ice, water, and wind. In chemical weathering, hydrolysis, hydration, acidification, oxidation, and dissolution breakdown, synthesize, and recombine minerals (Brady 1984). As such, weathering can be viewed as both a destructive and a synthesis process. Chemical and physical weathering occur simultaneously and, although driven by different agents and sub-processes, their combined effects constitute a relatively homogenous class of outcomes. Examples of consequences resulting from affectors acting on Physical and Chemical Weathering include: changes in the rate of weathering, changes in the rate of soil formation, and changes in the amount of essential nutrient elements.

Volcanism is the process by which magma and its associated gases rise into the crust and are extruded onto the Earth's surface and into the atmosphere. Volcanism is an igneous process and is a dominant geomorphic process within the Sierra Nevada that is responsible for the nature, origin, and development of the present landform (USDA Forest Service 1996). At the present time, at least one active volcano, Mammoth Mountain, exists in the Sierra Nevada. Examples of consequences resulting from affectors acting on Volcanism include: changes in geothermal activity and changes in landform.

Tectonics contributes to the formation of landforms through the movement of the Earth's crust. The lithosphere is composed of a small number of rigid plates (Isacks et al. 1968, Morgan 1968). Entire plates may move with reference to fixed axes, and rocks within plates spread from the margins of plate formation (crust) toward zones of subduction. Mountain belts, such as the Sierra Nevada, are the result of physical contact between plates along margins of plate formation. The Sierra Nevada is currently an active area of tectonic activity. Tectonic processes operate at continental and global scales. In the Sierra Nevada, examples of consequences of affectors on Tectonics include: changes in frequency of seismic events and changes in ground water properties.

SOCIOCULTURAL

We have organized sociocultural processes along a gradient from human interactions with the biophysical environment through functions involving human subsistence, and material culture to increasingly intangible dynamics of social relationships, communications, and values.

Land and Resource Transactions are human actions that directly impact biophysical systems. Types of transactions include resource acquisition, land and resource modification, waste deposition, and outdoor leisure activities. Specific actions include timber harvest, livestock grazing, prescribed burning, land development, water storage and diversion, landfill use, and pollution emission.

Anthropogenic affectors identified in the Ecosystem Models biological and physical spheres are thus a subset of Land and Resource Transactions. Isolation of these transactions from both the sociocultural dynamics that give rise to them, and the environmental impacts they generate, assists in disentangling the complex of variables impacting ecosystems (Dietz and Rosa 1994). Through Land and Resource Transactions, humans obtain the environmental materials and services necessary to sustain other sociocultural processes. These include the air, water, and habitable territory critical to human populations; the timber, forage, and forest scenery important in various forms of Economic Activity; and the cultural materials that help sustain traditional attitudes, beliefs, values, and behaviors. Examples of the consequences of affectors acting upon Land and Resource Transactions include changes in consumptive uses of land and resources, changes in non-consumptive uses of land and resources, and change in environmental conditions and services.

Human Population Dynamics encompasses change or stability in the demographic characteristics of human populations, including their size, rate of increase or decrease, spatial distribution, and socioeconomic profile. The dynamics of population movement, health, reproduction, fertility, and mortality are included within this key process (Borgatta and Borgatta 1992). Human population size, rate of growth and distribution are critical variables in modeling ecosystem impacts (Dietz and Rosa 1994), although the environmental impacts of population growth may be mitigated. Population socioeconomic characteristics that control per-capita consumption also condition effects upon environmental systems. These characteristics include affluence, gender, and age (Ehrlich and Holdren 1971, Dietz and Rosa 1994, Duane 1996). Human populations supply critical elements to other sociocultural processes: markets, labor, information (including genetic code) (Hawley 1986, Machlis et al. 1997), and creativity (Simon 1981). Examples of the consequences of affectors acting upon Human Population Dynamics include changes in human health and vitality, changes in human population size and distribution, and changes in human population sociodemographic characteristics.

Economic Activity may be defined as the production of goods and services for markets and their consumption via market exchange. The EPC Model definition (Manley et al. in press) focuses on the capitalist model of economic activity. Sub-processes include the investment and expenditure of money; saving and interest payment; trade; cinnerce; industry; manufacturing; shipping; re-manufacturing; and, the storage of products and materials. Thus the production, sale, processing, and distribution of marketable resource commodities (e.g. timber, minerals, water) are included within this key process set. Important outcomes of economic activity include wages and income, employment, and revenues.

Due to its effects through expanding technology on land and resources, economic activity may be the single most influential factor driving degradation of global ecosystems (e.g. Forester and Machlis 1996). Economic activity is also a critical variable conditioning impacts on social systems (e.g. Dietz and Rosa 1994). An important result of the interaction of economic activity and other sociocultural processes is the development and maintenance of community well-being. The well-being of resource dependent communities has often been defined in terms of commodity production and related attributes such as income and financial capitol. More recently, several other forms of capital (physical capital, human capital, and social capital) have also been viewed as integral to community well-being.

Technological Innovation and Diffusion is defined as change in tools, techniques, ideas, and material culture, and the adoption and diffusion of these changes across human populations. Technological Innovation and Diffusion includes development of concepts and ideas applied to the management of environmental systems and human communities, as well as tools, technologies, and ideas applied to other issues. Technological Innovation and

Diffusion facilitates human adaptation to environmental conditions by supplying tools and technologies to modify those conditions. Technology is therefore a critical variable mediating human impacts upon environmental systems (Ehrlich and Holdren 1971, Heberlein 1974). This process set can also precipitate significant changes in Human Population Dynamics (e.g., the enormous surges in global human population after the Agricultural and Green Revolutions), Economic Activity (e.g., the powerful effect of information technologies on the American economy 1990-1998) and other sociocultural processes. Examples of the consequences of affectors acting upon Technological Innovation and Diffusion include changes in data, ideas, and knowledge; changes in standard methods; and changes in the availability of new ideas and technologies.

Human Social Structure Dynamics give rise to formalized, or informal but routine, relationships within and among individuals and groups. This process suite describes the dynamics of relationships within and among families, tribes, communities, governments, and interest groups. Human social institutions require certain natural, socioeconomic, and cultural resources (Machlis et al. 1997); members of communities-of-place may undertake similar actions in resource-related activities (Starrs 1996). Social inequalities can also cause environmental change (Boyce 1994). Thus, human social organization is a critical variable in modeling human-environment interrelationships (Duncan 1959, Stern et al. 1992). In addition to stressing environmental systems, however, social structures can mitigate human impacts upon biophysical systems (Heberlein 1974), and provide for human adaptation to environmental and sociocultural conditions (e.g., Buckley 1967). [An important outcome of this process is the development of social capital: the ability and willingness of a community to work together for common goals (Kusel 1996).] Examples of the consequences of affectors acting upon Human Social Structure Dynamics include changes in agreements, changes in policies, and changes in relationships between individuals, groups, and institutions.

Human Communication is the transmission of messages between human parties (e.g., individuals, organizations, societies) through a common system of symbols or signals (Harre and Lamb 1986). The exchange of information is essential to most key processes within the Sociocultural Sphere: Economic Activity and Technological Innovation and Diffusion (information exchange), Human Social Structure Dynamics (human communication), and the Dynamics of Attitudes, Beliefs, Values, and Behaviors (socialization). Examples of the consequences of affectors acting upon Human Communication include changes in the legibility and credibility of a message, and change in response.

The process suite comprising the **Dynamics of Attitudes, Beliefs, Values, and Behaviors** describes transformations in and, in some cases, expressions of human attitudes, beliefs, and values. Subjective perception, including the sense of place, is an important consideration in this process set (Williams and Stewart 1998). The lack of a consistent cause-and-effect relationship between beliefs and behavior makes assessment and management of this critical feedback loop problematic (Heberlein 1974). Nevertheless, attitudes and beliefs condition human activities and impacts upon ecosystems, and are acknowledged as critical variables in modeling human impacts upon ecosystems (Stern et al. 1992). Examples of the consequences of affectors acting upon the Dynamics of Attitudes, Beliefs, Values, and Behaviors include changes in attitudes, changes in perception, and changes in sense of place.

METAPROCESSES

Nutrient Cycling is a biogeochemical cycle in which inorganic nutrients move through the soil, living organisms, air, or water (Allaby 1994). In Nutrient Cycling, chemical nutrients, the building blocks of biomass, change form as they associate with various components of each sphere. Begon et al. (1990) suggest that we can envision pools of chemical elements existing in compartments, some occurring in the atmosphere (carbon in carbon dioxide, nitrogen

as gaseous nitrogen), some in the Lithosphere (calcium as a constituent of calcium carbonate, potassium in feldspar), some in the Hydrosphere (nitrogen in dissolved nitrate, phosphorus in phosphate, carbon in carbonic acid), and some in living organisms in the Biosphere (carbon in cellulose or fat, nitrogen in protein, phosphorus in adenosine triphosphate). Thus, all spheres and many of their individual components are involved in the Nutrient Cycling metaprocess. Processes such as Photosynthesis and Respiration (Biosphere), Chemical Reactions (Atmosphere), Infiltration (Hydrosphere), and Physical and Chemical Weathering (Lithosphere) are identified as essential elements for Nutrient Cycling. In this metaprocess, examples of consequences of affectors include: changes in primary productivity, changes in accumulation of organic debris, and changes in decomposition rates.

Hydrologic Cycling is the distribution and circulation of water among the atmosphere, the Earth's surface, soil and underlying rocks, and biota. In Hydrologic Cycling, water in various states moves through the Atmosphere, Biosphere, Lithosphere, and of course the Hydrosphere. The major source of water is oceans, although freshwater systems are also contributors. Radiant energy makes water evaporate into the atmosphere, winds distribute it, and precipitation brings it down to Earth, where it is stored for periods of time in living organisms of the Biosphere, or in catchments associated with the Lithosphere and terrestrial Hydrosphere (Begon et al. 1990). Water may or may not return to the ocean before it is evaporated and transpired into the atmosphere. In Hydrologic Cycling, all of the essential elements consist of processes previously identified in spheres, such as Hydrodynamics (Atmosphere), Photosynthesis and Respiration (Biosphere), Evapotranspiration (Hydrosphere), and Surface Water Movement and Storage (Hydrosphere) (Ward 1995). In this metaprocess, examples of consequences of affectors include: changes in evaoptranspiration rates, changes in glacial/polar melting rates, and changes in precipitation distribution, frequency and intensity.

PROSPECTUSES APPROACH AND CONTENT

Following are abbreviated versions of one Process Prospectus from each sphere as an example of the structure and content of the prospectuses.

ATMOSPHERE — HYDRODYNAMICS

The hydrodynamics process consists of that portion of the hydrologic cycle taking place in the atmosphere. The atmosphere itself holds less than .001% of the total global water supply. Despite its apparently small storage capacity, the atmosphere's water content is of critical importance, since water vapor plays a major role in short term weather patterns, long term global climate changes, and atmospheric chemistry.

The atmosphere supplies a vital "hydrologic link" in the transport and phase distribution of water. Water is transferred from the earth's surface to the atmosphere through evaporation, and transported around the earth by wind. Precipitation is the primary mechanism for transporting water from the atmosphere to the earth, and may occur in different forms such as rain, snow, hail, sleet, or freezing rain.

Water vapor makes up only a small percentage of the atmosphere gases (0-4% by volume), however, it plays an important role in atmospheric processes, including weather, climate, and atmospheric chemistry. Human activities may impact the atmospheric portion of the hydrologic cycle in two ways. Air pollutants may either (1) alter the chemical composition of atmospheric water, or (2) influence changes in the physical equilibrium among the different states of water.
Water in the atmosphere may interact with anthropogenic pollutants as a gas, liquid, or

solid. Initially, a substance may be incorporated into droplets during the nucleation and growth phases of cloud formation. Anthropogenic particles may serve as condensation nuclei, providing a surface upon which water molecules form droplets. The droplets may then be exposed to other air pollutants of anthropogenic origin.

The deposition of contaminated precipitation and fog/cloud/mist onto vegetation, soil, rock, and bodies of water has varying ecological consequences. Wet acidic deposition can cause damage to aquatic ecosystems, soils, and vegetation (CARB 1993a), distinct from those caused by exposure to pesticides and heavy metals (USGS 1998a; Schnoor 1996). Selected species of fish, amphibians, macroinvertebrates, and zooplankton are acid-sensitive (Engle and Melack 1997), and alterations in soil chemistry could adversely impact flora and soil microfauna (Binkley 1989).

Human activities can also alter the hydrologic cycle through the production and emission of greenhouse gases. The resulting changes in global climate would affect the uptake, transport, and deposition of water by the atmosphere.

Candidate Attributes for General Condition

Outcomes are defined as products or emergent properties of a process. There are two outcomes of the atmospheric hydrodynamics process, (1) precipitation (rain and snow) and (2) cloud/fog/mist/rime ice. Atmospheric water vapor and terrestrial water sources (runoff, surface water, and groundwater) are considered to be essential elements, and were not considered as outcomes. To characterize the general condition of the atmospheric hydrodynamics process, it was decided to select candidate attributes to reflect each outcome. Essential elements were also reviewed for suitability. The following attributes were identified as being suitable for monitoring General Condition in the Sierra Nevada; (1) precipitation volume and chemistry; (2) cloud/fog/mist volume and chemistry; and (3) surface water chemistry

Precipitation chemistry: The following parameters would be considered for measurement: precipitation quantity, cations (Ca2+, Mg2+, Na+, K+, and NH4+), anions (Cl-, NO3-, and SO42), pH, conductivity, organic acids, heavy metals, and pesticides.

Cloud/fog/mist chemistry: The following parameters would be considered for measurement: cloud/fog/mist quantity, cations (Ca2+, Mg2+, Na+, K+, and NH4+), anions (Cl-, NO3-, and SO42-), pH, conductivity, organic acids, heavy metals, and pesticides.

Surface water chemistry: The following parameters would be considered for measurement: ANC, cations (Ca2+, Mg2+, or, and

is therefore limited to acidic materials (N&S) (CARB 1992, 1993a, Engle and Melack 1997). While there is ample evidence to support the effects of climate change on California's hydrologic cycle, the long-term nature of these changes are more appropriately suited to General Condition.

Key affectors are defined as the primary human activities that may affect the rates, outputs, or essential elements of the process. Based on the above rationale, key affectors for the atmospheric component of the hydrologic cycle are those that would impact the rate and amount of evaporation, the amount and distribution of water vapor contained in the atmosphere, and the quantity and quality of outputs (precipitation and clouds). Affectors that are known to impact the Sierra Nevada include:

(1) Gaseous pollutants: The Earth's atmosphere is composed primarily of gaseous nitrogen, oxygen, water vapor, and argon. The remaining gaseous constituents compose less than 1% of the atmosphere, but are crucial to both the chemical equilibrium of the atmosphere and radiative balance of the Earth (Seinfeld and Pandis 1998). Atmospheric gases are transferred to the Earth's surface by dry or wet deposition processes. Dry deposition involves the direct transfer of chemical species without the aid of precipitation. Wet deposition involves the transfer of gases in aqueous form, following their dissolution in airborne water droplets. Changes in the levels of selected gaseous compounds can create adverse health impacts in humans and animals, decreases in visibility, damage to sensitive plants, and alterations in global energy balance (IPCC 1995; Smith 1990; Seinfeld and Pandis 1998). In future decades, it is difficult to project whether air pollutant emissions will increase or decrease. Demographic data indicate that the state population will increase from 32 million in 1996 to 47 million by the year 2020 (California State Department of Finance 1997), but new pollution control measures are expected to keep total emissions from increasing (CARB 1995; 1996). However, since rates of population growth are expected to remain high in the Central Valley and Sierra foothills, it seems likely that pollutant exposures will continue to rise in the years ahead (CARB 1993b).

(2) Particulates: Particulate matter is defined as any substance, except pure water, that exists as a liquid or solid in the atmosphere, and is of microscopic size, but larger than molecular dimensions (Seinfeld and Pandis 1998). Fine particles have an aerodynamic diameter ≤ 2.5 μm, and coarse particles have diameters > 2.5 μm. Particulates contain a wide variety of chemical species including anions (sulfate, nitrate, chloride), cations (ammonium), trace metals, carbonaceous materials, crustal elements, and water. Primary particles are those that are directly emitted into the atmosphere, and secondary particles are those that form after reaction with other airborne compounds. Particles are removed from the atmosphere by precipitation, fog, cloud, and mist (wet deposition) processes, and serve as a medium for the transport of atmospheric pollutants to ecosystems. Particles are also involved in the mechanisms of anthropogenic forcing of global climate.

The following attributes were identified as being suitable for monitoring expected change in the Sierra Nevada bioregion: (1) precipitation chemistry; (2) cloud/fog/mist chemistry, and (3) surface water chemistry.

