APPENDIX F – Wildland Fire Monitoring Plan

Lassen Volcanic National Park
Wildland Fire Monitoring Plan

National Park Service
U.S. Department of the Interior

Lassen Volcanic National Park
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1.0 INTRODUCTION

Lassen Volcanic National Park (LAVO) has established a program of fire management to achieve the protection and stewardship of fire-adapted forest and shrub ecosystems. The purpose of fire monitoring is to provide effective evaluation of the wildland fire management program. The focus of the LAVO fire monitoring program is assessing the condition of vegetation and fuels, and how they are affected by the application of fire or fire-surrogates. The LAVO fire monitoring program is separate and independent from the Klamath Network Inventory and Monitoring (I&M) Program, which tracks a suite of ecosystem vital signs at each of six national parks including LAVO.

The LAVO fire monitoring program has been designed to determine whether fire and resource management objectives are being met, as well as to document any unexpected consequences of fire management activities. The monitoring program is intended to continuously inform the staff about results of management activities so that the fire management program can adapt to changing conditions using the best available information. To be the most effective, evaluation and integration of fire monitoring data will be a shared responsibility between fire management and natural and cultural resource management staffs.

As an appendix to the Wildland Fire Management Plan, this monitoring plan describes the framework for collecting, managing, evaluating and integrating fire effects information – the four core activities of the fire monitoring program. The overall sampling design is based on five major plant communities found within the park (i.e. *Montane Chaparral, Jeffrey Pine and White Fir, Lodgepole Pine, Red Fir/Western White Pine and Mountain Hemlock Forests)*; alpine fell fields are excluded. As new information and research results are obtained, relevant changes to the monitoring program will be made. These changes may include new or alternative monitoring techniques, changes in treatment prescriptions, or refinement of management objectives.

1.1 History of Fire Management and Monitoring

Lassen Volcanic National Park was established by an Act of Congress on August 9, 1916 (39 Stat. 442) “for recreation purposes by the public and for the preservation from injury or spoliation of all timber, mineral deposits and natural curiosities or wonders within said park and their retention in their natural condition and…provide against the wanton destruction of the fish and game found within said park and against their capture or destruction…” At the time of establishment, fire suppression was the dominant management strategy for the park and the surrounding forest communities. It wasn’t until the mid-1960’s that fire was recognized as an important natural process in western ecosystems (Leopold et al. 1963) and institutionalized as Departmental policy in 1968 (Kilgore 1973).

A formal fire monitoring plan has not been formulated until now, although the park has been systematically collecting fire effects information on prescribed fires since 1990 using up to seven different vegetation categories (monitoring types).

The current distribution of fire monitoring plots is summarized in Table 1 below. Some aspects of the monitoring program (e.g. monitoring objectives) are still under development.

Table 1. Summary of Fire Monitoring Plots by Major Plant Community.

Plant Community (i.e., monitoring type)	No. of Monitoring Plots Installed	No. of Monitoring Plots Needed	Monitoring Plot Type	Treatment Type	Existing Project Names
White Fir Forest	15	56-60	FMH – forest[1]	Rx burn	Warner Valley, Lost Creek and Butte Lake Burn Units
Ponderosa Pine Forest	4	36-40	FMH – forest	Rx burn	Warner Valley and Butte Lake
Red Fir Forest	9	20-24	FMH – forest	Rx burn	
Lodgepole Pine Forest	2		FMH – forest	Rx burn	
Sedge Meadows	4		FMH – grass	Rx burn	
Montane Chaparral	11	20 -24	FMH – brush	Rx burn	

[1] Refers to the plot layouts described in the NPS Fire Monitoring Handbook (NPS 2003a).

1.2 Monitoring Framework

The natural landscape at Lassen Volcanic National Park has been divided into more than 23 different vegetation associations. There is a great deal of species overlap between these 23 plant associations however, and when the differences in moisture, temperature and disturbance regimes are taken into account, 4-5 broad community types emerge. Changes to these broad plant communities can be assessed, mapped, and managed at a landscape scale, making them an effective framework for the LAVO fire effects monitoring program. These four major plant communities and their dominant species are listed below in Table 2, along with the plant species found growing in the rock crevices of the park's lava flows.

Table 2. Major Plant Community Types of Lassen Volcanic National Park.

Community Type	Dominant Species
Sedge Meadows (886 ac)	Sedges (*Carex* spp.), *Agrostis thuberiana*, *Deschampsia caespitosa*, and *Muhlenbergia filformis*. Or if on steep slopes or in larger gaps: satin lupine (*Lupinus obtusilobus*), mule ears (*Wyethia mollis*), *Artemisia douglasiana*, and *Alnus tenuifolia*.
Montane Chaparral (1,823 ac)	Manzanita (*Arctostaphylos patula*), snowbrush ceanothus (*Ceanothus velutinus*) and bush chinquapin (*Castanopsis sempervirens*).

Community Type	Dominant Species
Jeffrey Pine (13,739 ac)	Jeffrey pine (*Pinus jeffreyi*), white fir (*Abies concolor*), ponderosa and sugar pines (*Pinus ponderosa* and *P. lambertiana*), with occasional occurrences of incense cedar (*Calocedrus decurrens*), red fir and western white pine (Pinus monticola).
White Fir (9,238 ac)	White fir (*Abies concolor*), Jeffrey, ponderosa and sugar pines (*Pinus jeffreyi*, *P. ponderosa* and *P. lambertiana*), with occasional occurrences of incense cedar (*Calocedrus decurrens*), red fir and western white pine (Pinus monticola).
Lodgepole Pine (13,389 ac)	Lodgepole pine (*Pinus contorta* var. *murrayana*), with red and white fir (*Abies magnifica* and *A. concolor*) and mountain hemlock (*Tsuga mertensiana*) occurring as minor associates.
Red Fir (14,669 ac)	Red fir (*Abies magnifica*) in association with western white pine (*Pinus monticola*) and lesser amounts of lodgepole and Jeffrey pines (*Pinus contorta* var. *murrayana* and *P. jeffreyi*), white fir (*Abies concolor*) and mountain hemlock (*Tsuga mertensiana*).
Red Fir/ Western White Pine (33,158 ac)	Red fir (*Abies magnifica*) in association with western white pine (*Pinus monticola*) and lesser amounts of lodgepole and Jeffrey pines (*Pinus contorta* var. *murrayana* and *P. jeffreyi*), white fir (*Abies concolor*) and mountain hemlock (*Tsuga mertensiana*).
Mountain Hemlock (7,073 ac)	Mountain hemlock (*Tsuga mertensiana*) occurs with red fir (*Abies magnifica*) and western white pine (*Pinus monticola*) at lower elevations and with white bark pine (*Pinus albicaulis*) at treeline.