BIOSPHERE—SPECIES AND POPULATION DYNAMICS

The National Forest Management Act requires that the Forest Service maintain viable populations of all native species of plants and animals. A viable species consists of individuals that can survive and reproduce, and of populations that are well distributed throughout the species range. These self-sustaining populations must be sufficiently abundant and have sufficient genetic diversity to display the array of life-history strategies and forms that will provide for their persistence and

adaptability in the planning area over time (COS 1999). Species viability is influenced by many factors, including its size, sex ratio, age structure, reproductive and survival rates, and geographic distribution (COS 1999). In addition to total population size, the spatial distribution of local populations, and of individuals within populations, can have profound effects on the likelihood of persistence (COS 1999). Thus, there are many levels at which management activities could influence the population dynamics of a species.

A bioregional scale approach is needed to adequately address the geographic distribution of populations. With the continued development and loss of habitat on nonfederal land, the responsibility increasingly rests on the national forests to provide the conditions necessary for species to persist over time. Since habitat loss and fragmentation are major factors that put species at risk, the Forest Service planning process should stress the quantity, quality, and distribution of habitat necessary for species viability (COS 1999). Habitat alone cannot be used to predict wildlife populations, however. The presence of suitable habitat does not ensure that any particular species will be present or reproduce, therefore, populations of species must also be assessed and continually monitored (COS 1999).

General Condition and Expected Change monitoring are both prescribed in this prospectus as complementary monitoring elements that assess species viability. General Condition monitoring provides coarse information about population trends (i.e., changes in distribution) on a diverse and large number of species. It does not target specific species, but rather gathers data on a large number of species and serves as an early warning mechanism for population declines that may have otherwise gone undetected until a species was so rare that it is at risk of extirpation (e.g., the wolverine). Expected Change monitoring provides detailed information on population trends of a selected set of species that are of specific concern or interest. The goal of Expected Change monitoring is to detect smaller increments of change in shorter time frames than General Condition monitoring. Together, these two approaches provide a balance between extensively monitoring a large number of species across the Sierra Nevada study area and intensively gathering detailed population data for those species of greater interest.

The units of measurement for this process are individuals of native and exotic species, not their habitat. Wildlife-habitat relationship models are usually not sufficient to predict the occurrence of species in their typical habitat; we trust only the methods that produce verifiable confirmation of the presence of a species. We believe that the collection of presence/absence data at points throughout the planning area will be a firm foundation for the development of new, hierarchical, models of habitat use (e.g., Carroll et al. submitted) that may be useful for future monitoring efforts.

Candidate Attributes for General Condition

The candidate attributes are the ‘distributions of all species (or relevant higher taxa for inverts, nonvascular plants, and fungi) that are detectable using established protocols’. The probability of detection is known, to some level of confidence, for many of the species typically included in the multi-species protocols noted in Table 1. The distributions of species that have low probabilities of detection, and those that are rare or occur across a small portion of the bioregion are not candidates for attributes for this process.

Candidate Attributes for Expected Change

It would be impossible to monitor the status and assess the viability of all species; therefore, it is necessary to focus on a smaller subset of species. The Committee of Scientists (1999) suggested the term “focal species” for this subset of species to allow a variety of approaches to selecting those species to monitor and to assess for viability. Therefore, in order to evaluate the influence of affectors on Species and Population Dynamics (Fig. 1), it is necessary to first filter through the complete

assemblage of species that occur in the Sierra Nevada and to select candidate focal species. We will then determine the specific candidate attributes that could be monitored for each species.

We identified focal species of concern (COS 1999) whose populations either, (1) have declined in the recent past or have a high likelihood of changing in the near term because of characteristics of the species or its population, or (2) have especially high sociocultural value and population status is simply of interest. Focal species of concern represent a "fine filter" approach (Noss and Cooperrider 1994) to assessing the viability of all species (see introduction to section 3.4.5), targeting specific species and collecting more detailed information on each species.

Most data for applying criteria to identify focal species were derived from existing data sources and agency lists. Species listed as federally Threatened, Endangered, or Special Concern were provided by the U.S. Fish and Wildlife Service. Species listed as state Threatened, Endangered, or Special Concern were provided by the California Department of Fish and Game. Endemic and exotic species were identified by consulting species field guides and taxonomic identification manuals. Only those species endemic to the Sierra Nevada study area were considered endemic. Sierran endemic species were considered of concern because of their restricted distribution and their significant contribution to biological diversity. Harvested species were identified by consulting California Department of Fish and Game. Management Indicator Species were identified by consulting existing LRMPs for each of the 10 National Forests. Forest Service Sensitive Species were based on the April 1999 revision of the Region 5 Sensitive Species List. Vulnerability due to population decline was the only designation that required data collection and analysis by the monitoring team and is described below. Three hundred and forty-six focal vertebrate species were identified based on the various criteria described above.

Vulnerability due to population declines was determined based on a statistical analysis of population size, population trend, and changes in distribution for each vertebrate species (Keane and Zielinski in prep). These data were obtained by querying recognized taxa experts for estimates of the magnitude of change in population size, trend, and distribution over 150 years. The use of expert opinion has proven highly valuable in rapid assessments of risk to species viability (e.g., FEMAT 1993). Data for each of these three variables for all vertebrate species in the Sierra Nevada study area (approximately 400) were subject to a cluster analysis (SPSS statistical software) and decision tree analysis (S-PLUS statistical software) resulting in the identification of three vulnerability groups: High, Moderate, and Low. Species in the High and Moderate Vulnerability groups were included as focal species, with each of the two vulnerability groups being assigned to a different species monitoring group (Group C and D, respectively).

We identified six basic types of monitoring data for describing the status and change of species populations. They span a range of data types from distribution to demographic data. We included the need to first establish presence for some species before any real monitoring can be conducted, as well as the recognition that no monitoring may be appropriate for some species for which the interest is too low or the investment too high. We identified one or more of these types of monitoring data as appropriate for each species and species group. They are intended to serve as a starting point for more detailed description of monitoring data needs and specific metrics to be used to describe changes in species populations over time. The type of monitoring data appropriate to gather for each focal species varies according to vulnerability and reasons for inclusion as a focal species.

Table 3.1 Types of monitoring data ordered by increasing level of investment and data resolution.

Monitoring Data	Definition
None	We may decide that it is not appropriate to invest in monitoring populations of some species based on the range of the species or the feasibility of obtaining monitoring data relative to the level of interest or concern.
Presence	A few species are suspected to be extirpated from part or all of their range in the Sierra Nevada study area. Detecting the presence of these species is the first priority in a monitoring scheme to address their status.
Frequency of Occurrence	Frequency of occurrence is an accounting of the number of survey sites occupied by a species. It can provide both status and change data. The number of sites occupied by a species provides an index of population size, and analysis of occupied sites provides data on habitat relationships. Changes in the number of sites occupied by a species provide a crude measure of trend.
Distribution	Distribution data consist of changes in the presence of species across a number of sample locations. It is a spatially explicit version of frequency of occurrence data. At a spatial scale as large as the Sierra Nevada study area, changes in the distribution of species represent ecologically significant information on the status and change of populations.
Relative Abundance	Relative abundance is an index of abundance that can be derived a myriad of ways depending on the sampling method. Typically it is based on a count of individuals, but it can also be based on a count of occupied sites in a given sample area.
Population Size	Population size is a direct estimate of number of individuals. For very rare species, it could be an absolute count (census) of the population size (vs. an estimate).
Territory Occupancy	The proportion of all territories monitored (most likely a sample of all territories) that are occupied over time. This also includes territory turnover, which is the change in the individuals occupying a given territory over time. This type of data applies primarily to terrestrial species.
Reproductive Success	Reproductive success can be measured a variety of ways, depending on the species and sampling method. Reproductive success is most often pursued for bird species, where the number of eggs and fledglings can be readily enumerated to calculate number of young produced per adult. It is also described for some taxa in terms of the proportion of females reproducing. However, an index of the number of young produced per adult or breeding pair can be derived for most species.
Population Demography	Many measures of population growth and structure are available for use in monitoring. They range from individual attributes of a population (e.g., age ratios, sex ratio) to derived rates of change (e.g., mortality rates, fecundity rates, growth rates).

HYDROSPHERE – CRYOLOGIC DYNAMICS

Cryologic dynamics refers to processes occurring to water in its solid state at or near the ground surface (atmospheric and subsurface water are considered in other SNEPM processes). The most common expression of cryologic dynamics in the Sierra Nevada is the annual snowpack. Other expressions of cryologic dynamics in the Sierra Nevada include avalanches, permanent ice formations (glaciers) and seasonal ice formations (lake and stream surface freezing, rime, frost-heave, etc.).

The snowpack is a principal component of the hydrologic cycle in the Sierra Nevada (Kahrl 1978). It supplies much of the approximate 25 km3 of water discharged annually by the Sierra Nevada, as a critical source of water for urban, industrial, recreational, and agricultural uses as well as in-stream needs of native, rare, and economically valued biota (Kattelmann 1996).

Principal outcomes of cryologic dynamics in the Sierra Nevada include, in addition to the snowpack, a period of spring snowmelt runoff, sublimation, infiltration, evapotranspiration, mass movement (avalanching), acidic pulses in streamflow during snowmelt runoff (and the potential for sporadic lake acidification), glaciation and nutrient cycling. Localized outcomes include plant breakage, crushing of surface organic material, rock fracturing, soil erosion, etc.

Cryologic dynamics is a major component of seasonal habitat requirements for numerous aquatic Sierran wildlife species and communities. Numerous terrestrial wildlife species are served by the Sierran snowpack for winter habitat requirements.

The socioeconomic value of cryologic dynamics in the Sierra Nevada is substantial. To capture the runoff afforded by the Sierran snowpack, an extensive infrastructure of water developments on streams in the Sierra Nevada has been established during the twentieth century. Fourteen of the fifteen principal watersheds in the Sierra have been dammed, creating a range-wide network of reservoirs, diversions (ditches, flumes, tunnels) and hydroelectric power plants (California Department of Water Resources 1974). Water supply is a significant business in California due to the state's large population and intensive agricultural industry. The system of dams and diversions that exist is essentially responsible for supporting the economy of California. The reservoir system in the Sierra Nevada also provides a summer recreational opportunity on many of its national forests. The Sierran snowpack is also important to the winter recreation industry in California. Activities such as alpine and Nordic skiing, snowboarding, snowmobiling, and scenic enjoyment contribute to community stability throughout much of the Sierra Nevada.

Candidate Attributes for General Condition

Candidate attributes are described below for the major outcomes.

1) Snowpack depth: Snow cover depth throughout the full latitudinal range of the Sierra Nevada, at elevations ranging up from 1300 m in the south to 1000 m in the north. Metric options include depth (centimeters of snow) at selected points (currently collected manually as part of the California Cooperative Snow Survey), or as approximations of depths at selected points based upon automated sensing of snowpack water content.

2) Snowpack water content: Amount of water (as snow equivalent) throughout the full latitudinal range of the Sierra Nevada, at elevations ranging up from 1300 m in the south to 1000 m in the north. Metric options include water content (centimeters of water) at selected points (currently collected manually as part of the California Cooperative Snow Survey), or as automated measurements at selected points (currently collected as part of the California Cooperative Snow Survey).

3) Snowpack density: Density of the snowpack throughout the full latitudinal range of the Sierra Nevada, at elevations ranging up from 1300 m in the south to 1000 m in the north. Metric options include density as a calculated value based on snow depth and water content at selected points (currently collected as manual or automated data as part of the California Cooperative Snow Survey).

4) Snowpack cover/aerial extent: Snow-covered area (km2) throughout the full latitudinal range of the Sierra Nevada, at monthly intervals throughout the winter. Remote imagery is a primary source of this information.

5) Streamflow: Streamflow amount (m3/sec) and timing that quantifies net water production for the area/watershed gauged. Currently collected at selected locations throughout the Sierra Nevada by the US Geological Survey and California state agencies.

6) Avalanches: Frequency and geographic distribution of snow avalanches. No known systematic monitoring.

7) Acidification: Water chemistry monitoring of acidic pulses, typically as part of the first snowmelt flush, or chronic acidification from lake and stream chemistries monitored periodically. No known systematic monitoring.

8) Glaciation: Presence and aerial extent of glaciers. No known systematic monitoring.

Of the potential affectors, only climate change is believed to have an opportunity to change to status of the cryologic dynamics process at the bioregional scale. Climate change is occurring based on increased temperature readings worldwide over the past several decades (Suplee 1998) but its effects are difficult to quantify over short time periods.

Vegetation management practices are not expected to have a measurable effect on the outcomes of cryologic dynamics (i.e., snowpack water content, runoff, acidic deposition effects) at the bioregional scale.

Candidate Attributes for Expected Change

Candidate attributes are those expected to change over the next decade at the Sierra Nevada scale. As discussed above, neither vegetation management or precipitation modification is likely to be so. Climate change, notably its temperature attribute, may be able to be correlated with some change in cryologic dynamics. Other potential changes are the timing of melt off of the snow cover. Higher temperatures could potentially produce an earlier, and shortened, melt period. If runoff amounts remain constant, but the melt period is shorter, higher flows would be expected.

Changes in the timing and magnitude of runoff potentially affect many aquatic and biological goals of the Sierra Nevada EIS. Snowmelt flow changes could drastically influence flows into, through and from special habitats (e.g., seeps, springs, fens, bogs). Increased flows could elevate erosion rates and produce more sediment in stream channels. Changes in snow cover area could drive changes in faunal and floral distributions.

Attributes of expected change related to the above discussion are currently being monitored by out-agency scientists at such organizations as NOAA, the Natural Resource Conservation Service and the California State Department of Water Resources. Temperature, precipitation and snowpack attributes in the Sierra Nevada are well documented.

What remain as potential attributes for the Forest Service to monitor are the indirect effects of such change, with candidates as follows:

- Vegetation composition change in relation to temperature increase, especially in the area near the lower margins of the snowpack zone.

Mass wasting: slope, rainfall, antecedent soil moisture, vegetation, material properties (soil texture, material depth, soil strength).

Sediment transport and deposition: channel gradient, sediment supply, amount of channel flow or discharge.

In lieu of directly measuring erosion and sediment in watersheds several models have been developed to estimate erosion and sediment yield. These models rely on measuring or estimating variables that the model uses to determine erosion and sediment yield. Some models that have been used are: A Mathematical Model of Soil Erosion and Deposition Process, Rose et al; Universal Soil Loss Equation; Revised Soil Loss Equation; Component Modeling; Mystery Model; Stochastic Model; Combination Models; WEPP, ONEROS, WATSED and Modified Soil Loss Equation. Other methods for estimating soil loss include: Using Cesium- 137 , erosion bridges, erosion pins, troughs, fabric dams, ground cover transects, photo points, and rainfall simulator.

Candidate Attributes for General Condition

Erosion Hazard Rating is the relative rating of soil erodibility (California Soil Survey Committee 1989), and is a unitless metric.

Effective Soil Cover or ground cover density is the average percentage (%) of cover over an area. Cover includes: living vegetation (grasses, forbs, and prostrate shrubs); plant and tree litter (fine organic matter); surface rock fragments; and applied mulches (straw and chips) (USDA Forest Service 1995).

Soil Organic Matter is the organic fraction of soil. It includes plant, animal, and microbial residues, fresh and at all stages of decomposition, and the relatively resistant soil humus (USDA Forest Service 1995). Soil Organic Matter is measured in the upper 12 inches of the soil profile and is expressed as a percent (%) of what is found under natural conditions for the same or similar soils.

Soil porosity (indirect method) refers to that portion occupied by air and water (Brady, 1974). Change in total soil porosity is used instead of change in soil bulk density because it correlates more directly to change in plant growth. Generally, the relationships between soil bulk density and plant growth is not linear; that is, incremental increases in bulk density does not necessarily cause incremental decreases in plant growth. To set limits of allowable bulk density increases that are responsive to effects on plant growth, requires that increments of allowable increase become smaller in absolute value as bulk density increases. This is accomplished by basing the allowable increments on decreases in total soil porosity USDA Forest Service 1995). Soil porosity is expressed as percent pore space which is equal to:

$$\% \text{ pore space} = \frac{100 - \text{bulk density X } 100}{\text{particle density}}$$

Erosion rate is the amount of erosion over an area within a given period of time. Erosion rates can be expressed as tns/ac/year, kg/ha/year, or yds3/ac/yr, m3/ha/decade by watershed basin or ordinal ranking by very high, high, moderate, low.

Sediment delivery rate is the amount of sediment accumulated in an aquatic environment over a given period of time. Sediment delivery rate can be expressed as tns/ac/year, kg/ha/year, or yds3/ac/yr, m3/ha/decade by watershed basin or ordinal ranking by very high, high, moderate, low.

Sediment-delivery ratio is the ratio of sediment yield of a drainage basin to the total amount of sediment moved by sheet erosion and channel erosion (Chow 1964, p. 17-12). Sediment-delivery ratio is expressed in percent (%).

Sediment load is the solid material (load) that is transported by a natural agent, esp. by a stream. The total sediment load of a stream is equal to bed-material load plus wash load, and is expressed as the dry weight of all sediment that passes a given point in a given period of time. Sediment load can be expressed as a distribution

curve of sediment particle size over total volume or weight of sediment.

Sediment particle size is the general dimensions (such as average diameter or volume) of the particles in a sediment. Sediment particle size can be expressed as a fraction of an inch (1/4, 1/2), or in millimeters.

V* (V-star) is defined as the fraction of pool volume filled with fine sediment, and is an excellent index of sediment supply (watershed condition), water quality, and stream habitat. V* is easily measured by setting up transects and measuring water depths and sediment depths; a crew of two can set up and measure a monitoring reach in a day or two. V* is very objective, quantitative and will show a rapid response to changes in sediment supply and watershed processes. V* is a ratio of the total depth of sediment divided by the pool depth.

Landslide frequency rate is the percentage of landslide area per unit area over time.

Key Affectors

Erosion and sediment dynamic processes have been altered by several affectors that include: roads, vegetation management, wildfire fire, grazing, mining, recreation, and residential development. These affectors have resulted in disturbing the watershed to varying degrees.

Roads

Landings are areas along forest roads that are designed for decking and loading logs. There are approximately 45,000 miles of inventoried "system" roads on National Forest's in the bioregion. Roads are being reviewed for decommissioning, obliteration, reduced maintenance and improvements. Problems with roads are; native surface roads, road location, road design (insloped and water control) or lack of design. Some landings are concentrating water and accelerating erosion due to poor location and design. Roads increase runoff and accelerate erosion resulting in increased sediment delivery rates. This is due to direct sediment inputs from road prisms and concentrations of surface water from roads onto upland slopes and riparian areas. Roads can increase erosion rates many times above natural rates. When soil loss and sediment transport occur at unusually high rates in response to some human disturbance, erosion and sedimentation become issues of concern for long term soil productivity and water quality.

Vegetation Management

Vegetation management includes all human activities directed at the manipulation of vegetation. This includes: timber harvest, slash treatment, prescribed burning, brush control, post-fire revegetation efforts, and type conversion. According to SNEP, 1996, current logging practices has had relatively little effects on soil erosion compared with the roads used for removing the logs. In practice, comparatively little soil leaves harvested areas. Several factors appear to mitigate potential adverse effects of harvesting. These factors include: only small and discontinuous areas are compacted to an appreciable extent; infiltration capacity is generally maintained over large areas; a lot of slash is left behind; and some type of vegetation usually reoccupies the cutover land quickly. A major assumption that forest's have made is that accelerated erosion does not occur if soil cover is maintained at 50% for slopes less then 30% and 70% for slopes greater then 30%. Another important factor to date has been the concentration of harvests in the most productive sites and most accessible areas, which tend to be on relatively gentle slopes. Timber harvest activities have occurred within the bioregion for over 100 years. Soil physical properties, accelerated erosion and sediment delivery rates may not have fully recovered from past timber harvest activities.

Mechanical treatment of slash and hand grubbing are common practices to artificially regenerate a forest. These treatments compact and expose soil to precipitation events and extreme temperature changes. Some watersheds are degraded with high sediment loads in channels.

Prescribed fire and fuels reduction (timber thinning) is a growing practice that will increase in the next 5-10 years. Prescribed fire will

consume litter and organic matter and could reduce groundcover, accelerate erosion and increase sediment delivery. Very little research exists on the consequences of prescribed fire to erosion rates and sediment delivery rates.

Wildfire

Fire kills and/or consumes vegetation and organic matter, thereby reducing hillslope stability. The volatilization of vegetation and dead organic material reduces effective soil cover, that protects nutrient rich surface soils from accelerated erosion. This erosion or the wearing away of the land surface by running water may occur as sheet, rill, and gully erosion, or gravitational creep.

The loss of vegetation and additional runoff will result in increased landslide and debris flow occurrences. Roots provide strength to soil and when they are damaged or killed, the soils are less stable. Burned slopes are highly susceptible to debris slopes the first winter, but the susceptibility decreases with time. A debris flow is a mass movement involving rapid flowage of soil and rock under various conditions. Landslides are more likely to occur starting after the third winter, when the anchoring effect of roots is lost due to the decay of dead plants.

Fires also increase runoff and erosion due to the formation of hydrophobic layers. The water repellent layer is formed when litter and organic matter that has accumulated at or near the soil surface is heated sufficiently to volatilize and/or decompose the organic matter. This layer, which may be at the surface or driven deeper into the soil by intense heat, is resistant to wetting, thus causing runoff and erosion. Rainfall will infiltrate only to a limited depth before the wetting front reaches the water repellent layer. When the thin mantle above the water repellent layer becomes saturated, it along with some of the underlying water repellent layer may be carried off by surface runoff (Dabbing et al. 1967).

All of the above processes lead to increased sediment yields and sediment deposits in channels and streams. The loss of this nutrient rich surface soil leads to reduced soil productivity, which in turn may lead to reduced sustainability of plant and animal productivity and health.

Residential Development

Residential construction around lake Tahoe has been a major contributing factor in accelerating erosion and increasing nutrients to the lake (SNEP 1996). Residential development has occurred at the forest-urban interface and in private land in-holdings within National Forest system lands. Residential development is not considered a major affector to the Erosion and Sediment Dynamics process on National Forest System lands with the Sierra Nevada Bioregion.

Domestic Livestock Grazing

Domestic livestock grazing is the consumption and physical disruption of vegetation by herbivores. Examples include domestic cattle and sheep grazing. Historic overgrazing has had an impact on streams, water quality, and soil productivity in the Sierra Nevada. Livestock grazing has been concentrated in small areas such as meadows and riparian areas. This concentrated activity has compacted soils and formed trails. In some areas, accelerated gully erosion has increased and removed well-developed soil and recent alluvium from the site. This has resulted in some wet meadows being converted to dry meadows and a decrease in soil productivity.

Mining

Disturbances from mining have occurred from historical mining activity. The effects of this historical mining include disturbances to flood plains where placer mining occurred and the construction of shafts and tunnels from load mining. Placer mining activities left piles of alluvium in the floodplain and changed the sediment dynamics of the channels. These areas have since stabilized by the reworking of sediment and with riparian vegetation. These areas are not considered to major erosion and sediment sources. Load mining resulted in the construction of shafts and tunnels. These sites are inventoried in an abandoned mine inventory. Information from this inventory indicates that

tailings are eroding and a source of sediment. These abandoned mines occur throughout the Sierra Nevada Bioregion and are concentrated along major geologic features such as faults and geologic contacts. It is not known if load mining disturbances are major erosion or sediment sources.

Candidate Attributes for Expected Change

Soil Hydrophobicity
Soil cover
Soil organic matter
Soil porosity
Soil infiltration rates
Erosion rates
Sediment delivery rates
Landslide frequency rate
V*
Channel stability

SOCIOCULTURAL—TECHNOLOGICAL INNOVATION AND DIFFUSION

Monitoring technological change is an important component of monitoring the entire sociocultural environment in order to continually integrate human dimensions in ecosystems management. It is important because modern technology is a unifying expression of the social, political, cognitive (psychological), and economic constituents of culture. It is also a means for interacting with and providing information about natural resources and the sociocultural spheres (Manley et al. in press). For instance, it supports landscape-scale research and management through applications of Geographical Information Systems (GIS), remote sensing technologies, and computer assisted analysis, modeling, and decision-making. It is part of the dimension of community and agency resources (Human Dimensions Framework Steering Group 1998), the interconnected system of manufacturing, communication, information acquisition, and transportation.

Candidate Attributes for General Condition and Metrics

a. Profit: capital investment in grazing, mining, timber harvest and milling, and other industries. This attribute is to provide information on the use of resource extractive technologies. Metric: ratio.

b. Green sticker applications, wilderness permits, lift tickets, Nordic trail tickets, appeals and complaints. This attribute is to provide information on recreation technology use. Metric: Totals per category per year.

c. Retail sales for specialized recreation equipment (mountain sports, bicycle shops, recreation vehicle dealers) and computer/software sales. This attribute is also to provide information on technology use. Metric: total per year.

d. Courses in information technology offered by local colleges. Metric: total per year.

e. Jobs related to recreation and information technology advertised. Metric: total per year.

f. Distribution of employment by sector--traditional forest and agricultural products, recreation and tourism, information technology. Metric: percent.

g. Planning documents containing data produced by computerized modeling and analysis. Metric: total number per year.

h. Data bases created by Geographic Information Systems. Metric: Total number per year.

i. Current levels of public facilities and service. This attributes provides information about technological innovation regarding recreation and interpretive facilities and services. Metric: Total number.

j. Resource uses. Indicates a community's dependence upon and use of ecological resources, which is often dictated by the available technology. Metric: percent of each resource.

The Expected Change Attributes section is based on the Notice of Intent (NOI) for the Sierra Nevada Forest Plan Amendment Environmental Impact Statement (EIS). As such, it is an interim effort in defining Expected Change affectors and attributes. The complete discussion is given in the Introduction to the prospectuses. The process addressed in this prospectus is an integral part of adaptive management, landscape analysis, and public interaction and collaboration, three processes listed in the NOI (p. 7) needed to address the five problems identified for action in the EIS. Affectors (Manley et al. 1998) were derived from these five problems and three processes since the stated purpose of the EIS is to select alternatives that will bring about institutional changes and changes in resource use and distribution through amendment of forest plans. All the affectors listed in the model seem to be pertinent for causing significant changes in the process during management of the EIS problems. These are carried forward as key affectors, listed below with expected consequences.

Candidate attributes are defined from expected consequences of the key affectors and based on how the process of technological innovation and diffusion operated in the past and is operating at present.

Key Affectors

Costs/funding

Expected continued increase in costs and decrease in funding will obviously limit the adoption of new technology, resulting in more efficient use and time-sharing of available technological resources.

Institutional culture and creativity

Change is expected in land management planning toward emphasis on science-based monitoring, decision analysis, collaborative stewardship, and adaptive management methods. This will result in:

(1) Greater use of technology transfer, including microelectronics scientific instrumentation for data collection, data analysis, monitoring, remote sensing, etc. This is addressed as an element in the approach taken in the Sierra Nevada Science Review (Science Review Team 1998, p. 11) because this technology will increase the effectiveness to analyze cumulative effects at all spatial scales and at least decadal to century time scales. It is also part of the Cultural, Demographic and Socioeconomic Changes issue in that many new residents and business people of the Sierra Nevada are bringing a sophisticated knowledge of information technology that will allow them to understand the complexity of land management and become helpful collaborators of the national forests.

(2) Increased use of computer simulation models (such as EZ-IMPACT (Bonnicksen 1993)), and expert systems for decision making concerning environmental and resource management issues (Ecosystem Management Decision Support (EMDS) (USDA Forest Service 1998)), and for modeling vegetation systems (FORET), climate systems (CCM) and other resources and processes.

(3) Adoption of nontraditional methods for establishing baseline data sets to assess forest and wetland ecosystems at appropriate landscape and temporal scales, such as pollen, macrofossil, and tree-ring analysis.

Education/training

Change is expected in needed skills and knowledge to operate and maintain new technologies and development of education programs by the Forest Service with the goal of informing the public and agency personnel of science-based management technologies.

Environmental conditions and services

Continued growth in resident populations and visitor use is expected to result in greater demands for access to national forest

environmental resources for recreation and resource goods and services with resulting negative impacts on forest and wetland ecosystems. Agency response may be an improved and environmentally appropriate infrastructure, and innovative designs for disability access and recreation and interpretive facilities.

Human communication patterns

According to Kusel et al. (1996) "information and knowledge are both the foundation and a product of adaptive management". Also, maximizing the development, interpretation, and flow of information between managers, scientists, and the public is crucial to a process-oriented collaborative approach. This is expected to create a need for faster and more efficient communications between managers, scientists, and the public, resulting in increased development of computer-based telecommunications technology including communication and dissemination of information via the Internet. This could also lead to an online "virtual collaborative community" (Rheingold 1993) of all the primary groups in the adaptive process.

Candidate Attributes for Expected Change

a. Environmental assessments containing data produced by computerize modeling and analysis. Metric: Total number per year.

b. Data bases created by Geographic Information Systems. Metric: Total number per year.

c. Regional training courses in information and adaptive management technology, and landscape analysis. Metric: Total number of course offerings per year.

d. Forest service and community-of-interest web sites devoted to collaborative stewardship for projects implementing the EIS action items. Metric: Total number per year.

e. Decision making computer software used by forests. Metric: Total number of purchases by type per year.

f. Monitoring plans and landscape analyses using new technologies and nontraditional methods. Metric: Total number of documents per year

g. Innovative low-impact transportation/recreation/interpretive plans. Metric: Total number per year.

h. Innovative interpretative facilities with disabilities access. Metric: Total number per year.

i. Proliferation of non-system roads. Metric: miles of new roads per year.

j. Impacts on designated wilderness. Metric: wilderness needs assessment report statistics.

LITERATURE CITED

Alcock, J. 1984. Animal behavior: an evolutionary approach. Sinauer Associates, Sunderland, Massechusetts.

Allaby, M. 1994. The concise Oxford dictionary of ecology. Oxford University Press, New York.

Bates, R. L., and J. A. Jackson. 1995. Glossary of geology, 2nd ed. American Geologic Institute, Alexandria, Virginia. CD-ROM

Begon, M., J. L. Harper, and C. R. Townsend. 1990. Ecology: individuals, populations and communities, 2nd ed. Blackwell Science Publishers, Boston, Massachusetts.

Beissinger, S. R., and M. I. Westphal. 1998. On the use of demographic models of population viability in endangered species management. Journal of Wildlife Management 62:821-841.

Binkley D. 1989. Sensitivity of forest soils in the western U.S. to acidic deposition. IN: Olson RK and Lefohn AS (eds). Effects of Air Pollution on Western Forests. APCA Transactions Series, 16: 561-573.

Bonnicksen, T.M. 1993. The Biosocial Perspective. In, Sustainable Ecological Systems: Implementing an Ecological Approach to Land Mangement. USDA Forest Service, General Technical Report RM-247. Rocky Mountain Forest and Range Experiment Station, Fort Collins.

Borgatta, E. F., and M. Borgatta (eds.). 1992. Encyclopedia of sociology, vols. 1-3. Macmillan Publishing Company, New York.

Boyce, M. S. 1992. Population viability analysis. Annual Review of Ecology and Systematics 23:481-506.

Boyce, J. K. 1994. Inequality as a cause of environmental degradation. Ecological Economics 11:169-178.

Brady, N. C., 1974. The Nature and Properties of Soils, 8th Edition., MacMillan Publishing Co., Inc. pg. 53.

Brady, N. C. 1984. The nature and properties of soils, 9th ed. McMillan Publishers, New York.

Buckley, W. 1967. Sociology and modern systems theory. Prentice-Hall, Englewood Cliffs, New Jersey.

CARB (California Air Resources Board). 1992. The Atmospheric Acidity Protection Program: Annual Report to the Governor and the Legislature, 1991. Research Division, Sacramento, CA.

CARB (California Air Resources Board). 1993a. The Atmospheric Acidity Protection Program: Annual Report to the Governor and the Legislature, 1992. Research Division, Sacramento, CA.

CARB (California Air Resources Board). 1993b. California Emission Trends 1975-2010. Technical Support Division, Sacramento, CA.

CARB (California Air Resources Board). 1995. Emissions Inventory 1993. Technical Support Division, Sacramento, CA.

CARB (California Air Resources Board). 1996. Statewide Emissions by Category: 2010 Forecasted Annual Average Emissions. Technical Support Division, Sacramento, CA.

California State Department of Finance. 1997. Interim County Population Projections. Sacramento, CA.

California Department of Water Resources. 1974. Hydroelectric energy potential in California. Bull. No. 194. California Resources Agency. Sacramento, CA.

California Soil Survey Committee, 1989., "Interagency Erosion Hazard Rating (EHR) System for Sheet and Rill Erosion, USDA - Forest Service - Forest Service Handbook 2509.22.

Carroll, C., W. J. Zielinski, and R. Noss. Submitted. Predicting the distribution of the fisher in northwest California using survey data and GIS modeling. Conservation Biology

Carson, M. A., and M. Kirby. 1972. Hillslope form and process. Cambridge University Press, London, England.

Chow, V. T., 1964. Handbook of Applied Hydrology. McGraw-Hill, San Francisco. Chapter 17, p. 12.

COS (Committee of Scientists) 1999. Sustaining the People's Lands. Washington D.C., U.S. Department of Agriculture.

Dabbing, et al. 1967.

Dietz, T., and E. A. Rosa. 1994. Rethinking the environmental impacts of population, affluence, and technology. Human Ecology Review 1:277-300.

Duane, T. P. 1996. Recreation in the Sierra. Pages 557-609 in Sierra Nevada Ecosystem Project, Final Report to Congress, vol. II, Assessment summaries and management strategies. Wildland Resources Center Report No. 37, University of California, Centers for Water and Wildland Resources, Davis, California.