1.3 Fire Regime

Lassen Volcanic National Park covers approximately 500 km^2 of the southernmost peaks of the Cascade Mountain range. Most of the park below 2400 m is forested, with the distribution of conifer species being affected by elevation (Parker 1991). Red fir *(Abies magnifica)* and lodgepole pine *(Pinus contorta var. murrayana)* dominate upper elevations (2100 to 2400 m), whereas white fir (*A. concolor)* and Jeffrey pine (*P. jeffreyi)* are most abundant at lower elevations (<2100 m). Limited stands of mountain hemlock *(Tsuga mertensiana)* occur along the treeline >2400 m. Other minor vegetation communities occurring in the park include (1) montane chaparral and (2) seasonally wet habitats located in valley meadows and along streams and lake margins (White et al. 1995).

Bekker and Taylor (2001) found that plant species distribution and abundance in the southern Cascades are influenced by both environmental gradients and fire regimes; and variation in fire regimes may not be independent of environmental gradients or vegetation patterns. Furthermore, modifications to historical fire regimes can and has led to shifts in landscape scale vegetation patterns.

The park's fire history shows the largest fire within the park happened in 1918 and consumed approximately 5,000 acres of parkland. Other large fires in the park have ranged from 1,500 to 2,2oo acres. In recent decades the majority of fires in the park have been between 1/10 of an acre to one acre in size. The reason these fires have been so small is mainly due to fire suppression efforts. The actual size and number of fires would depend on weather patterns, the location of lightning strikes, and the extent of fire spread before naturally extinguished or suppressed.

1.3.1 Disturbance Regime

Landscapes consist of a dynamic mosaic of patches, which are created by successive disturbances of various types, including fire (White and Pickett 1985). Exchange networks exist between patches facilitating recolonization, however in a highly anthropized landscape the dynamic is more complex and unpredictable (Pickett and White 1985). Disturbances are defined as “any relatively discrete event in time that disrupts ecosystem, community, or population structure and changes resources, substrate availability, or the physical environment” (White and Pickett 1985). Disturbances affect community structure and dynamics at various spatial scales (Pickett et al. 1989). Factors such as fire, landslides, and precipitation variability usually act at relatively large spatial scales, while disturbances such as herbivory, burrowing, and falling tree limbs often impact communities at much smaller spatial scales (Pickett and White 1985). Fire/disturbance regimes help to define the pattern or mosaic of age classes, successional stages, and vegetation types on the landscape (Turner et al. 1993); and are often necessary to maintain regional diversity (Burel and Baudry 2003).

The fire regime is a subset of the disturbance regime of a given area. In turn, disturbance regimes are described by the following characteristics: type, landscape characteristics, synergism, predictability, frequency, magnitude, rotation, seasonality and spatial extent (White and Pickett 1985, Agee 1993). These terms are defined as follows:

Type: This characteristic is simply the type of disturbance, for example the types of disturbances that play or have played a role in the LAVO environs include: browsing, human development, disease, drought, fire, earthquakes, glaciation, human, mass wasting, mowing, overgrazing, planting, pollution, relatively rapid climate change, trampling, volcanic, and windstorm.

Landscape characteristics: Within a given landscape, the behavior of the disturbance type will vary on a variety of spatial scales, which is influenced by local microclimate, topography (see the Climate and Topography section), and fuel conditions (see Fuels section). This varying behavior then interacts with the post-disturbance climate to stimulate ecosystem responses that result in varying landscape mosaics.

Synergism: Disturbances can interact with each other; e.g., an outbreak of a fungal or viral pathogen can cause a stand of trees to be more susceptible to wind-throw or a high intensity wildfire. These interactions are often complex and may be difficult to quantify. Still, managers must consider this characteristic when making management decisions.

Predictability: The variation in frequency over time can influence the presence or absence of some organisms within an ecosystem depending on their adaptations to that disturbance. For example, if an organism requires 5 years to complete its life cycle, it will vanish from an area that regularly burns every 2 years. However, this same organism would have the ability to re-colonize the area if there is a fire free cycle for more than five years.

Frequency: How often the disturbance occurs within a given time period. This characteristic is often described in terms of return intervals rather than frequency. The return interval is the length of time between fires.

Magnitude: Refers to both intensity and severity of a disturbance. Intensity describes the amount of energy released from a fire. Intensity may or may not be directly related to the resulting effects from a disturbance. Severity is related to the change in the ecosystem caused by the disturbance and can be either quantitatively or qualitatively related to disturbance effects. For example, low-severity fires are usually described as fires that only consume surface fuels, where woody vegetation survives. Whereas, high-severity fires are fires that kill large trees over large areas.

Rotation: The length of time necessary to “disturb” an area equal to the area or landscape of interest. For example, if one is working with a landscape of 100,000 acres and it takes fifty years for fires to burn 100,000 acres within that landscape, the disturbance rotation would be fifty years. A key point being that all 100,000 acres need not be disturbed if some acres are disturbed more than once.