Duncan, O. D. 1959. Human ecology and population studies Pages 678-716 in P.M. Hauser and O.D. Dunca (eds.). The study of population: an inventory and appraisal. University of Chicago Press, Chicago.

Ehrlich, P. R., and J. P. Holdren. 1971. Impact of population growth. Science 171: 1212-17.

Engle D. L. and J. M. Melack. 1997. Assessing the Potential Impact of Acid Deposition on High Altitude Aquatic Ecosystems in California: Integrating Ten Years of Investigation. Draft Final Report, Contract No. 93-312. California Air Resources Board, Sacramento, CA.

Estes, J. A. 1995. Top-level carnivores and ecosystem effects: questions and approaches. Pages 151-158 in C. G. Jones and J. H. Lawton (eds.), Linking species and ecosystems. Chapman and Hall, New York.

FEMAT (Forest Ecosystem Management Assessment Team). 1993. Forest ecosystem management: An ecological, economic, and social assessment. Report of the Forest Ecosystem Management Team. J. W. Thomas team leader. USDA Forest Service, PNW Research Station, La Grande, OR.

Flexner, S. B., and L. C. Hauck (eds.). 1983. The Random House dictionary of the English language, 2nd edition, unabridged. Random House, New York.

Forester, D.J. and Machlis, G.E., 1996. Modeling Human Factors that affect loss of biodiversity. Conservation Biology, Vol. 10, No. 4: 1253-1263.

Freitag, S., and A. S. Van Jaarsveld. 1997. Relative occupancy, endemism, taxonomic distinctiveness and vulnerability: prioritizing regional conservation actions. Biodiversity and Conservation 6:211-232.

Futuyma, D. 1986. Evolutionary biology. Sinauer Associates, Sunderland, MA.

Gordon, N. D., T. A. McMahon, and B. L. Finlayson. 1992. Stream hydrology: an introduction for ecologists. John Wiley and Sons, Chichester, England.

Graber, D. M. 1996. Status of terrestrial vertebrates. Pages 709-734 in SNEP, Sierra Nevada Ecosystem Project, Final Report to Congress, vol. II, Assessments and scientific basis for management options. Wildland Resources Center Report No. 37, University of California, Centers for Water and Wildland Resources, Davis, California.

Hanski, I., and M. Gilpin. 1991. Metapopulation dynamics: brief history and conceptual domain. Biological Journal of the Linnean Society 42:3-16.

Hanski, I., A. Mailanen, and A. Gyllenberg. 1996. Minimum viable metapopulation size. American Naturalist 147:507-541.

Harre, R., and R. Lamb (eds.). 1986. The dictionary of personality and social psychology. MIT Press, Cambridge, Massachusetts.

Hauer, F. R., and W. R. Hill. 1996. Temperature, light, and oxygen. Pages 93-106 in F. R. Hauer and G. A. Lamberti (eds.), Methods in stream ecology. Academic Press, San Diego, California.

Hawley, A. H. 1986. Human ecology: a theoretical essay. University of Chicago Press, Chicago, Illinois.

Heberlein, T. A. 1974. The three fixes: technological, cognitive, and structural. Pages 279-296 in D. R. Field, J. C. Barron, and B. F. Long (eds.). Water and community development: social and economic perspectives. Ann Arbor Science Publishers, Ann Arbor, Michigan.

Human Dimensions Framework Steering Group. 1998. Guidelines for Conducting Social Assessments Within a Human Dimensions Framework (Draft). Southeast Research Station, Athens.

Huschke, R. E. (ed.). 1959. Glossary of Meteorology. American Meteorological Society, Boston, Massachusetts.

Hynes, H. B. N. 1970. The ecology of running waters. Liverpool University Press, England.

Ipcc (Intergovernmental Panel on Climate Change). 1995. Climate Change 1995: The Second IPCC Scientific Assessment. IPCC, World Meteorological Organization/United Nations Environment Programme. Cambridge University Press, Cambridge.

Isacks, B., J. Oliver, and L. Sykes. 1968. Seismology and the new global tectonics. Journal of Geophysical Research 73:5855-5899.

Karr, J. R., and D. R. Dudley. 1981. Ecological perspectives on water quality goals. Environmental Management 11:249-256

Kattelmann, R. 1996. Hydrology and water resources. Pages 855-920 in SNEP, Sierra Nevada Ecosystem Project, Final Report to Congress, vol. II, Assessments and scientific basis for management options. Wildland Resources Center Report No. 37, University of California, Centers for Water and Wildland Resources, Davis, California.

Kahrl, W. (ed.) 1978. California Water Atlas. Sacramento: California Governor's Office of Planning and Research.

Keane, J. J. and W. J. Zielinski, in prep. Prioritizing vertebrates for conservation in the Sierra Nevada.

Kusel, J. 1996. Well-Being in Forest-Dependent Communities. Part 1. A New Approach. Pages 361-374. in SNEP, Sierra Nevada Ecosystem Project, Final Report to Congress, vol. II, Assessments and scientific basis for management options. Centers for Water and Wildland Resources, Davis, California.

Kusel, J, S.C. Doak, S. Carpenter, and V.E. Sturtevant. 1996. The Role of the Public in Adaptive Ecosystem Management. In, Sierra Nevada Ecosystem Project : Final Report to Congress, Vol. II, Assessments and Scientific Basis for Management Options, pp. 611-624. University of California Centers for Water and Wildland Resources, Davis.

Machlis, G. E., J. O. Force, and W. R. Burch. 1997. The human ecosystem, part I: The human ecosystem as an organizing concept in ecosystem management. Society and Natural Resources 10:347-367.

Manahan, S. E. 1991. Environmental chemistry. Lewis Publishers, Michigan.

Manley, P., W. J. Zielinski, C. M. Stuart, J. J. Keane, A. J. Lind, Cathy Brown, B. L. Plymale, and C.O. Napper. In Press. Monitoring Ecosystems in the Sierra Nevada: The Conceptual Model Foundation. Journal of Environmental Monitoring and Assessment.

Morgan, W. J. 1968. Rises, trenches, great faults, and crustal blocks. Journal of Geophysical Research 73:1959-1982.

Noss, R. F., and A. Y. Cooperrider. 1994. Saving nature's legacy. Island Press, Covelo, California.

Odum, E. P. 1971. Fundamentals of Ecology. 3rd edition, Saunders Company, Philadelphia, Pennsylvania.

Power, M. E., D. Tilman, J. A. Estes, B. A. Menge, W. J. Bond, L. Scott Mills, G. Daily, J. C. Castilla, J. Lubchenco and R. T. Paine. 1996. Challenges in the quest for keystones. Bioscience 46:609-620.

Rheingold, H. 1993. The Virtual Community: Homesteading on the Electronic Frontier. Addison-Wesley Publishing Co., Reading.

Sawyer, J. O., and T. Keeler-Wolf. 1995. A manual of California vegetation. California Native Plant Society, Sacramento, California.

Schindler, D. W. 1987. Detecting ecosystem responses to anthropogenic stress. Canadian Journal of Fisheries and Aquatic Sciences 44:6-25.

Schnoor, J. L. 1996. Environmental modeling: fate and transport of pollutants in water, air, and soil. John Wiley and Sons, New York.

Science Review Team. 1998. Sierra Nevada Science Review. USDA Forest Service, Pacific Southwest Research Station.

Seinfeld, J. H., and S. N. Pandis. 1998. Atmospheric chemistry and physics: from air pollution to climate change. John Wiley and Sons, New York.

Simon, J. L. 1981. The ultimate resource. Princeton University Press, Princeton, New Jersey.

Smith W. H. 1990. Air Pollution and Forests: Interactions Between Air Contaminants and Forest Ecosystems, Second Edition. Springer-Verlag, New York.

SNEP (Sierra Nevada Ecosystem Project). 1996. Final Report to Congress, vol. I, Assessment summaries and management strategies. Wildland Resources Center Report No. 36. University of California, Centers for Water and Wildland Resources, Davis, California.

Starrs, P. F. 1996. The public agents of policy. Pages 125-144 in SNEP, Sierra Nevada Ecosystem Project, Final Report to Congress, vol. II, Assessments and scientific basis for management options. Wildland Resources Center Report No. 37, University of California, Centers for Water and Wildland Resources, Davis, California.

Stern, P. C., O. R. Young, and D. Druckman (eds.). 1992. Global environmental change: understanding the human dimensions. National Academy Press, Washington, D.C.

Suplee, C. 1998. Untangling the science of climate. In National Geographic. Vol 193. No. 5. May 1988. National Geographic Society. Washington, DC.

Turner, M. 1989. Landscape ecology: the effect of pattern on process. Annual Review of Ecology and Systematics 20:171-197.

USDA Forest Service. 1995. Forest Service Handbook 2509.18, Pacific Southwest Region.

USDA Forest Service. 1996. A geomorphic classification system, ver. 1.3. USDA Forest Service, Pacific Southwest Region, San Francisco, California.

USDA Forest Service. 1998. EMDS: a Knowledge Based System for Ecological Assessment. Pacific Northwest Research Station http://www.fsl.orst.edu/home/usfs/emds/system.htm.

USGS (United States Geological Survey). 1998a. Pesticides Analyzed in NAWQA Samples: Use, Chemical Analyses, and Water Quality Criteria. National Water Quality Assessment Program.

USGS (United States Geological Survey). 1998b. National Water Quality Assessment Program: San Joaquin-Tulare Basins Study Unit: Surface Water Activities. National Water Quality Assessment Program.

USGS (United States Geological Survey). 1998c. National Water Quality Assessment Program: San Joaquin-Tulare Basins Study Unit: Aquatic Ecology Activities. National Water Quality Assessment Program.

Vane-Wright, R. I., C. J. Humphries, and P. H. Williams. 1991. What to protect? – Systematics and the agony of choice. Biological Conservation 55:235-254.

Ward, A. D. 1995. Environmental hydrology. Lewis Publishers, Michigan.

Wetzel, R. G. 1983. Limnology. Saunders College Publishing, Philidelphia, Pennsylvania.

Williams, D. R., and S. I. Stewart. 1998. Sense of place: an elusive concept that is finding a home in ecosystem management. Journal of Forestry XX: 18-25.

CHAPTER 4
SIERRA NEVADA FRAMEWORK INVENTORY, MONITORING & RESEARCH STRATEGIES

**Excerpt from the SNFP DEIS*

The SPAM Team was selected to develop the monitoring strategy for the SNFP Draft EIS in early Fiscal Year 1999. Throughout the year, the SPAM Team focused on developing and refining a strategic monitoring plan for the Draft EIS. As noted in Chapter 5, SPAM Team efforts included numerous formal and informal meetings, workshops, and one-on-one contacts. The following edited excerpt from the Draft EIS provides an overview of the inventory, monitoring and research strategies that were developed for each alternative. Specific issues associated with each alternative are not presented in this excerpt in order to focus on the methodology—the SNF Draft EIS is scheduled for distribution in spring of 2000. For copies of the Draft EIS, contact the Sierra Nevada Framework Project, 801 "I" Street, Sacramento, California 95814;

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Web address:
http://www.r5.fs.fed.us/sncf/

The Draft EIS proposes to establish management direction on the National Forest system lands on the Modoc, Lassen, Plumas, Lake Tahoe Basin Management Unit, Tahoe, Eldorado, Stanislaus, Sequoia, Sierra, and Inyo National Forests in California, and the portion of the Humboldt-Toiyabe National Forest in Nevada that is in the Sierra Nevada Range. The Draft EIS proposes to address problems related to: (1) old forest ecosystems and associated species; (2) aquatic, riparian, and meadow ecosystems and associated species; (3) fire and fuels; (4) noxious weeds; and (5) lower westside hardwood forests. Each of the LRMPs for the affected Forests and Regional Guides will be amended with this updated management direction.

The proposed action would also guide the Forest Service in meeting trust and other responsibilities with all native people, whether they are members of Federally recognized or unacknowledged tribes. Government-to-government and other relationships, as appropriate, between individual national forests and tribes would be established. Consultation with tribes would be a part of planning and implementing projects developed from the direction in this Draft EIS. Tribes have historical knowledge of the Sierra Nevada ecosystem. This knowledge would be incorporated where suitable. Barriers to existing traditional uses would be addressed.

Scientific thinking and public expectations are not definitive for these problems and so a policy of adaptive management is part of the proposed action. Adaptive management principles will be used to adjust management direction for future events, changing knowledge, or dynamic social views. Adaptive management involves: (1) establishing desired outcomes and steps towards achieving them, (2) monitoring to generate new information, (3) adjusting management objectives and strategies in15.4(g15.4(g13.1(r)16(n( )]Tswl)13.3rs

learn from experience and use that knowledge to adjust policy.

The proposed action also calls for an assessment of existing environmental conditions and identification of management options at the watershed and sub-watershed scale to: (1) link decisions at the project scale to forest plan decisions, (2) link forest plans to the efforts of other agencies, (3) prioritize treatments within the watershed or sub-watershed, and (4) facilitate local collaborative stewardship.

ADAPTIVE MANAGEMENT AND THE ROLE OF SCIENTIFIC INFORMATION

THE GOAL OF ADAPTIVE MANAGEMENT

This Draft EIS seeks to ensure the biological integrity and ecological sustainability of multiple ecosystems on Forest Service lands in the Sierra Nevada. Sustainability is defined here as "development or resource use that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland 1987; see also Hunsaker et al. 1999). Strong economies are dependent on healthy ecosystems to provide the basic services and functions upon which societies ultimately depend (Lubchenco et al. 1991, Perring 1995, Costanza et al. 1997).

Adaptive management is a continuing process of adjusting management strategies based on results of experience. Adaptive management is fueled by new information and is dynamic because of changing social needs and demands.

Adaptive management is interpreted and carried out in many and varied ways despite the specific definitions of adaptive management in the primary literature. As such, the players involved in resource management, namely researchers, resource managers, agency administrators, and the public, often have different perceptions and expectations of adaptive management. The term itself has intuitive appeal because it connotes tracking one's successes and failures, learning as one goes, and changing with the times – all time-tested tenets of good business. The intuitive appeal and the practical applications of the concept are both important facets of adaptive management. Our interpretation and application of adaptive management to the significant issues addressed in this Draft EIS are described below.

Adaptive management has three important goals: (1) to explicitly recognize uncertainty regarding how to achieve management goals, (2) to reduce uncertainty by implementing management strategies to yield better information about their successes, and (3) ultimately to increase the quality and quantity of management successes. The complexity and interconnectedness of ecological systems, combined with technological and financial limitations, makes a complete understanding of all the components and linkages virtually impossible. Not only is our knowledge incomplete, but the systems themselves are constantly changing through both natural and human caused mechanisms, making the effort to comprehend ecosystem dynamics and foretell their trajectories even more challenging (Gunderson et al. 1995). Uncertainty will always be a part of the management of ecosystems, and adaptive management provides a mechanism by which uncertainty can become, "the currency of decision making instead of a barrier to it" (Walters 1986).

We base our interpretation of adaptive management on three fundamental principles: systems thinking, experimentation, and collaborative learning. These principles lay the groundwork for continuous generation of improved insights and their ongoing and effective integration into systems-based management (Maarleveld and Dangbegnon 1999).

Systems thinking strives to counter the blind spots in traditional reductionist analysis. Because problems in natural resource

management often emerge at a different level of conceptual analysis than the causes that give rise to them, we have developed a model that provides for varying levels of analysis of ecosystem processes, their interrelationships, and conditions of interest caused by these relationships. The model also provides for ongoing revision at any level as our understanding of ecosystems changes (Manley et al. in press).

Experimentation seeks to address uncertainties in our understanding of ecosystems. By treating various types of resource use, policies, and management as experiments, we can derive systematic learning from experience. An experimental approach to management is designed with clear expectations in mind, monitors to collect the information that will allow assumptions to be checked, and translates findings into learning by correcting errors in understanding and changing plans based on improved insight.

Continuous communication between scientists, users, managers and planners is necessary for systems-based learning and effective adaptation to take place, A collaborative learning perspective provides an alternative to traditional resource management that may rely upon the generation of focused scientific knowledge isolated from its systems context. Collaborative learning corrects this problem by integrating data from biophysical and sociocultural systems into the process of knowledge generation. Using collaborative learning, scientific findings may also be integrated into management more effectively through the discovery of solutions mutually amenable to scientists, planners, managers and the public. It is through collaborative learning that the biophysical sphere may be effectively managed in the context of social, cultural and political realities (Maarleveld and Dangbegnon 1999),

Adaptive management is often portrayed as a cycle that can be engaged at any point or stage. The adaptive management cycle is portrayed here as a series of steps or stages (Figure 4.1). The adaptive management cycle is analogous to birth, death, and rebirth processes that are a part of every system. The death of old ideas, structures, and processes is driven by new information and changing perceptions, needs, and desires. A period of disorganization and exploration follows the death of old paradigms and modes of operation, characterized by evaluation, assessment, confusion, debate, and multiple proposals for a new direction. This is the rebirth process, and this Draft EIS is an example of such a period of disorganization, exploration, and rebirth. When a new direction is finally solidified (i.e., a signed record of decision for the Draft EIS selecting an alternative to be implemented), a period of stabilization and organization follows consisting of implementation of the new direction and characterized by organizational structure, standardization of protocols, quality control, quality assurance, monitoring, and a cohesive vision of where one is headed. This period of stabilization and organization remains until new information and changing needs once again precipitate the death and rebirth process.