Seasonality: The seasonality, or timing, of a disturbance is important in relation to the moisture content of the soil and fuel, the phenology of the vegetation, and the resulting effects. The vegetation found within a particular ecosystem has adapted over time to the season or seasons in which the disturbances generally occur.

Spatial extent: Refers to the size or area covered by a disturbance and the spatial patterns created by multiple disturbances.

Few disturbance history studies describe the all of the disturbance regime characteristics mentioned here. For example, many describe the fire frequencies for points (a single tree) or small sites, and some include seasonality as interpreted from the location of the scar in the rings (i.e., late-wood or early wood) of the year of the fire. Few studies have attempted to describe the rotation, spatial extent, or magnitude of past fires, because acquiring these data requires intensive sampling of many sites over a landscape. However, based on available knowledge, each of these characteristics is summarized in Table 4 on page 13.

1.3.2 Lassen Area Disturbance History

A 6.3-meter sediment core from Little Willow Lake provides a 13,500-year pollen record of vegetation history for Lassen Volcanic National Park (West 2003). Located 1,829 meters above sea level within a mixed red fir forest, Little Willow Lake covers approximately 2.5 hectares. The pollen profile provides a sequence of local and regional vegetation for the southern Cascades. The vegetation succession covers the transition from the late glacial climates of the Pleistocene to the post-glacial climates of the Holocene. A sagebrush steppe occupied the region prior to 12,500 yrs B.P.; then a pine dominated forest from 3100-12,500 yrs B.P., and finally the red fir forest of today. However, much of the park was glaciated up until 12,000 yrs B.P. (Crandell 1972; Kane 1975).

Abrupt transitions from sagebrush steppe to pine forest and the shift to the red fir forest took place in <500 years in response to millennial scale climate change. Between 12,500-13,500 yrs B.P. the climate was more seasonal, analogous to the climates of high elevations within the Great

Basin today. Conditions were warmer than today between 3100-9000 yrs B.P., with the warmest period between ca. 7500-9000 yrs. B.P. The expansion of fir beginning ca. 3100 yrs B.P. and appears to be congruent with that observed in the central and southern Sierra and eastern Klamath Ranges, indicating that the climate cooled and moisture levels increased; particularly winter snow depths.

Native Americans and early European settlers may have influenced fire regimes on in the Lassen area. There are Native American occupation sites near and in Lassen, and tribes in the Lassen area are known to have used fire to drive game and manage plant populations for food and fiber. At the time of Anglo-American contact members of the Atsugewi, Mountain Maidu, and Yana/Yahi American Indian groups used the park area. Detailed ethnographic accounts for these groups (Garth 1978; Johnson 1978; Riddell 1978) and for the park (Schultz 1954) portray seasonal use of the park area by all three groups to exploit seasonally available food resources and to follow mobile game. These authors also indicate that these groups used burned forests, shrublands and meadows to: drive game, stimulate growth of tobacco, seed and berry plants, clear forests, collect insects and at times to assist in warfare. Garth (1939) notes that the Atsugewi burned the mountain and butte areas for game by firing 5-6 butte areas per year on a rotation, while burning the higher mountain slopes every 3 years or so.

For an in-depth review of settlement patterns and subsistence strategies, the reader is referred to these publications. Europeans first traversed the study area in large numbers in 1850 with the opening of Noble's trail (Strong, 1973). Parts of LVNP were heavily grazed by sheep and cattle between 1870 and 1905 (Strong, 1973; Taylor, 1990b) but the impact of stockmen and grazing on fire regimes is poorly known.

Increased clumping in pine and mixed conifer forests resulted from a surge in establishment that followed the last fire. Subsequent logging did not trigger further establishment, but it accelerated earlier successional changes caused by fire suppression and grazing. Between 1675 and 1850, changes in fire frequency, extent and season were largely controlled by climate variability, but since then, fire and vegetation dynamics were increasingly the result of local anthropogenic factors. Before 1850, fires occurred during warm/dry years and were more extensive following cooler and wetter years. Fires were more extensive during El Niño events when the PDO was in a negative phase, but larger fires occurred during La Niña events. During the twentieth century, fires were more numerous during dry summers that followed cool autumns, and area burned increased following dry winters. Both the historical and contemporary forests developed from non-equilibrium dynamics imposed by continuous cultural and climate change. Realistic forest management goals should incorporate a temporal and spatial context that is provided by historical ecology.

1.3.3 Forest Fire Regime Studies

Table 3 on page 10 summarizes the fire regime studies that have been conducted in the Lassen area. In various studies, Taylor (1990a, 1990b, 1995, 1997, and 2000) found that approximately 35% of the park's vegetation has been substantially altered by 20th century anthropogenic activities. These changes have been wrought by excessive grazing and logging (both inside and outside the park), fire suppression, and park and neighboring land management activities. Studies from other similarly affected ecosystems in California and the west have shown that that prolonged (up to a century) of widespread fire suppression has produced dense, low vigor forest stands that are highly susceptible to insect epidemics, increased pathogen incidence, and high intensity wildfire. Changes brought about by these types of anthropogenic agents, however, must be clearly separated from natural vegetation changes (such as those resulting from climatic changes) which have been recently documented in the park's sub-alpine forest vegetation (Taylor 1997). An aggressive ecosystem restoration program using prescribed and use of wildland fire has been recommended to help restore natural regimes to the park's major forest types (Taylor 2000).

Table 3. Summary of fire regime studies in the Lassen area.

Area and vegetation	Location	Median or mean FRI a	Range of FRIs	Fire severity and extent	Period of record	Type of record	Size of sample area	Source
Ponderosa pine	Southern Cascades, CA	16	8 - 32	low severity	not reported	composites of multiple trees	< 10 ha	(Olson 1994)
Jeffrey pine	Prospect Peak, LAVO	4 - 6*	1 - 29	low to moderate severity, median fire size of 200 ha (39-792 ha)	1656 - 1994	composites of multiple trees	742 ha	(Taylor 2000)
Douglas-fir / mixed conifer	Mill and Deer Creeks, CA	15*	2 - 56	increasing severity and decreasing frequency of fire from lower to upper slope positions	1800 - 1996	composites of multiple trees	11 sites, 0.25 to 3.0 ha each	(Norman & Taylor, in press)
Mixed conifer / white fir	Southern Cascades, CA	9 (10)	3 - 71 (3 - 71)	low severity	not reported	composites of multiple trees	< 10 ha	(Olson 1994)
Jeffrey pine / white fir	Prospect Peak, LAVO	5 - 10*	1 - 29	low to moderate severity, median fire size of 167 ha (6-666 ha)	1656 - 1994	composites of multiple trees	753 ha	(Taylor 2000)

Area and vegetation	Location	Median or mean FRI a	Range of FRIs	Fire severity and extent	Period of record	Type of record	Size of sample area	Source
Jeffrey pine / white fir	Southern Cascades, CA	12 (12)	4 – 157 (4 - 157)	not reported	not reported	composites of multiple trees	2 ha	Skinner unpublished data, reported in Skinner & Chang (1996)
White fir / mixed conifer	Caribou Wilderness, CA	14*	not reported	mixed severity, with 13-33% high severity. Mean fire size ~ 128 ha	not reported	composites of multiple trees	506 ha	(Taylor and Solem 2001)
White fir / mixed conifer	Southern Cascades, CA	10 (13)	3 - 24 (5 - 24)	not reported	not reported	composites of multiple trees	2 ha	Skinner, unpublished data, reported in Skinner & Chang (1996)
White fir / mixed conifer	Southern Cascades, CA	9 (10)	3 - 26 (4 - 26)	not reported	not reported	composites of multiple trees	2 ha	Skinner, unpublished data, reported in Skinner & Chang (1996)
White fir / mixed conifer	Thousand Lakes Wilderness, CA	4 - 9	not reported	> 50% high severity, most remainder moderate severity. Mean fire size 103-151 ha	not reported	composites of multiple trees	2042 ha	(Bekker & Taylor, 2001)

Area and vegetation	Location	Median or mean FRI a	Range of FRIs	Fire severity and extent	Period of record	Type of record	Size of sample area	Source
White fir	Southern Cascades, CA	9 (11)	4 - 56 (4 - 56)	not reported	not reported	composites of multiple trees	2 ha	Skinner unpublished data, reported in Skinner & Chang (1996)
Red fir / western white pine	Prospect Peak, LAVO	9 - 27*	1 - 46	low to moderate severity, median fire size of 129 ha (11-733 ha)	1751 - 1994	composites of multiple trees	1135 ha	Taylor (2000)
Red fir / mixed conifer	Caribou Wilderness, CA	29 - 35*		mean fire size ~128 ha	not reported	composites of multiple trees	506 ha	(Taylor & Solem 2001)
Red fir	Swain Mountain, CA	*16 - 19**	1 - 57	low severity, mostly small fire size (13 – 400 ha)	1740 -1985	composites of multiple trees	3 ha plots and across 400 ha area	(Taylor 1993)
Red fir	Swain Mountain, CA	*40 - 42*	5 - 65	moderate severity	1830 -1985	stand origin data	2 plots, 1.0 and 0.48 ha	(Taylor & Halpern 1991)

The historical fire regime characteristics for the major vegetation types found within the park are summarized below in Table 4. Descriptions from the Interagency Fire Regime Condition Classification (FRCC) system are included as a cross-reference. More information on the Interagency FRCC system can be found at < http://www.frcc.gov >. Figure 1, page 14, shows the relative abundance and distribution of historical fire regimes found within the park.

Table 4. Historical fire regime characteristics and the Fire Regime Classes used by the Interagency FRCC Guidebook.

Vegetation Type (park acres)	Mean Fire Return Interval (range)	Fire Regime Characteristics	Fire Regime Class	Fire Frequency & Severity Class
	(consolidated from fire ecology literature[1])		(from Hann & Bunnell 2001)	
Sedge Meadows (886 ac)	Unknown	Infrequent Fire	?	Unknown
Montane Chaparral (1,823 ac)	Unknown (10-50)	Fields maintained or cycled by frequent fire; shrubs typically re-sprout and dominate within 5 years	II	0-35 years frequent stand replacement
Jeffrey Pine (13,739 ac)	16 years (9-32)	Frequent surface fires Low/Moderate severity	I	0-35 years frequent low severity
White Fir (9,238 ac)	30 years (15-38)	Frequent surface fires Low/Moderate severity	I	0-35 years frequent low severity
Lodgepole Pine (13,389 ac)	47 years (28-54)	Mix of crown/surface fires Mixed severity	IV	35-100 years less frequent stand replacement
Red Fir (14,669 ac)	41 years (4-127)	Mix of crown/surface fires Mixed severity	III	35-100 years less frequent mixed severity
Red Fir/ Western White Pine (33,158 ac)	70 years (26-109)	Mix of crown/surface fires Mixed severity	III	35-100 years less frequent mixed severity
Mountain Hemlock (7,073 ac)	115 years	Mix of crown/surface fires High severity	V	>100 years infrequent stand replacement

[1] (Bekker & Taylor 2001, Taylor 1993, Taylor 1999, Taylor 2000, Taylor & Solem 2001)