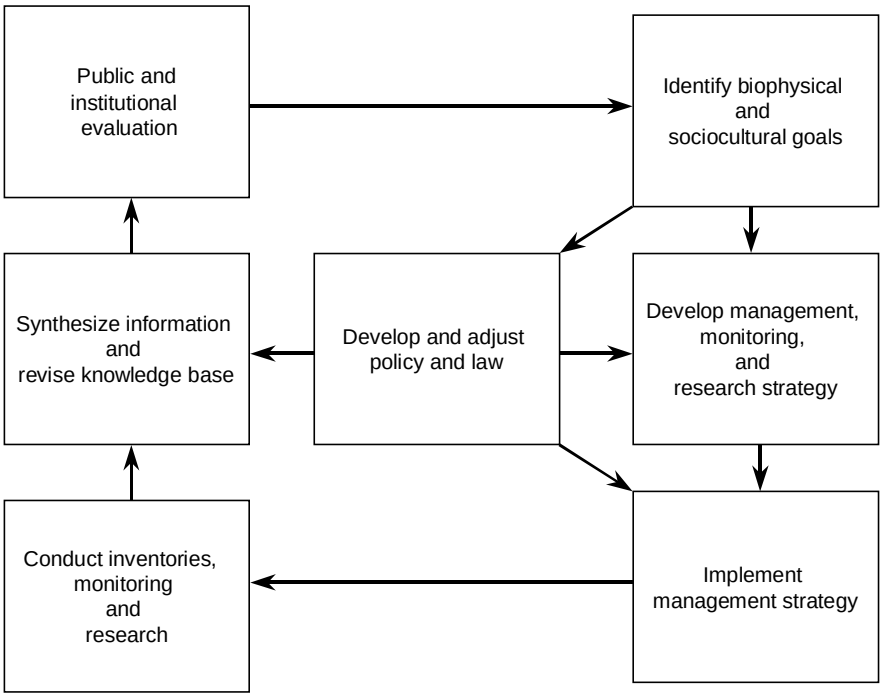

Figure 4.1. Adaptive management cycle as constructed for the Sierra Nevada Framework Project.

Figure 4.1 suggests some of the "nodes" in the development of new ideas and their application in a fully integrated adaptive management strategy. There is no particular sequence to the course of knowledge or information through the cycle—some portions of the cycle may be repeated and revisited more frequently than others. Each node represents an investment of time, thought, and resources on the part of participating agencies and the public.

INFORMATION NEEDS

Decision making and the implementation of management direction demand a variety of forms of information, including scientific information, as well as policy, law, and public opinion. The scientific information needed to complete the adaptive management process for this Draft EIS lies in the realms of inventory, monitoring, and research (See Figure 4.2). A scientifically credible inventory, monitoring and research strategy is the cornerstone for implementing adaptive management (Holling 1978, Walters 1986).

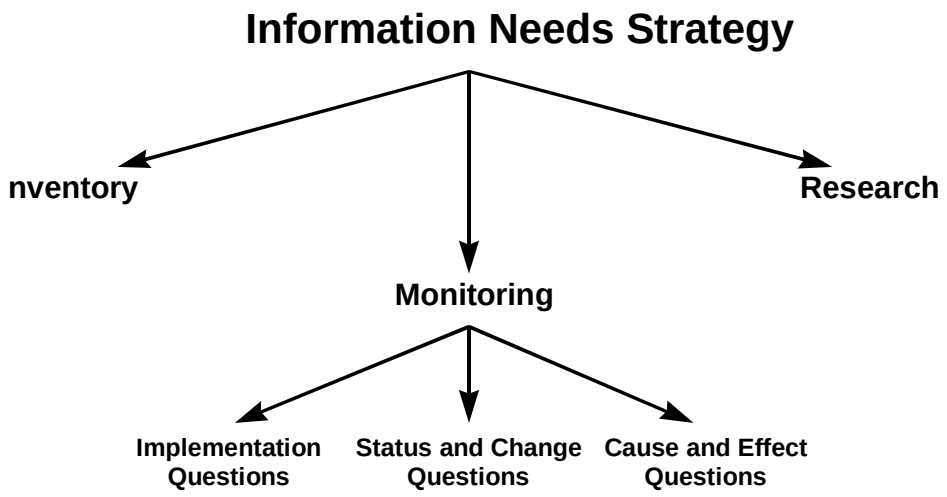

Figure 4.2 Components and organization of the scientific information needs strategy.

Inventory. An inventory refers to an estimate or census related to a given resource or use. Inventories differ from monitoring in that inventories entail a count of items in order to describe current conditions, and so their adequacy is judged by how thoroughly or accurately they describe a condition at a point in time. In contrast, monitoring is focused on change, and therefore the precision of estimates, not accuracy, is of greater interest and concern. Inventory needs associated with the Draft EIS do not vary substantially among the alternatives, including the no action alternative.

Monitoring. Monitoring describes actions, conditions, and relationships and how they change over time and space. Hellawell (1991) aptly defined monitoring as, "Intermittent (regular or irregular) surveillance carried out in order to ascertain the extent of compliance with a predetermined standard or the expected norm." Monitoring needs associated with the Draft EIS vary substantially among the alternatives, but these variations apply more to some types of monitoring than others. Some types of monitoring entail estimation of conditions, while other types entail hypothesis testing and therefore reside jointly in the realms of monitoring and research.

Research. Research provides a strong complement to information provided through inventory and monitoring. Research in support of land management generates new information in many areas, namely (1) the operation of key processes, (2) the interrelationships of key components and structures, and processes, (3) ecosystem thresholds, and (4) the development and testing of techniques and approaches not yet implemented by management. A strong adaptive management approach requires that research-related information needs be defined and pursued in concert with the implementation of management direction and monitoring.

The history and development of the three sources of scientific information (inventory, monitoring, and research) vary substantially, and play a part in how best to address these information needs in the future. The inventory of resources and activities is not new to the Forest Service. Inventory has historically been a mainstay of the National Forest System in support of forest management. The National Forest System is likely to adapt well to additional inventory needs. Similarly, the pursuit of information through research is well institutionalized through the research branch of the Forest Service. However and in the past, Forest Service research was less directly applicable to management than it is today, and the shift to more directly applied research is still in progress. Research and management will need to tighten their working relationships to create a more seamless flow of information and speed its integration into decision making in the

pursuit of adaptive management. In contrast to inventory and research, monitoring has historically been a minor activity in the Forest Service. It demands technical skills that are rarely required in the National Forest System, and it was not typically considered in the realm of research. In essence, monitoring has been lying dormant in the median between management and research. Establishing a new large-scale, multi-resource monitoring program will require significant institutional momentum and input. Overall, increased emphasis on monitoring and applied research creates the need for greater integration and coordination among all three types of efforts to acquire scientific information.

The geographic area to which the Information Needs Strategy applies is defined at its greatest extent by the SNEP study area boundary (SNEP 1996) (Figure 4.3.

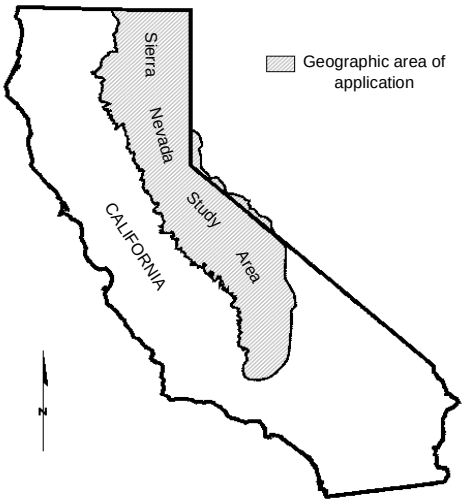

Figure 4.3 Geographic area of consideration for the Sierra Nevada Framework Project and Draft EIS Information Needs Strategy.

The SNEP study area boundary encompasses the 11 National Forests, and extends beyond the Sierra Nevada mountain range to include surrounding areas of influence, such as the Modoc Plateau and the foothills of the Sierra on both sides of the Sierra Crest. The use of this geographically inclusive study area facilitates discussion about information needs and collaborative opportunities that lie beyond the boundaries of the National Forests in the Sierra Nevada. Inventory needs identified here apply only to National Forest System lands within the Sierra Nevada study area. Monitoring will be also be restricted to National Forest System lands, but with the hope that collaborative efforts among agencies and with the public will broaden the area over which monitoring is occurring and to which monitoring results can be applied. Research may be conducted on a variety of land ownerships to broaden the applicability of the results beyond National Forest System lands.

The inventory strategy simply identifies the inventory information needs directly related to standards and guidelines. Inventory needs related to existing LRMP management direction but not related to the problem areas in this Draft EIS are not identified. The logistics of accomplishing inventory objectives are not trivial, however they fall into the realm of implementation that is not addressed in this draft strategy. In the final strategy, the potential obstacles to successful implementation will be addressed. A more fully developed inventory strategy will accompany the Record of Decision for the Draft EIS.

The monitoring strategy contains a discussion of concepts applied to its development, the model developed to serve as the ecosystem foundation, and the specific monitoring questions proposed and how they vary among alternatives. Design and analysis options available to answer monitoring questions are not presented or discussed. In the course of developing the final monitoring strategy, a variety of designs will be considered and evaluated as to their efficacy and adequacy, and a final design and analysis approach will be included in the final monitoring strategy.

The research strategy identifies the potential contribution of research in supporting monitoring and management decision making, and points toward topic areas in the greatest need of support and investment of research. A more fully developed research strategy will accompany the Record of Decision for the Draft EIS.

THE INVENTORY STRATEGY

The objectives of the inventory strategy are to (1) identify the primary existing inventory activities and the new inventory needs generated by the Draft EIS, (2) evaluate the potential for existing and new inventories to contribute to monitoring needs, and (3) integrate inventory activities with monitoring and research to the extent practicable and beneficial.

Inventory needs were identified by reviewing the standards and guidelines and querying Draft EIS and Science Integration team members. As a result, the specificity of the inventory needs was noted to be quite variable, ranging from broad categories of information (e.g., timber harvest activities) to very specific entities (e.g., number of snags per acre). Inventory data needs varied only slightly among alternatives.

We recognized that before inventory needs can be addressed, an accounting of major existing inventory efforts will need to be accomplished.

THE MONITORING STRATEGY

THE ROLE OF MONITORING IN ADAPTIVE MANAGEMENT

Monitoring plans are required by the National Forest Management Act (1976), which pertains to the management of National Forest System lands. Monitoring in relation to land management is intended to provide information on the implementation of management direction, the condition of resources, the effectiveness of management direction in meeting resource objectives, and the validity of assumptions made about cause-effect relationships during the development of management direction. A fourth intent of monitoring less often cited in relation to management is to establish baseline reference conditions to serve as a context for validating desired conditions and interpreting existing conditions.

Monitoring is an essential component of adaptive management (Figure 4.1). Adopting an adaptive management approach, whereby the results of monitoring are used to learn from past management and improve subsequent management, enables management to proceed with a higher likelihood of success despite uncertainties. The success of an adaptive management approach is determined by the strength and breadth of the associated monitoring and the corporate will to change management direction based on monitoring results. Thus, developing a scientifically credible monitoring strategy is the cornerstone for implementing an adaptive management process to monitor and refine management designed to achieve specific goals, such as sustainability (Holling 1978, Walters 1986).

KEY FEATURES OF THE MONITORING STRATEGY

The challenges of managing large areas for multiple objectives can only be met with efficient and informative monitoring strategies. Monitoring is a critical tool for dealing with uncertainty in the management of large-scale systems (Hellawell 1991, Noon et al. 1999). Monitoring needs to provide a broad array of information, including the status and dynamics of biophysical conditions and processes, as well as management activities and their compliance with agency direction, legal and regulatory obligations, and institutional intent. Here, we identify some key considerations in the development of large-scale ecosystem monitoring, and describe how we are addressing these considerations in the SNFP Monitoring Strategy.

Ecosystem Foundation

Need. Recent reviews of large-scale monitoring plans have identified failures in both process and content. Frequently, monitoring efforts have had poor foundations in ecological theory, little consideration of cause and effect relationships, and inadequate or uninformed approaches to

selecting, justifying, and evaluating the specific indicators to monitor (Hellawell 1991, National Research Council 1995, Noon et al. 1999, Bricker and Ruggiero 1998). The development of a conceptual model has been touted as a key component of a scientifically based, ecologically founded monitoring plan (Barber 1994, National Research Council 1995, Noon et al. 1999) that can avoid these common pitfalls. Conceptual models express ideas about components and processes deemed important in a system, document our assumptions about how components and processes are related, and identify gaps in knowledge—they are a working hypothesis about system form and function (Walters 1986, de Wit 1993, Huggett 1993).

Action. A conceptual model, the EPC Model, was developed to serve as the ecosystem foundation of the SNFP Monitoring Strategy (Manley et al. in press). The EPC Model serves as a foundation by providing (1) members of the multidisciplinary scientific team with a common view of the dynamics of all aspects of the ecosystem across scales; and (2) an objective, structured, and hierarchical framework by which we can select specific attributes (indicators) to monitor. Using the EPC Model as the ecosystem foundation of the monitoring strategy confers, (1) clarity in how ecosystems are perceived for this effort, (2) credibility from the scientific validity of foundation, and (3) stability because problem areas, goals, and policy can change without invalidating the foundation of the monitoring strategy. The EPC Model is centered on ecosystem processes, considers humans as part of ecosystems, and serves as a framework for selecting attributes for monitoring. The model is hierarchical, and has three levels: (1) an ecosystem model that identifies five spheres, (2) sphere models that identify key ecosystem processe, and (3) key process models that identify the 'essential elements' that are required for the process to act, the human activities ('affectors') that have negative and positive effects on the elements, and the 'consequences' of affectors acting on essential elements.

The EPC Model was developed to provide the scientific foundation regarding ecosystem dynamics, and a tool to facilitate the selection of attributes to answer monitoring questions. We define an attribute broadly, in the sense of Noon et al. (1999), as "any biotic or abiotic feature of the environment that can be measured or estimated." For each key process in the EPC Model, we developed a "prospectus" which consists of a literature review describing the key process and its operation, and recommends attributes that are good candidates for monitoring the process (candidate attributes). Candidate attributes consist of all attributes that are determined to be "information rich" reflections of ecosystem condition. In the identification of attributes for any given goal (or strategy), we identified the key processes associated with the goal, and then evaluated the relative merit of the candidate attributes identified in the prospectuses for the key processes. Attributes have been selected for Status and Change questions. Evaluation of the merit of candidate attributes for status and change monitoring is described in the Status and Change section. See Chapter 3 for key ecosystem processes.

Monitoring Categories

Need. The National Forest Management Act (1976) regulations (36 Code of Federal Regulations 219.12(k)) provide guidance on the monitoring and evaluation requirements to be included in Forest Plans. According to National Forest Management Act, monitoring strategies are to address a suite of information needs, including implementation, effectiveness, and validation monitoring activities (Forest Service Manual 1922.7, Noss and Cooperrider 1994). However, debates on the distinctness of these categories ensue when we attempted to operationalize their definitions. A clear distinction of the categories of monitoring and their associated questions is an important element of any monitoring effort. For a large-scale monitoring effort such as this, a balance of types of monitoring questions best serves the information needs of managers.

Action. For the SNFP Monitoring Strategy, we refined the classification provided in the Forest Service manual to better distinguish and define the types of monitoring that are contained within

the Draft EIS monitoring plan. They simply represent a repackaging of the National Forest Management Act monitoring requirements. First, we identified three main categories of monitoring: Implementation, Status and Change, and Cause and Effect (Table 4.1).

- *Implementation monitoring* simply records what, when, where, and how management actions are carried out (or not carried out, as the case may be). These results are compared to management direction (i.e., expected actions) and performance is based on the comparison of expected to observed.

- *Status and Change monitoring* consists of two emphasis areas: (1) condition monitoring which describes important biophysical and sociocultural conditions to gauge if desired conditions are being achieved, and (2) affector monitoring which describes management actions plus biological and physical processes that have the potential to rapidly alter sociocultural processes. Status and Change monitoring estimates the condition and change of resources over time. It also includes describing correlative relationships between affectors and conditions that are of particular interest or concern. Implementation and Status and Change monitoring represent routine monitoring, as defined by the Committee of Scientists (COS 1999), and serve a critical role in determining if desired outcomes are being achieved.