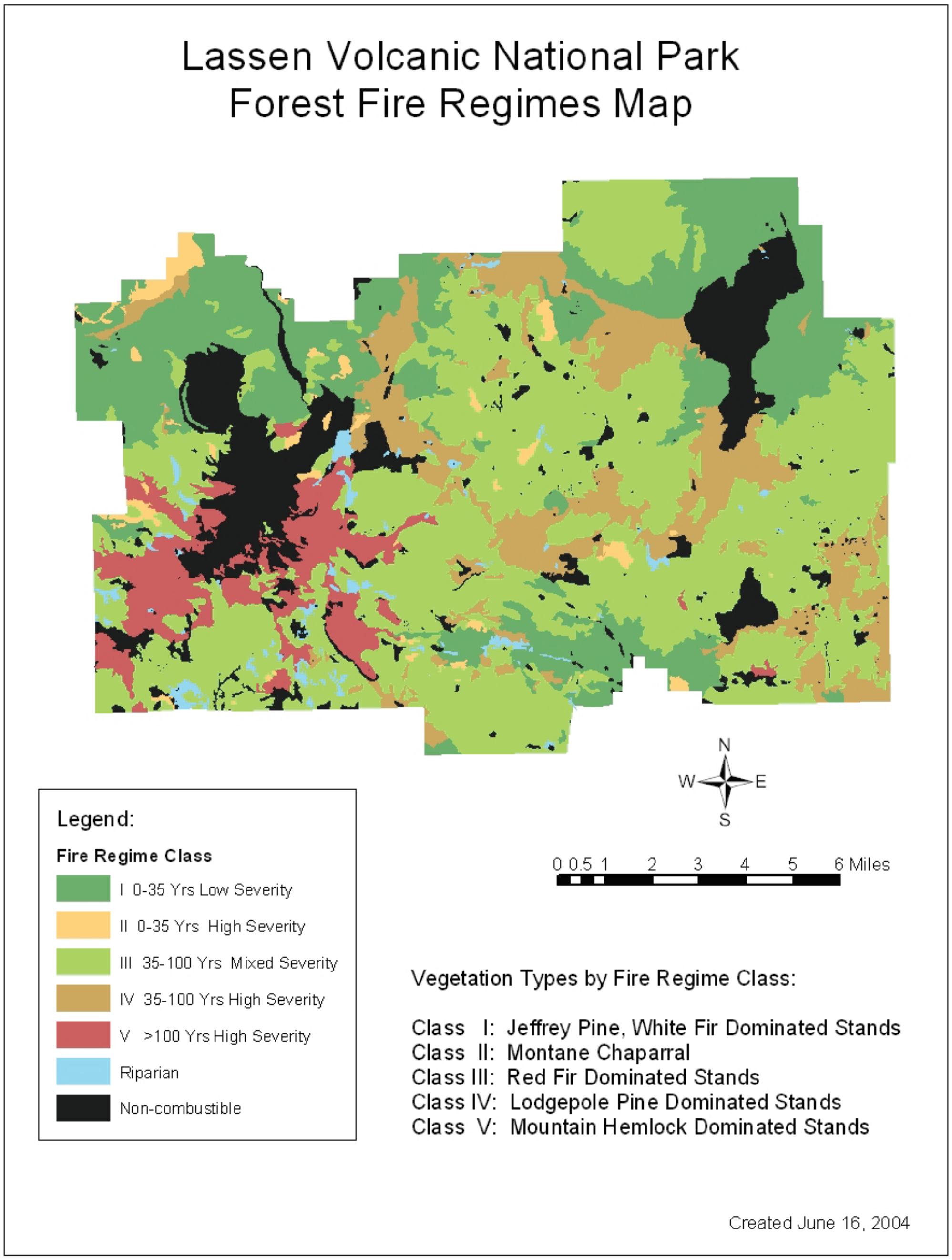

Figure 1. Historical Forest Fire Regimes Map for Lassen Volcanic National Park.

2.0 ECOLOGICAL MODEL DESCRIPTION

This section provides a brief description of the dominant plant communities found within the park. A model of post-fire succession will be developed at a later date. The information in this section along with local resource management objectives was used to develop the monitoring design found in sections 3.0 and 4.0.

2.1 Plant Communities

Wet Meadows (900 ac)

This herbaceous plant community occurs at upper elevations scattered throughout the park, generally above 5,000 feet. The soils are less acidic and nutrient-rich compared to bogs and fens (Holland 1986). Meadows can occur near seeps streams and lakes that contain primarily monocotyledonous species including hydrophytic sedges, which may include: abrupt-beaked sedge (*C. abrupta*), golden-fruited sedge (*Carex aurea*), and Nebraska sedge (*C. nebracensis*), *Agrostis thuberiana*, *Deschampsia caespitosa* ssp. *cespitosa?*, and *Muhlenbergia filformis* (Taylor 1990b). Or they can be found in the less densely vegetated areas composed of mostly broad-leaved dicots such as satin lupine (*Lupinus obtusilobus*), mule ears (*Wyethia mollis*), *Artemisia douglasiana*, and *Alnus tenuifolia* on steep slopes or in larger gaps within forested areas (Pinder et al. 1997). Representative montane wet meadows include Corral Meadow, Cameron Meadow, and Upper Meadow.

Climate, interacting with fire, has played a role in maintaining meadows (Taylor 1990b). Tree invasion of meadows began during the late 1800s and peaked during the early 1900s following a decline in fire frequency. Establishment occurred during cool and/or normal to wet springs, but was delayed along stock trails where grazing effects were most severe (Norman and Taylor 2003).

Several special-status plant species have the potential to occur in montane wet meadows such as Sierra corydalis (*Corydalis caseana* ssp. *caseana*), scalloped moonwort (*B. crenulatum*), shore sedge (*Carex limosa*), Red Bluff dwarf rush (*Juncus leiospermus* var. *leiospermus*), and Wilkin's harebell (*Campanula wilkinsiana*).

Montane Chaparral (2,000 ac)

Pinder et al. (1997) found that most chaparral species in the park occur below 2300 m on relatively xeric sites (e.g. warmer aspects and steeper slopes). Greenleaf manzanita (*Arctostaphylos patula*), several ceanothus species including snowbrush ceanothus (*Ceanothus velutinus*), huckleberry oak (*Quercus vaccinifolia*) and bush chinquapin (*Castanopsis sempervirens*) dominate these shrublands. This community may be relatively persistent where edaphic factors limit tree growth (Bolsinger 1989; Sampson and Jespersen 1963). More commonly, shrub fields of montane chaparral are the result of secondary succession as it regenerates following stand-replacing fires, logging, or other disturbances (e.g., Leiberg 1902; Bock and Bock 1977; Bolsinger 1989). In these cases, its persistence will depend on the frequency and severity of subsequent fires. Fires that recur during the life of the shrubs and prior to the establishment of the succeeding forest will tend to maintain the shrublands (Wilken 1967). Montane chaparral has thus been described as having a self-reinforcing relationship with fire (Show and Kotok, 1924).

Fire is a dominant natural force in the montane chaparral environment where fire frequency ranges from 10-50 years. The various shrub species that occupy montane chaparral sites have several strategies for adapting to a fire-prone environment. Greenleaf manzanita for example, regenerates after fire by resprouting. Snowbrush ceanothus is a prolific seed producer and can regenerate from seed or resprouts depending on fire frequency and severity (Keeley and Keeley 1993).

Jeffrey Pine and White Fir (23,000 ac)

Jeffrey pine and white fir forest types are found below 1900 m usually in a mix, although on individual sites either species may be strongly dominant in terms of basal area and/or stem density. Other minor cohorts include ponderosa and sugar pines (*Pinus ponderosa* and *P. lambertiana*), with occasional occurrences of incense cedar (*Calocedrus decurrens*), red fir and western white pine (*Pinus monticola*). The soils associated with these forest types have significantly higher pH values and greater exchangeable basic cation content (potassium, calcium, and magnesium) than most other Lassen Park forest types (Parker 1991).

The mixed-conifer forests within Lassen Park have experienced significant ecological change since fire suppression efforts began in the early 1900s. Fire exclusion has allowed a major increase in white fir density and the chances of stand-replacement fire, characteristic of high-severity fire regimes, are much greater now than historically.

Historically, fires tended to be of low intensity, rarely scorching the crowns of older, mature trees. Fires tended to be small, frequent, and patchy, in that they consumed too little fuel to scar trees. The historical mean fire return interval is 16-30 years (range 9-38 yrs). Fire is linked with other disturbance factors in pine-dominated forests, most notably post-fire insect attack. Scorched trees are more likely to be successfully attacked by western pine beetle (*Dendroctonus brevicomis*), mountain pine beetle (*D. ponderosae*), red turpentine beetle (*D. valens*), or pine engraver beetles (*Ips* spp.). Reduction in tree vigor during drought is also associated with insect attack. Fire may help control dwarf mistletoe infestation by pruning dead branches and consuming tree crowns with low hanging brooms.

Lodgepole Pine (14,000 ac)

Lodgepole pine stands occur between 1900 and 2300 m and are most common on flat, valley bottom sites or lower slopes, often in margins of meadows and lakes. In this forest type, lodgepole pine is strongly dominant, with red and white fir and mountain hemlock occurring as minor associates.

Lodgepole pine forests have a mixed-severity fire regime. Most stands show an origin from a more widespread stand replacement-type fire and most have a patchy history of fire occurrence and spread. The mean fire return interval is 47 years (range 28-54 yrs), with areas bordering higher productivity forest on the low end of the range. Strong winds are likely associated with the rare stand replacement fire in the lodgepole pine type. Mature lodgepole pines are quite resistant to fire damage. Under most conditions, these forests will act as natural fuel breaks, where fire suppression, if desired, would be relatively easy.

Red Fir (49,000 ac)

Red fir is the most widespread forest type in the park and is a common upper montane forest type throughout the Sierra Nevada and southern Cascade ranges. In the park, red fir forest is found between 2000-2400m on upland flats and sloping terrain surrounding sedge meadows and lodgepole pine forests. In this forest type, red fir is dominant in terms of basal area and/or stem density. It is most often found in association with western white pine and lesser amounts of lodgepole and Jeffrey pines, white fir and mountain hemlock.

Red fir ecosystems have a classic mixed-severity fire regime. Red fir, when mature, is relatively fire tolerant. A range of fire frequencies of 4-127 years (mean 41 yrs) combined with a range of fire intensities leads to a patchy mosaic of different age structures across landscapes of this type. Within Lassen Park, typical large fire sizes in red fir forests have been about 400 acres. Small patches of low, moderate, and high-severity fire typically occur, with high-severity fire often covering less than one-third of the landscape. Old-growth stands of red fir are least likely to burn with high severity. Although there has probably been some increase in older patches, it is unclear from the literature if red fir stands in Lassen Park have been affected substantially by fire exclusion over the past 80-100 years (Taylor and Halpern 1991, Taylor 2000).

Stand development patterns in red fir forests are complex because red fir is not only fire-tolerant but is also shade-tolerant. It does well with or without disturbance. Several stand development patterns are common. If a stand replacement fire occurs, scattered mature red fir trees usually survive to provide a seed source for slow, recolonization by red fir and other species. In moderate-severity patches, some red fir dominants remain and provide seed for colonization by red fir, which does well in these partially shaded conditions, creating a multiple age class stand. In low-severity patches, understory trees are killed but little growing space is opened for regeneration, and red fir reproduces slowly in small gaps where sun flecks occur.

Mountain Hemlock (7,000 ac)

Mountain hemlock stands occur from 2400 to 2600 m in elevation, generally on middle to upper slopes of Lassen Peak and nearby mountains (Taylor 1990b). Mountain hemlock occurs with red fir and western white pine at lower elevations and with white bark pine (*Pinus albicaulis*) at treeline. Mountain hemlock is usually found on nutrient-poor sites with coarser textured soils than red fir dominated sites (Taylor 1990b).