- *Cause and Effect monitoring* represents a broad category of inquiry directed at better understanding patterns of behavior, and relationships between ecosystem components. Specifically confirming cause and effect relationships is only one facet of this more general category of questions. Cause and Effect monitoring consists of two emphasis areas: (1) management effectiveness monitoring to better understand the results of specific management actions on a desired condition, and (2) validation monitoring to determine if assumptions made at any stage of the development of management plans are valid, including interpretations of scientific underpinnings, management strategies, and selected desired conditions.

Table 4.1. Categories of monitoring and the information they are targeted to address.

Monitoring Category	Target Information
Implementation	Actions taken
Status and Change	Affectors Resource conditions Affector-condition correlations
Cause and Effect	Management effectiveness Validation of assumptions

Our monitoring strategy consists of a balance of questions across the three categories of monitoring questions to form complementary lines of inquiry. The Committee of Scientists suggests that this combination of routine monitoring and active adaptive management is the strongest approach to meeting the scientific information needs of land management.

Monitoring Plan Topic Areas

Need. The monitoring strategy needed to be explicitly organized around ecosystem topic areas to clearly show the link between monitoring and the Draft EIS problem areas, and to structure the application of monitoring information to decision making.

Action. Within each of the categories of monitoring (Implementation, Status and Change, and Cause and Effect), eight topic areas are addressed individually. Five of the topic areas stem directly from the five problem areas in the Draft EIS: old-forests, lower westside hardwoods, aquatic/riparian/meadow ecosystems, fire and fuels, and noxious weeds. Three additional monitoring topic areas were closely associated with the five problem areas: air quality, soil productivity, and sociocultural conditions.

Explicit Monitoring Questions

Need. Monitoring is a long-term investment that requires the ability to adjust to changing information needs and priorities, and at the same time requires some temporal constancy to yield results. For a monitoring effort to be effective in rapid periods of change, the following characteristics are desirable: (1) a clear set of questions to be answered; (2) a specified period of time required to obtain an answer to each question; and (3) the ability to add and delete questions without redesigning the conceptual foundation or abandoning the experimental and sampling design. In light of current high public involvement and the correspondingly rapid rate of policy changes, it is prudent to consider adaptability as the core of any effort that strives for enduring utility.

Action. The SNFP Monitoring Strategy has identified a suite of questions organized in a hierarchical manner from broad, general questions reflecting goals, assumptions, or standards and guidelines, to specific questions related to individual attributes to be monitored. We relied on the EPC Model to guide the development of specific questions associated with goals and assumptions by identifying the key processes associated with each goal or assumption, and then consulting the prospectuses to ascertain which attributes best reflected the pertinent aspects of the processes. Because the EPC Model is a broad conceptual model, we can continue to rely on it as new questions, and even new topic areas and goals, arise in the course of developing, implementing, and evaluating management direction.

Actively Probing Areas of Uncertainty

Need. In the development of the management direction to achieve the goals stated in the Draft EIS, a number of areas of uncertainty inevitably arose. To be successful in land management, we need to explicitly identify areas of uncertainty and understand how we can improve our knowledge and success rates in the course of our management. Uncertainty can be seen as arising from three sources that define segments of an 'uncertainty continuum': the unknowable, the unknown, and the poorly described (Hillborn 1987, Dovers et al. 1996). Uncertainty arising from "the unknowable" recognizes that ecosystems are so complex that we will never know everything about them, that there are facets of ecosystems that we will never be able to predict, and that surprise is inevitable. Uncertainty arising from "the unknown" results from a lack of knowledge that is deemed attainable (Christensen et al. 1996, Dovers et al. 1996). Uncertainty arising from "the poorly described" results from existing data that are weak or biased in some manner (Christensen et al. 1996, Dovers et al. 1996).

Action. Cause and Effect monitoring, in combination with a coordinated research program, can serve to address and reduce key areas of uncertainty and risk associated with management activities (including monitoring). Together, Cause and Effect monitoring and research constitute the most active component of the adaptive management approach. Uncertainty can arise from many sources, such as lack of key information, relying on untested methods, and imprecise estimates of how the system will respond to treatments. Risk levels are associated with the value of the conditions affected by the uncertainties. Uncertainty and risk are the basis for identifying and prioritizing information needs for Cause and Effect monitoring and companion research efforts. Probing these areas of uncertainty is intended to reduce uncertainty and clarify risks associated with management options.

IMPLEMENTATION MONITORING

Implementation monitoring is typically tied to specific actions identified in standards and guidelines, as well as existing laws and regulations that must be followed. Implementation monitoring identified here pertains to legal compliance, compliance with broad strategies, and implementation of specific standards and guidelines from both this EIS project, as well as connected standards and guidelines in current LRMPs. Legal compliance applies to all alternatives; therefore, Implementation monitoring associated with legal compliance spans all alternatives.

Implementation monitoring varies by the strategies, standards, and guidelines associated with each of the alternatives identified in the Draft EIS. Management strategies and standards and guidelines vary among alternatives: sometimes unique to an alternative, sometimes shared by multiple alternatives, and sometimes applied to all alternatives. Implementation questions generally reiterate the standard or guideline in the form of a compliance question (e.g., "Was [the standard/guideline] implemented as specified in the plan?").

STATUS AND CHANGE MONITORING

As described earlier, Status and Change monitoring consists of two emphasis areas: condition monitoring and affector monitoring, including individual descriptors of conditions and affectors and correlative relationships between them. In this section, the link between topic area goals and Status and Change monitoring is discussed first, followed by descriptions of condition and affector monitoring.

Management Goals: Focal Points for Status and Change Monitoring

Goals serve to identify desired conditions in terms that are not quantified, with no specific details for their achievement. Monitoring status and changes in resource conditions needs to tie back to explicit goals for these resources. Goals were identified for each of the eight topic areas, and they apply to all alternatives.

Goals varied among topic areas. Goals were similar for the three ecosystem-related topic areas (old forest, lower westside hardwood, and aquatic/riparian/meadow). Old forests and lower westside hardwood topic areas have exactly the same goals, which address ecosystem, species, and habitat conditions. The aquatic/riparian/meadow topic area goals addressed similar aspects of condition, but the goals were parsed into finer, more specific subject areas for a total of 10 goals. The three fire and fuels goals encompassed both ecological and socioeconomic concerns. The two air quality goals addressed basic legal and policy concerns regarding air quality in Class I (wilderness) and Class II (non-wilderness) airsheds. The two soil productivity goals addressed two scales of concern, site-specific soil conditions and watershed-scale erosion conditions. The watershed condition goal is identical to the goal with the same name in the aquatic/riparian/meadow topic area. Three goals were identified in association with the sociocultural topic area: sustainability, legal compliance, and adaptive management.

The sustainability goal was primarily defined from the Purpose and Need for Action in the NOI, from the Sierra Nevada Science Review, and from various chapters in the Sierra Nevada Ecosystem Project report. Cultural, demographic, and socioeconomic changes are priority issues in the Sierra Nevada identified by the science review team. The NOI asserts that resolution of the problem areas addressed in the Draft EIS "will influence and be influenced by social, cultural and economic values" and that "the need is to ensure that forest management direction accounts for...public expectations." The NOI further indicates that current forest plan direction does not recognize the "shift in public values" and "expectations for goods and services from the Sierra Nevada National Forests," nor does it provide certainty for providing products and services while sustaining

long-term productive capability of forest lands and meeting legal requirements.

The legal compliance goal was defined from the Purpose and Need for Action in the NOI. The NOI explicitly recognized that legal requirements for clean water, clean air, biological diversity, and endangered species were not to be violated while pursuing the goal of providing goods and services.

The adaptive management goal was defined from the Purpose and Need for Action in the NOI, from the Sierra Nevada Science Review, and from the organizing principles of the Sierra Nevada Ecosystem Project report (SNEP 1996). The charge to the science review team included reviewing and synthesizing new scientific information because the "Forest Service is required to review ongoing management of national forests in light of new information and consider adjusting management if necessary and appropriate." Therefore, the science review team marked adaptive management and monitoring as a priority consideration for implementing national forest management actions in the Sierra Nevada and the approach was one of the three processes identified in the NOI to address the problems.

General Condition and Expected Change Monitoring

Status and Change monitoring can be directed at general conditions or it can be more narrowly directed at only those conditions expected to change as the result of management. The considerations in choosing one or the other approach and the course selected for the monitoring strategy are described here.

For monitoring environmental conditions at large-scales, two strategic approaches have been defined: retrospective and predictive. These strategic approaches yield different and complementary benefits. Retrospective, or effects-oriented, monitoring seeks to detect changes in status or condition. It is based on detecting an effect after it has occurred as the result of including a wide array of attributes in the monitoring program (National Research Council, 1995). This inductive approach is valuable for a variety of management and conservation uses, but is not helpful in understanding why observed changes are occurring. Predictive, or stress-oriented, monitoring seeks to detect undesirable effects before they have a chance to occur or become serious (National Research Council, 1995). It is an efficient monitoring approach where there is a high level of confidence in regard to particular cause-effect relationships. The weakness of this approach is that assumptions about cause-effect relationships may be inaccurate, effects may have multiple causes, or unforeseen changes may go undetected. Retrospective and predictive monitoring are complementary, and a balance of these two approaches constitutes the best approach to monitoring large-scale systems.

This monitoring strategy strives for a balance of retrospective and predictive monitoring such that the weaknesses of each approach are counter-balanced by the strengths of the other. To accomplish this, we stratified Status and Change questions into General Condition (the retrospective approach) and Expected Change (the predictive approach) to better capture important changes in processes, structures, and components associated with each topic area and goal.

CAUSE AND EFFECT MONITORING

Cause and Effect monitoring entails testing hypotheses directly related to the effectiveness and underlying bases of management direction and actions. Cause and Effect monitoring relies, to the extent possible, on existing management activities to provide the "experimental laboratory" for investigating cause and effect relationships. Effectiveness and validation monitoring at the multi-project, landscape or bioregional scale are essentially research endeavors, entailing ranges of treatments, replicate samples per treatment, and hypothesis testing. As described here, Cause and Effect monitoring represents the essence of active adaptive management (Holling 1978, Walters 1986, COS 1999).

Cause and Effect monitoring questions were formulated to highlight subject areas where key uncertainties were coincident with vulnerable or at-risk elements of the ecosystem. Areas of uncertainty and risk were identified by consulting and reviewing management direction, assumptions, data gaps, and legal requirements. Cause and Effect questions were identified for uncertainties and risks related to the effectiveness of management direction and strategies, as well as those related to basic assumptions adopted in the process of developing management direction.

The Cause and Effect monitoring questions we developed represent a list of potential questions that could be pursued in association with one or more alternatives. It is unlikely that all the Cause and Effect questions identified for any one alternative would be pursued if the alternative were selected for implementation. Further discussion and refinement of these subject areas is required before a final set of Cause and Effect questions can be determined. A final set of Cause and Effect questions will be identified and discussed in the final monitoring strategy. For every Cause and Effect question ultimately selected for implementation, a companion Status and Change and Implementation monitoring question will also be selected to provide a stronger context for interpreting and acting on the results of Cause and Effect monitoring.

A total of 80 unique Cause and Effect monitoring questions have been identified as of September 1999, of which 35 were management effectiveness and 45 were validation monitoring questions. A hierarchical approach was used to display the questions, which helps illustrate the thought process of how specific questions serve to address the broad topic area. The aquatic/riparian/meadow topic area had the largest number of questions (n = 22), followed by lower westside hardwoods (n = 18), old forest (n = 10), fire and fuels (n = 7), air quality (n = 6) and finally noxious weeds and soil productivity (n = 3 each). Eleven additional questions were common to all three ecosystem-related topic areas. Aquatic/riparian/meadow, in addition to having the greatest total number of Cause and Effect questions, also showed the greatest variation in the number of questions among the alternatives. The soil productivity topic area had few Cause and Effect questions, and they only applied to a subset of alternatives. The Cause and Effect questions for the remaining topic areas generally applied to all alternatives except Alternative 1 (no action).

THE RESEARCH STRATEGY

The role of research in support of land management has changed dramatically over the past few decades. As the global human population grows and natural resources become more scarce and valuable, the world turns toward science to provide a path by which expansion of populations and wealth can be accompanied by a high quality of life, including access to a diversity of products and services from the natural environment. This demand exists because research has the potential to define more clearly social and environmental thresholds beyond which the sustainability of one or more elements would be lost. With these thresholds defined, managers and society can make more cogent choices about the diversity of products and services for which they wish to manage. Moreover, if sacrifices must be made, they are made knowingly.

The increasing demand on natural resources and reliance on scientific information is evident in current land management planning efforts. Credible scientific information has become the turnkey element of planning efforts, particularly those addressing large geographic areas. The demand for scientific credibility and a growing emphasis on planning at larger geographic scales

investment for scientists and researchers in this new era of planning and management: (1) creating knowledge of relevance to collaborative planning, (2) developing the integrative science for bioregional assessments, (3) helping managers understand the application of scientific and technical knowledge, (4) helping to design effectiveness monitoring procedures and adaptive management experiments, and (5) evaluating the use of scientific information in planning and implementation. The research strategy will build on the existing charter of the Science Integration Team (existing team of Forest Service scientists providing support to the Draft EIS) to support adaptive management in all five of these areas of investment. Perhaps more simply stated, the research strategy for adaptive management across the 11 National Forests has two primary goals: (1) generate new information through research and existing information to inform management decisions and improve the ability of management to achieve its goals, and (2) provide guidance and expertise in the arena of research techniques to improve the quality and applicability of endeavors undertaken by management. However, in the context of information needs and the generation of new information, only the first goal is relevant to this document. A more comprehensive description and discussion will be provided in the final research strategy.

Research classically gains new knowledge through hypothesis testing and enhances understanding by synthesizing existing knowledge. As noted in the monitoring strategy, Cause and Effect monitoring also entails hypothesis testing, and therefore resides in the realms of both monitoring and research. Within the context of the research strategy, research efforts that are independent of Cause and Effect monitoring fall into three categories: (1) filling basic information gaps in regard to key areas of uncertainty and risk, (2) developing and testing new management and monitoring methods yet to be implemented, and (3) assessing and synthesizing existing information to facilitate better integration into decision making.

A program of work for research in support of the selected alternative will be developed. In the interim, a set of potential research questions pertinent to one or more of the proposed alternatives was developed. These questions are intended to provide a starting point for discussion, revision, and prioritization to ultimately craft a research strategy that complements the Status and Change and Cause and Effect questions posed in the monitoring section. Questions relating to basic information gaps include the habitat relationships of focal species and emission levels generated by different types of prescribed burns. Questions relating to developing and testing new management and monitoring methods include the development of ecosystem indicators and the development of appropriate landscape character goals for the Sierra Nevada. Questions relating to the synthesis of existing information include the key issues in recreation and estimated trends in demand over the next 20 years. The research strategy will be refined further for the final Draft EIS document.

LITERATURE CITED

Barber, M. C. (ed.). 1994. Environmental monitoring and assessment program indicator development strategy, EPA/620/r-94. US Environmental Protection Agency, Office of Research and Development, Environmental Resources Lab, Athens, Georgia.

Bricker, O. P. and M.A. Ruggiero. 1998. Toward a national program for monitoring environmental resources. Ecological Applications 8:326-329.

Brundtland, G. 1987. Our common future. Oxford University Press, Oxford, England.

Christensen, N.L., A.M. Bartuska, J.H. Brown, S. Carpenter, C. D'Antonio, R. Francis, J. F. Franklin, J.A. MacMahon, R.F. Noss, D.J. Parsons, C.H. Peterson, M.G. Turner, and R.G. Woodmansee. 1996. The report of the Ecological Society of America committee on the scientific basis for ecosystem management. Ecological Applications 6:665-691.

Committee of Scientists. 1999. Sustaining the people's land. Recommendations for stewardship of the national forest and grasslands into the next century. USDA, Washington, D.C.

Costanza, R., and H.E. Daly. 1997. Natural capitol and sustainable development. Conservation Biology 6(1): 37-46.

de Wit, C. T. 1993. Philosophy and terminology. Pages 3-6 *in* Leffalaar, P. A. (ed.). On systems analysis and simulation of ecological processes. Kluwer Academic publishers, Boston, Massachusetts.

Dovers, S. R., T. W. Norton, and J. W. Handmer. 1996. Uncertainty, ecology, sustainability, and policy. Biodiversity and Conservation 5:1143-1167.

Gunderson, L. H., C. S. Holling, S. S. Light, eds. 1995. Barriers and bridges to the renewal of ecosystems and institutions. Columbia Univ. Press, New York, NY.

Hellawell, J. M. 1991. Development of a rationale for monitoring. Pages 1-14 *in* Goldsmith, F. B. (ed.). Monitoring for conservation and ecology, Chapman and Hall, New York.

Hilborn, R. 1987. Living with uncertainty in resource management. North American J. of Fisheries Mgt 7:1-5.

Holling, C.S. 1978. Adaptive environmental assessment and management. John Wiley and Sons. New York, NY.

Huggett, R. J. 1993. Modeling the human impact on nature: systems analysis of environmental problems, Oxford University Press, New York.

Hunsaker, C. T., J. D. Christman, A. B. Coley, and M. A. Kane. 1999. Ecological sustainability, Part 1: issue paper and literature review. Unpublished document, U. S. Environmental Protection Agency.

Lubchenco, J., A. M. Olson, L. B. Brubaker, S. R. Carpenter, M. M. Holland, S. P. Hubbell, S. A. Levin, J. A. MacMahon, P. A. Matson, J. M. Melillo, H. A. Mooney, C. H. Peterson, H. R. Pulliam, L. A. Real, P. J. Reagal, and P. G. Risser. 1991. The sustainable biosphere initiative: an ecological research agenda. Ecology 72(2): 371-412.

Maarleveld, M. and C. Dangbegnon 1999. Managing natural resources: A social learning perspective. Agriculture and Human Values 16: 267-280.

Manley, P.N., W.J. Zielinski, C.M. Stuart, J.J. Keane, A.J. Lind, C. Brown, B.L. Plymale, and C.O. Napper. In press. Monitoring ecosystems in the Sierra Nevada: the conceptual model foundation. Journal of Environmental Monitoring and Assessment.

NFMA. 1982. Department of Agriculture , Forest Service, 36 Code of Federal Regulations Part 219. National Forest System Land Resource Management Planning. Federal Register. Vol. 47. No. 190.

National Research Council. 1995. Review of EPA's environmental monitoring and assessment program: overall evaluation. National Academy Press. Washington, D.C.

Noon, B. R., T. A. Spies, and M. G. Raphael. 1999. Conceptual basis for designing an effectiveness monitoring program. Pages 21-48 in B.S. Mulder, B.R. Noon, T.A. Spies, M.G. Raphael, C.J. Palmer, A.R. Olsen, G.H. Reeves, and H.H. Welsh, Jr. The strategy and design of the effectiveness program for the Northwest Forest Plan. USDA Forest Service General Technical Report, PNW-GTR-437, Pacific Northwest Research Station, Portland, Oregon.

Noss, R. F. and A.Y. Cooperrider. 1994. Saving nature's legacy. Island Press, Covelo, California.

Perrings, C. and B.H. Walker. 1995. Biodiversity loss and the economics of discontinuous change in semi-arid rangelands. Pages 190-210 In C.A. Perrings, K.G.

Walters, C.J. 1986. Adaptive management of renewable resources. MacMillan, New York, NY.

CHAPTER 5
COORDINATION AND COLLABORATION

Multiple facets of coordination and collaboration were used to facilitate the integration of the monitoring effort with the various facets of the SNFP EIS and Framework effort. The following is a list of the SNFP Teams that have been involved with the monitoring effort via the monitoring team either formally (e.g., meetings) or informally (e.g., phone).

- Adaptive Management Team
- Collaboration team
- Design Team
- EIS team
- Forest Contact Team
- Interagency Team
- Monitoring Team
- Science Team
- Sierra Nevada Forest Supervisors' Team

The Monitoring Team and the EIS Team exchanged information and ideas on a regular basis throughout the year. Table 5.1 displays the dates, participants, and discussion topics of significant meetings held or attended by the SPAM Team, the EIS Team, the Science Team, and other teams involved in the development of the EIS.

Table 5.1 Significant meetings between SPAM and EIS Teams.

Dates	Meeting – Main Focus	Participants
Sep. 98	SPAM Team merges with SNFP	SPAM Team / EIS Science Team
Oct. 98	EPC Model discussion / review	SPAM Sociocultural Team / PSW Social Scientist
Dec. 98	EPC Model / EIS integration	SPAM Sociocultural Team / EIS Interdisciplinary Team Economist
Jan. 99	SPAM Team coordinates and shares information	SPAM/EIS Teams
	with SNFP EIS	
Jan. 99	EPC Model discussion	SPAM Sociocultural Team / EIS Team
Jan. 99	EPC Model discussion	SPAM Sociocultural Team / PSW Social Scientist / Science Team Social Scientist
Jan. 99	SNFP EIS / Lake Tahoe Basin Watershed Assessment monitoring strategy development	SPAM Sociocultural Team / PSW / LTBMU Watershed Assessment Team
Feb. 99	Adaptive Management	Adaptive Mgt. Team
Feb. 99	SPAM Team – identify core attributes	SPAM Team
Mar. 99	Coordination Meeting	EIS/Science Teams, Forest Supervisors, forest contacts, Public Tc(v)irisvOec Tc((r)-6.9( )]TJ ET 79 626.4 0.4 -0
99	AdapA i Ma(nagei)-482e	AdapA i MgpA TeaA

Dates	Meeting – Main Focus	Participants
Mar. 99	SPAM Team – conference call	SPAM Team
Mar. 99	SPAM Team meets with SNFP EIS and Science Teams	SPAM/EIS/Science teams
Mar. 99	Development of sociocultural goals for EIS	SPAM Sociocultural Team / EIS Interdisciplinary Team Economist / Science Team Social Scientist
Apr. 99	Design Team	Design Team
Apr. 99	SPAM Team meets with SNFP EIS – goals, standard and guidelines, alternatives	SPAM/EIS/Science Teams
Apr. 99	SPAM Team – conference call	SPAM Team
May 99	Adaptive Management	Adaptive Management Team
May 99	SPAM Team meets with SNFP EIS – Sociocultural Team	SPAM/EIS/Science Teams
May 99	SPAM Team – monitoring chapter	SPAM Team
May 99	Meeting to review development of sociocultural monitoring questions to date	SPAM Sociocultural Team / EIS Interdisciplinary Team / Region 5 Program Leaders / Science Team Social Scientist
May 99	Conference call to review fire monitoring questions and develop sampling design	SPAM Sociocultural Team / PSW
May 99	Integration of EIS issues and monitoring strategy	SPAM Sociocultural Team / EIS Team specialists
Jun. 99	Interagency Meeting with SNFP	Agency Reps
Jun. 99	Discussion of assumptions and risks inherent in EIS/ generate cause and effect research questions	SPAM Sociocultural Team / EIS Team
Jun. 99	Monitoring Strategy Statistical Workshop	SPAM Team, Statisticians
Aug. 99	Interagency	Agency Reps
Sep. 99	Review of DEIS Environmental Justice section	SPAM Sociocultural Team Leader/ EIS Interdisciplinary Team Economist
Sep. 99	SPAM Team meets with SNFP EIS and Science Teams – monitoring questions	SPAM/EIS/Science Teams

As the SPAM Team sought out expert opinion and information exchange to further develop and refine the monitoring strategy for the EIS, partnerships with other agencies and groups were developed. The SPAM Team coordinated and collaborated with other Regional and Forest representatives, and federal, state and local agencies (See Table 5.2). Agencies involved in this coordination and collaboration effort included the following.

- Air Resources Board
- Bureau of Land Management
- California Department of Fish and Game
- California Department of Forestry
- California Resources Agency, Department of Parks and Recreation
- California Water Regional Control Board
- Environmental Protection Agency
- High Sierra Resource Conservation and Development
- National Park Service
- Natural Resource Conservation Service
- North Fork Rancheria
- San Joaquin valley Association of County Supervisors
- US Fish and Wildlife Service

Table 5.2 Meetings and significant contacts with other agencies and groups.

Dates	Meeting / Contact – Main Focus	Participants
Mar. 99	EPA Statisticians	Statisticians
Mar. 99	EMAP Symposium	SPAM Team Members
Apr. 99	SNFP	Agency Reps
May 99	Monitoring plan direction for Air Group	SPAM Air Group, FS Research, other specialists
Jun. 99	Science Coordinating Committee	Agency Reps
Jun. 99	Interagency Coordination Team	Agency Reps
Jun. 99	Statistics Workshop (EPA, BLM, NRCS)	Statisticians, SPAM Team
Jun. 99	California Off-Highway Motor Vehicle Recreation Division	Sociocultural Group Rep, Agency Rep
Jul. 99	NRIS Socioeconomic Database Development Coordinator	Development Coordinator, Sociocultural Group Rep
Jul. 99	California ORV Association / California Association of 4WD Clubs	Sociocultural Group Rep, Agency Reps
Jul. 99	SNFP public meeting	General, Agency Reps
Jul. 99	Forest Supervisor meeting	Forest Supervisors
Jul. 99	Contact with Region 5 National Recreation Use Sampling Pilot Project Implementation Coordinator	Project Implementation Coordinator, Sociocultural Group Rep
Jul. 99	California Off-Highway Motor Vehicle Recreation Division	Sociocultural Group, Agency Reps
Jul. 99	Sam's Coalition	Group Leader
Aug. 99	Region 3 Inventory and Monitoring Group	Region 3 Staff and Monitoring Team
Sep. 99	NetWeaver	SPAM Data Group, Inventory and Monitoring Institute
Sep. 99	Remote Sensing of Forest Structure	University of Maryland, Geography Dept. and NASA Goddard Space Center
Sep. 99	Remote Sensing of Forest Structure	University of Michigan, Forest Service Remote Sensing Lab, Sierra National Forest, PSW Fresno, Adaptive Management Services

APPENDICES

APPENDIX A

BIOGRAPHIES

LEADERSHIP

Pat Manley

Pat Manley is a Wildlife Ecologist for the Pacific Southwest Region of the Forest Service and the leader of the Sierra Nevada Monitoring Team for the SNFP. She is also a member of the Watershed Assessment Science Team for the Lake Tahoe basin, where she has been studying the relationship between biological diversity and disturbance in the Lake Tahoe Basin. She began working for the USDA Forest Service in California in 1984. She has a bachelor's and master's degree from Humboldt State University, and is nearing completion of her Ph.D. at the University of California at Berkeley. Pat is a native of California and currently lives in South Lake Tahoe.

Peggy O'Connell

Peggy O'Connell, an Ecologist, is the Assistant Team Leader of the Sierra Nevada Monitoring Team for the SNFP. Peggy's areas of expertise are resource management, environmental laws and regulations, and forest planning. She has a bachelor's and master's degree from Humboldt State University. In her career with the USDA Forest Service, Peggy has held the positions of Forester, Assistant Planner and NEPA Coordinator, NEPA and Federal Energy Regulatory Commission expert, Lands and Engineering Officer, Forest Resource Officer, Province Ecologist, and Ecosystem Program Manager. She has worked for the Forest Service for 24 years.

TEAM MEMBERS

Suraj Ahuja

Dr. Suraj Ahuja is currently a Province Air Quality Specialist for the Forest Service supporting air program for the eight northern national forests. He has worked for the Forest Service for twenty years in the Southwest and Pacific Southwest Region in various positions. Suraj received his Ph.D. from the University California at Davis and received an Air Quality Certification from University of California (Extension) in Davis. He has written various technical documents and papers for Forest-wide and Region-wide use

Aaron Bilyeu

Aaron Bilyeu, a Wildlife Biologist who received his bachelor's degree from Humboldt State University, has been working as a Wildlife Data Analyst for the Sierra Nevada Monitoring Team since 1997. His primary responsibilities have included designing and refining the Sierran All Species Database. Aaron works for the SPAM Team from his office in Camino, California. Prior to working with the SPAM Team, Aaron worked as Wildlife Biological Technician and a Wildlife Biologist involved in field surveys of Threatened and Endangered Species, compiling NEPA documentation, data entry and database management.

Anne Bradley

Anne Bradley is the Regional Botanist for the Pacific Southwest Region, where she is responsible for management of federally listed and Forest Service designated sensitive plant species for the Region. She has worked in the Region since 1991 in a variety of roles, primarily in developing policy and direction related to the management of wildlife and rare plant resources. Prior to here assignment in California, Anne was the botanist/ecologist for the Prescribed Fire and Fire Effects Research

Unit at the Rocky Mountain Station (formerly the Intermountain Research Station). She is the primary author of two publications describing the fire ecology of forest habitat types in the intermountain region. Anne has a bachelor's degree in biology from Colorado College and a master's degree in botany from the University of Montana.

Cathy Brown

Cathy Brown is a Wildlife Biologist stationed at the Pacific Southwest Research Station, in Albany, California, where she is specializing in herpetology. As part of the Sierra Nevada Monitoring Team, she is currently Monitoring Team Leader for the Aquatic, Riparian, and Meadow Problem Area. Previously she served as Data Team Leader as well as provided terrestrial and aquatic biological expertise.

Ms. Brown has a multi-disciplinary background with expertise in both ecology and computer programming. She has a Master's Degree from Oregon State University where she investigated associations between habitat heterogeneity and the population structure of a montane, pond breeding amphibian, the Cascades frog (*Rana cascadae*), at multiple spatial scales. In addition, Ms. Brown has participated in population, behavior, resource utilization2gee611.1(an)215.7(d)210.6( )]TTJ 12.9J 0 -1.1273 TD -0.0066 Tc 0.0111 T(r t

the Biodiversity Team, he was responsible for constructing the invertebrate, fungi and lichen, and non-vascular plant databases; he also authored several Focal Species and Ecologically Sensitive Area accounts. Erik, who received his bachelor's degree from California State University, Sacramento, is a native of Northern California who has worked for the Forest Service for over 20 years in various capacities in Southern California, Costal Oregon, and the Sierra Nevada.

Carolyn Hunsaker

Dr. Hunsaker started with the Forest Service in 1998. Previously she was a research staff member in the Environmental Sciences Division at Oak Ridge National Laboratory in Tennessee for 16 years. As a Forest Service Research Ecologist Carolyn is designing an instrumented watershed study to evaluate current uneven-aged harvesting and intensive prescribed fire on aquatic ecosystems in the Sierra Nevada. Attributes being evaluated include nutrients, flow, sediment, temperature, and macroinvertebrates. The watershed work is part of the Kings River Sustainable Forest Ecosystem Project for which Carolyn is the lead scientist. She is helping with plans for Forest Service ecological monitoring under the Sierra Nevada Conservation Framework. Carolyn will continue her work on landscape ecology with an initial focus on relationships between forest structure and California spotted owl productivity. She is also the lead editor on a new book to be published in 2000, "

Sylvia R. Mori

Sylvia R. Mori is a mathematical statistician who provides statistical consulting, data analysis and reviews of manuscript and study plans for Pacific Southwest Research Station. She also collaborates with scientists from several research groups within the Forest Service and Pacific Southwest Research Station in disciplines such as silviculture, wildlife, soil, entomology, range, plant ecology, urban forestry, genetics, and hydrology. Sylvia received her bachelor's degree in mathematics from the Universidad de Chile in Santiago, Chile. She also has a master's degree in mathematics from the Universidad Tecnica del Estado in Santiago, Chile and a master's degree in statistics from the University of California in Berkeley. She is currently working on her Ph.D. in statistics at University of California, Davis.

Sylvia has statistical expertise in data exploration; ANOVA, linear and non-linear regression; general linear models; logistic regression—Poisson, Binomial (Logit), Multinomial, etc.; discriminant analysis, cluster analysis, classification and tree regression; generalized additive models (smoothing); and, analysis of spatial data.

Carolyn O. Napper

Carolyn O. Napper, who received her bachelor's and master's degrees from California Polytechnic State University in San Luis Obispo, California. She is the Forest Soil Scientist, for the Lassen National Forest. She is the program leader for the soils and hydrology program on the Lassen. Ms. Napper has worked for the USDA Forest Service since 1989. Before working on the Lassen, she worked on the Stanislaus National Forest as the District soil scientist, hydrologist and range program leader for the Calaveras Ranger District. She has been active in providing regional training for the Burn Area Ecosystem Recovery program. In 1999 she was selected as a member of the National Roads, Riparian Team program to provide soils input for that program.

Trent Proctor

Trent Procter is currently the Air Resource Specialist serving the Sierra Nevada National Forests from the Sequoia to the Lake Tahoe Basin. He attended Cal Poly State University in San Luis Obispo studying natural resource management and has 21 years of experience with the US Forest Service. His experience includes development of monitoring programs to detect air pollution impacts on forest resources, air quality NEPA analysis, and development of Forest Service air quality regulatory compliance programs.

Beth Pymale

Beth Plymale, an Air Quality Specialist who received her bachelor's degree from California Polytechnic State University, San Louis Obispo, is presently working or her master's degree in planning. She has been a Forest Service employee since 1989; her areas of expertise include Recreation, Wilderness and Air Quality.

Linda Reynolds

Linda Reynolds has worked as an archaeologist and applied anthropologist with the USDA Forest Service since 1978. Currently, she is the Heritage Resources and Tribal Relations Programs Manager on the Inyo National Forest. Linda received her Ph.D. in anthropology from the University of Nevada, Reno in 1996. Her dissertation research investigated the interplay of cultural and environmental change through 8,000 years in the Inyo Mountains of eastern California.