Because Mountain hemlock is a thin-barked species susceptible to fire damage, fires, regardless of fire intensity, are often of stand replacement severity. At lower elevations, the presence of red fir and western white pine may denote a more mixed-severity fire regime. Almost a century of fire exclusion has had little impact on the behavior of fires today in mountain hemlock forests. However, near treeline mountain hemlock forests have increased in density since the mid-1800s because of climate change (Taylor 1995).

2.2 Post-fire Succession Model

To be developed.

3.0 MANAGEMENT OBJECTIVES AND TARGET CONDITIONS

LAVO park managers use an adaptive feedback process to guide and evaluate the fire and fuels management program as shown in Figure 2 below. This process begins with policy direction and incorporates the most current information to make knowledge-based management decisions about how best to restore and maintain fire-related natural resource components and processes. These decisions are periodically evaluated against monitoring results, new research and other relevant information. Recommendations and changes are integrated into the planning and execution phases to help guide the management program.

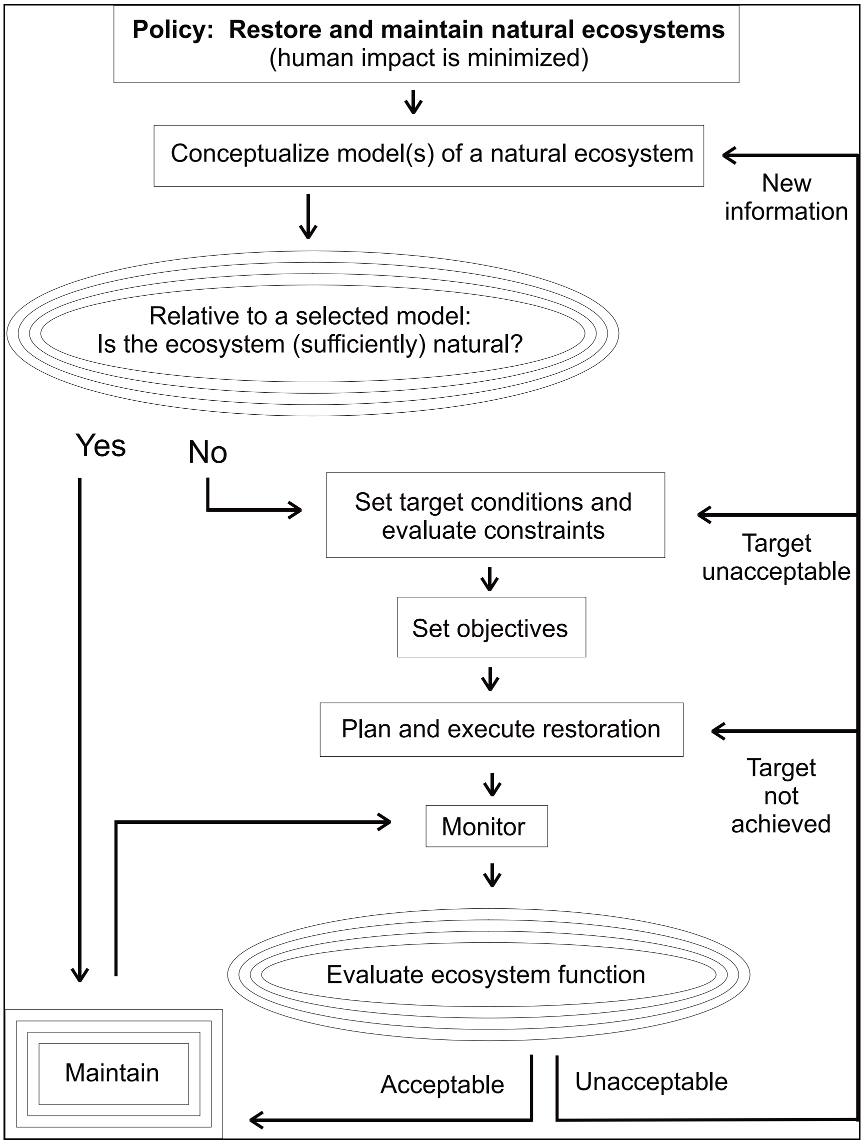

Figure 2. Model of adaptive feedback process (Keeley and Stephenson 2000).

Fire management program goals and objectives are described in Chapter 3 of the Park's Fire Management Plan. Cumulatively, these goals and objectives emphasize the desire to understand the effects of fire management actions by monitoring and evaluating the effects of fire and fuels management activities on park natural and cultural resources. To accomplish this task, specific, measurable benchmarks are needed as a point of reference to determine if the resource conditions resulting from fire management actions are meeting park goals and objectives for restoring and maintaining natural conditions. To answer the question, “What would the resource look like if we achieve our goals?” target conditions are needed to describe resource goals more specifically and to serve as standards by which to measure fire management program success.

Information used to develop the target conditions includes research data where available, historic photos and written documents, and expert opinion. Target conditions must be periodically evaluated to determine whether they are still realistic and wanted in light of a changing environment. For example, target conditions may be based on our knowledge of past long-term climate conditions; however, future climate changes may preclude achieving these targets. The target conditions will be further refined as new research provides information that increases our knowledge of past, current, and future conditions.

To describe explicitly how to arrive at the target conditions, specific management objectives are developed by adding a method and timeframe to the target conditions. For example, if the target condition is a stand density of 20-250 trees/ha, then the management objective would be to use prescribed fire to reduce stand density to 20-250 trees/ha by 2 years following treatment. Target conditions and specific treatment objectives are described below.

In areas of the park currently in the restoration phase of the program, structural targets and objectives are used to assess program success. Once these structural conditions are restored, then the area moves into the maintenance phase of the program and process targets are used to evaluate the program goal achievement. Figure 3, below, illustrates the changing nature of targets/objectives over time from the restoration phase to the maintenance phase using an example of fuel load objectives.