Linda's engagement with American Indian issues in the larger Sierra Nevada bioregion began with authorship of "The Role of Indian Tribal Governments and Communities in Regional Land Management" for the Sierra Nevada Ecosystem Project's final report to Congress. She has since worked to directly involve tribes in the Sierra Nevada Framework Project through organizing the first Tribal Summit Meeting in 1998 and the Eastside Tribal Summit in 1999, as well as participating in other subregional tribal meetings. In addition to her work with the SPAM Team, Linda is a member of the Framework Interdisciplinary Team,

providing expertise in tribal relations and heritage resources.

Ken Roby

Ken Roby has over 25 five years experience in aquatic resource and watershed management. Experience has been obtained as an aquatic ecologist, fisheries biologist and hydrologist in positions with the Pacific Southwest Research Station, the Lassen, Plumas and Six Rivers National Forests and the East Bay Regional Park District. His areas of expertise include monitoring of stream systems with an emphasis on macroinvertebrates, watershed and landscape analyses and aquatic and watershed restoration. He has authored several publications which document effects of wildland resource management on stream systems. He assisted in development of the regional Best Management Practices Evaluation Program, Stream Condition Inventory, and monitoring plan for the Quincy Library Group Forest Health Pilot. Ken earned his undergraduate and master's degrees in Conservation of Natural Resources and Aquatic Ecology from the University of California, Berkeley. For the past 10 years, he as taught classes in stream survey and stream ecology at Feather River Community College.

Rema Sadak

Rema Sadak is a Wildlife Biologist who joined the Six Rivers National Forest in northwest California in 1991, working in forest planning, threatened, endangered, and sensitive species, and watershed assessment. She began working for the Sierra Nevada Monitoring Team in 1999. Before working on the Six Rivers National Forest, Rema worked on the Siskiyou National Forest in Oregon, where she helped develop the Forest Service's New Perspectives program, and developed a sensitive species program on the Gold Beach Ranger District. She has given presentations throughout the northwest on incorporating biological diversity, ecosystem management, and integrated resource analysis in project planning. Rema worked in Washington, D.C. for the Federal Energy Regulatory Commission, Office of Hydropower Licensing, evaluating environmental effects and developing mitigation for wildlife and riparian resources, focusing on projects in the western US. She has also worked for the Huron-Manistee National Forests in Michigan with the endangered Kirtland's Warbler, and for the Forest Service's Northeast Experiment Station. Rema received her bachelor's degree from the University of Michigan, and her master's degree from Humboldt State University.

Matthew Schlesinger

Matthew Schlesinger is Wildlife Biologist who has worked as a member of the Lake Tahoe Watershed Assessment project and the Sierra Nevada Monitoring Team. For the Lake Tahoe Watershed Assessment, Matt helped conduct an assessment of species, ecologically significant areas, and aquatic ecosystems in the Lake Tahoe basin. Matt has also assisted in the development of the monitoring plan for the National Forests in the Sierra Nevada. Prior to starting with the Forest Service in April of 1997, he worked for the National Park Service and the Biological Resources Division of United States Geological Survey as a Biological Science Technician performing field surveys. Matt has a bachelor's degree from Wesleyan University and a master's degree from the University of Michigan.

Gary J. Schmitt

Gary J. Schmitt, who received his bachelor's degree from Colorado State University, first started working seasonally for the Forest Service in Region 2 while in college. These seasonal jobs supported timber, range, and watershed functions. In 1972 Gary accepted a temporary Range Conservationist position with the Bureau of Land Management in Grand Junction, Colorado to work on watershed condition surveys. Shortly thereafter, he was offered a permanent position with the Soil Conservation Service in Alamosa, Colorado. Gary mapped soils in south central Colorado from 1973 to 1976. From 1976 through 1979 he was the Forest Soil Scientist for the Routt National Forest in Region 2.

Gary has been a Zone Soil Scientist on the Sierra National Forest since 1980. In this position, Gary has Regional Office responsibilities for quality control on soil surveys and management

services on the Southern Sierra Zone Forests that include the Sierra, Stanislaus, Sequoia, and Inyo National Forests. He also has responsibility for the soils program on the Sierra National Forest. Gary has been a Burned Area Emergency Rehabilitation Team Leader on six major fires and a Soil Specialist on 10 other major fires since 1987.

Claudia Stuart

Claudia Stuart has led the Sociocultural work group of the Monitoring Team since 1997. Claudia holds a bachelor's degree from Bryn Mawr College and a Master's of Landscape Architecture from the University of California at Berkeley. While at the University of California, she was awarded the Thomas Church prize for her "Vision Plan for East Palo Alto".

Claudia began working for the Forest Service in 1991. During her first two years with the agency, she served as a Landscape Architect on the Mendocino National Forest. From 1993 to 1994, Claudia worked in Eastern Europe as a resident consultant on democracy and participatory planning to the city of Budapest, Hungary. She returned to the Forest Service in 1994, serving for three years as a community planner conducting watershed analysis under the President's Northwest Forest Plan. Her work abroad during this period included interpretive planning at Tikal National Park, Guatemala.

Wally Woolfenden

Wally Woolfenden received his Ph.D. in geosciences from the University of Arizona with a research emphasis in paleoecology. During his studies at the university, he was a Graduate Associate in Research with the Laboratory of Tree-Ring Research and developed a 6000-year old climatic chronology from lower forest border bristlecone pine tree-ring series, White Mountains, California. His dissertation research, completed while a member of a United States Geological Survey study team analyzing an 800,000-year core retrieved from Owens Lake, was the analysis of pollen and spores deposited over the past 155,000 years to reconstruct the terrestrial and aquatic vegetation history of the southern Owens Valley region, to correlate climatically sensitive pollen taxa with marine oxygen isotope and other chronostratigraphies, and to model the response of vegetation to climate change during the past glacial cycle.

Wally has worked for the Forest Service for over 20 years, primarily in heritage resource management. Between 1977 and 1987 he designed, implemented, and administered the cultural resource management program for the Stanislaus National Forest, after which he transferred to the Inyo National Forest where he continued to serve as an archaeologist with collateral duties as historical ecologist and research natural area coordinator. In 1998 he joined Mountain Heritage Associates, an enterprise team with the Region 5 Reinvention Lab. Wally served as special consultant to the Region 5 ecosystem management team for the development of Sustaining Ecosystems, A Conceptual Framework and wrote an assessment report, "Quaternary Vegetation History of the Sierra Nevada", for the SNEP final report to Congress.

William J. Zielinski

William Zielinski is a Research Wildlife Ecologist for the Pacific Southwest Research Station, Redwood Sciences Laboratory where he conducts research on the inventory and monitoring of terrestrial vertebrate species, the ecology and biogeography of mammalian carnivores, and the effects of forest management on mammals.

William, who received his master's degree from the University of California in Berkeley and his doctorate from North Carolina State University, is also an Associate Faculty in the Department of Wildlife at Humboldt State University in Arcata, California.

NEW TEAM MEMBERS FOR FISCAL YEAR 2000

Mike Arbaugh

Mike Arbaugh received a bachelor's degree in biology and a master's degree in statistics from the University of California in Riverside; he received a Ph.D. in forest ecology from Colorado State University in Ft. Collins. Mike has worked as a statistician from 1986 – 1994 for the USDA Forest Service, and since 1995, he has worked as a Forest Ecologist for the Atmospheric Deposition Effects Project at Riverside Fire Laboratory. His research interests include landscape scale development and testing of air pollution monitoring techniques, estimation of regional air pollution effects on vegetation, and simulation modeling of prescribed and wildland fire tradeoffs on vegetation and smoke emissions in the western United States.

Neil Berg

Neil Berg is a Hydrologist who is presently the National Coordinator for Cumulative Watershed Effects Assessment for the USDA Forest Service, Pacific Southwest Research Station in Albany, California. Neil has also served as the National Water Quality Liaison to the Environmental Protection Agency, and, for a period of six years, was the Supervisory Hydrologist and Project Leader of Cumulative Effects of Resource Management on Forested Watersheds, Aquatic Ecosystems and Fish Communities in California's Inland Mountains Research Work Unit for the Pacific Southwest Research Station.

Neil received his Ph.D. in physical geography from the University of Colorado, Boulder, his master's degree from the University of California, Davis, and bachelor's degree from the University of California, Berkeley. His areas of expertise include water quality (monitoring, management effects), assessment of cumulative watershed effects, in-channel woody debris, surface water hydrology, fish habitat relationships, and snow hydrology

Ann Carlson

Ann Carlson is a Fisheries/Aquatic biologist. Ann, who has worked for the USDA Forest Service since 1989, is the Forest Fisheries Program Manager for the Tahoe National Forest in Nevada City, California. She received her masters degree in aquatic ecology from Utah State University in Logan, Utah.

Tom Frolli

Tom Frolli is a state certified Rangeland Manager with the Sierra National Forest. Tom has extensive experience with conservation and management of western rangelands relative to livestock and wildlife grazing ecology. He has worked on several different national forests and Bureau of Land Management Districts in the High Plains, Rocky Mountains, Great Basin and west slope Sierra Nevada's. Tom's primary work has been as a grazing permit administrator and NEPA planner for twenty years. His emphasis has been on resolving environmental impacts from grazing activities and supporting viable ranch operations. He has contributed to the development and applied use of grazing standards, guides, effectiveness monitoring and ecological scorecards at the watershed, landscape and bioregion levels. Tom received his bachelor's degree from Humboldt State University in 1979. He returned to California from the Intermountains in 1994. His next assignment will be to the Tahoe National Forest as Province Rangeland Manager.

Mary Grim

Mary Grim is a Zone Fisheries Biologist who works on the Tahoe National Forest. Prior to working on the Tahoe, Mary was a cooperative education student with the George Washington and Jefferson National Forests in Virginia. She also worked as a Fisheries Management Specialist with the National Marine Fisheries Service where her duties included summer

flounder quota setting, multi-permit vessel review system and overfished stock review. Mary received her bachelor's degree in biology from West Virginia University and did her graduate studies in fisheries at Virginia Tech.

Christine M. Mai

Christine M. Mai has worked in Placerville, California as a Hydrologist on the Eldorado National Forest for the last 10 years. Christine received her bachelor's degree in watershed management from the University of Arizona in Tucson. Prior to coming to the Forest Service Christine worked for the USDA, Agricultural Research Service on the Watershed Erosion Prediction Project. As part of the WEPP team Christine helped to conduct rainfall simulations over much of the southwestern United States and was responsible for the synthesis of much of the data for the rangeland portion of the simulations. Her area of expertise is cumulative watershed effects analyses. Christine frequently participates on Burn Area Emergency Rehabilitation teams and recently presented the methods and models used for predicting increases in peak flows and erosion associated with wildfire at a National Burn Area Emergency Rehabilitation conference in Reno, Nevada. While working on the Sierra Nevada Monitoring Team Christine is also serving on a team that is developing a regional protocol for assessing watershed condition for all forests in California.

Chris Riley

Chris Riley is a Fisheries Biologist who works on the Inyo National Forest. Chris, who has worked for the USDA Forest Service for over 20 years, received a bachelor's degree from Oakland University, Rochester, Michigan and a master's degree from Montana State University, Bozeman, Montana. Prior to working on the Inyo, Chris worked on the Hoonah Ranger District of the Tongass National Forest, the Lolo National Forest, the Wenatchee National Forest, the Deschutes National Forest, and the Tahoe National Forest.

Dave Weixelman

Botanist, Humboldt-Toiyabe National Forests
Biography not available.

APPENDIX B

THE MONITORING STRATEGY STATISTICAL WORKSHOP

Workshop Overview

The Sierra Nevada Framework Project Monitoring Team sponsored "Monitoring Strategy Statistical Workshop" in June of 1999. The purpose of the workshop was to share information between statisticians involved in various national survey and monitoring programs; to explore the possibilities of forming a statistical advisory group; to develop partnerships between statisticians involved in monitoring programs; and, to discuss marketing strategies designed to help decision makers use monitoring information.

The invited participants included Jim Baldwin, Statistician, PSW; Mike Sieg, Inventory and Monitoring Institute; Doug Powell, National Monitoring & Evaluation Coordinator, WO; Tony Olsen, Statistician, EPA; Patrice Janiga, Inventory and Monitoring Institute; Jim Alegria, Statistician, Bureau of Land Management; Hans Schreuder, Statistician, RMRS-FIA; Kerry McMenus, Planner, R01; Gary Williams, National Park Service; Jeff Goebel, Statistician, Natural Resource Conservation Service; and Peter Stine, Statistician, United States Geological Survey.

Selected Points Made in Workshop Discussions

- *The perspective of monitoring has changed over last 30 years from local to global.*
- *In terms of sample questions, there is a tendency for larger scale questions to become more policy oriented.*
- *Study objectives determine the survey design; people tend not to define target population.*
- *Regarding near term versus long-term monitoring: Near term may be stated by EIS and be fairly explicit. Long-term monitoring is usually more science based.*
- *There is an attempt to get a consistent national framework.*
- *Monitoring types:*
  Compliance determines if standards and criteria are met.
  Baseline monitoring – implementation, effectiveness and value.
- *There is a need to invest in the structure of implementing; to get an infrastructure in place.*
- *If you have a successful program, it will change.*
- *FIA objectives changed, especially in '85-86,because the program became more interested in the "whys."*
- *The database is the basic product and typically the data are under analyzed.*
- *A pilot project is underway that will define what levels of accuracy can be achieved with what levels of investment/sampling intensity. It will map 400,000 acres and will put in 0.8-mile grid; it's a Cadillac sampling intensity.*
- *Research (effectiveness monitoring) is a valuable part of monitoring.*
- *Information should be geared down to local scale; having something there for everyone assures long-term survivability of a monitoring program.*
- *There is a need to institutionalize an organization for monitoring; monitoring hasn't been institutionalized for the NW plan, but they are trying.*
- *Information management is extremely important, i.e. data standards, and database structure.*
- *The more people use the data the more support it will get.*

- *It has taken management a while to understand the need for monitoring.*
- *It's important to educate others about monitoring efforts and results.*
- *We need to use simple understandable information – e.g. National Resources Inventory pamphlet.*
- *The wealth of data is very important and useful in doing modeling.*
- *Quality assurance should be built in.*
- *There is a need for consistency to obtain and maintain credibility.*
- *It's important to define target populations.*
- *Avoid the "I'll know it when I see it" approach.*
- *Know ahead of time, what the managers may do with information.*
- *Help management understand how they can use the data.*
- *The National Park Service has similar problems as FS, i.e., difficulty trying to institutionalize monitoring, and manage effectively with little data quality and assurance.*
- *National Park Service had workshops where individuals were brought together from parks, other agencies, universities, and people with knowledge on how ecosystems function.*
- *National Park Service publishes a protocol for a specific monitoring/inventory that bridges the gap between management and science.*
- *National Park Service is trying to set up infrastructure for accountability procedures.*
- *In the area of data management, National Park Service also produces reports for managers.*
- *Budget per park for monitoring is $400,000-$600,000.*
- *Region 1 looked at ways to link the inventories among forests because there are big gaps at landscape level.*
- *R-01 uses 'NetWeaver' to organize the pieces.*
- *Keep pushing managers – get them on the team.*
- *The feedback loop that monitoring provides is important.*
- *The Inventory and Monitoring Institute that can be accessed through the Inventory and Monitoring Institute web site, http://fsweb.ftcol.wo.fs.fed.us/imi/*

Monitoring Discussions

The conversations between visitors and the monitoring team included the following topics:

- Monitoring questions.
- Target population(s) and the subpopulations defined by reporting units.
- Attributes and metrics. Disturbances.
- Sampling design:
  Sample size (optimization for given dollars),
  Sampling units; grid points and primary sampling units.
  Systematic versus random sampling,
  Stratification,
  Probability sampling,
  Sample scale,
  Consistency,
  Longitudinal data collection,
  Adaptive sampling designs,

- A statistic advisory group is established through the Inventory and Monitoring Institute coordinate by Patrice Janiga. Mike Sieg will be the contact for other efforts and interregional coordination.
  Consultants for statistic expertise:
  Tony Olsen – aquatic.
  Jeff Goebel – soils.
  Hans Schreuder – forest structure and surveys with public.
  Tom Bobby (RSAC – Salt Lake) – remote sensing.

- SPAM will develop a concrete proposal with three levels of monitoring for the manager to choose from with a marketing strategy designed for people without statistics or monitoring experience. The marketing strategy is to help decision makers distinguish among the levels of monitoring. It will include some simple examples about the benefits of the additional information at higher levels.

- The proposed three monitoring levels:
  Economy = minimum information needed to address goals and to meet legal requirements, peppered treatment across the resources and categories of monitoring (Implementation, Status and Change, Cause and Effect).
  Coach = better resolution, more sensitive measures, more precise estimates, more spatially explicit, bigger sample size
  1st class = this level best meets the needs of the IS, Region, Forests, PSW, and collaborators.

- A Pilot Study will be designed as an exercise to test each proposal level. The proposal will be sent to the statistic advisory group for review prior to pilot study design. The final proposal will be offered to forest managers.