Like target conditions, management objectives must be evaluated on a regular basis. As the monitoring results become available, they are used to determine if management objectives are achieved and to determine if management activities need to be adjusted. Also at this time, an assessment of whether the management objectives are still desired is warranted in light of ongoing monitoring results and any new information that is made available. In this adaptive way, we can be sure that the monitoring program will adequately assess the success of the fire management program. Any changes or additions will be included in future revisions of this fire monitoring plan.

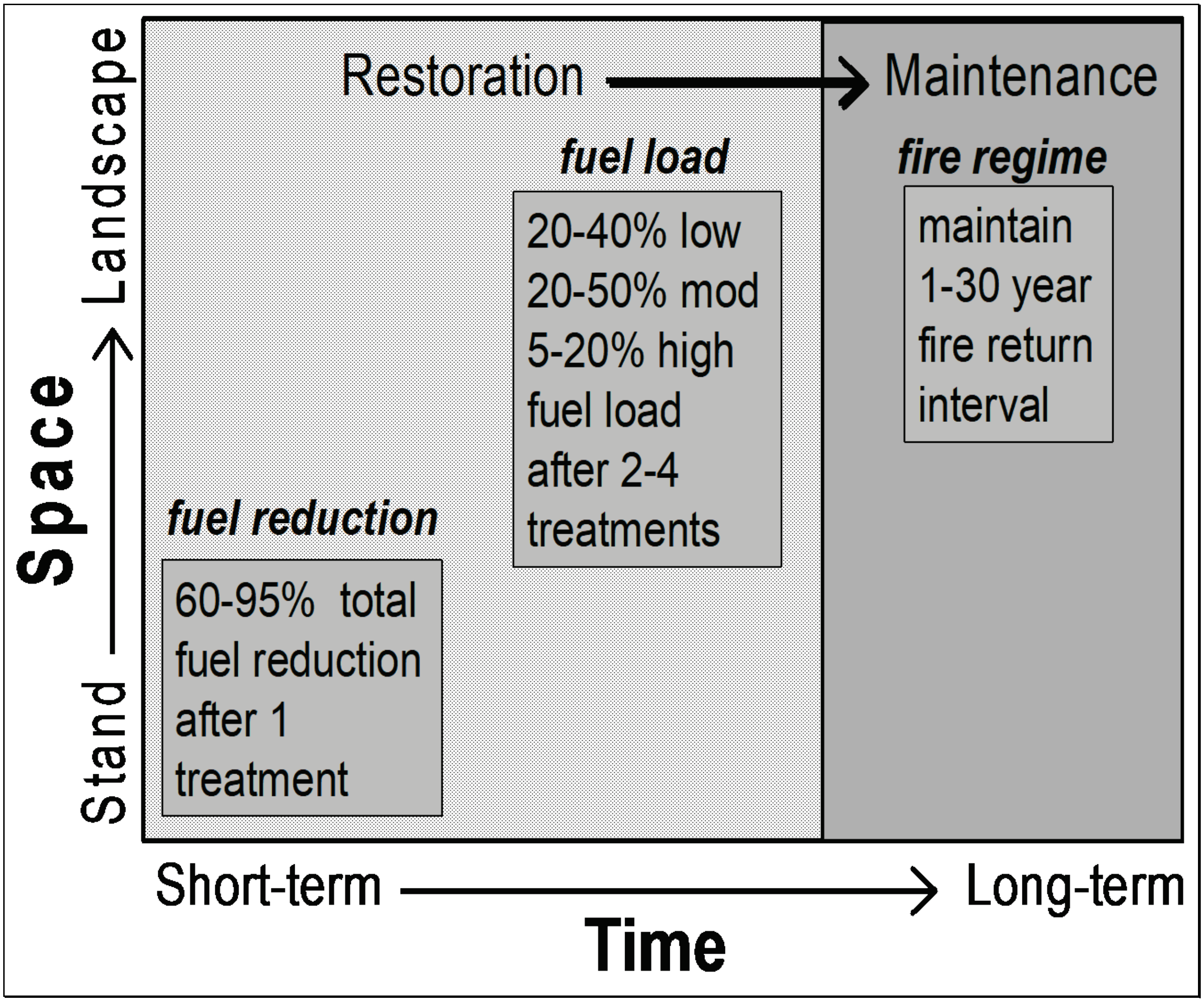

Figure 3. How Management Objectives Change Over Time and Space.

3.1 Resource Management Objectives

For many years, park managers have recognized that successful natural resource stewardship at LAVO includes restoring plant communities to within their range of historical variation. Recent management documents (NPS 1999) have highlighted this need by identifying very broad resource stewardship goals. Specifically, they have developed desired future conditions for the park and some of the measures that would be associated with successful natural resource stewardship:

> *To restore and maintain natural terrestrial, subsurface, and atmospheric ecosystems so they may operate unimpaired by:*
>
> - *Conducting and supporting appropriate research;*
> - *Restoring altered ecosystems as nearly as possible to conditions that would have existed had natural balances not been disturbed;*
> - *Identifying and perpetuating natural processes wherever feasible;*
> - *Protecting sensitive species and their habitat, and where practical and success probable, reintroducing displaced native species;*
> - *Reducing the spread of non-native species by rehabilitating sites disturbed by construction or maintenance of facilities or by other management activities.*

Because fire has historically played a major part in ecosystem processes such as shaping plant community composition, it is important that fire regimes be restored to as much of the park as possible. Wilderness policy also advocates a return of natural fire to established wilderness areas within the park. Though not explicitly stated, restoring natural fire regimes is the park's most important fire-related resource management objective.

3.2 Target Conditions

Table 5, on page 22 summarizes the set of target conditions that should guide fire management actions within each plant community type. They have been formulated from a combination of reference condition information and expert opinion. The desired target conditions are not meant to replicate historical conditions, rather they provide an approximation for management that is within the range of natural variability for the park's ecosystems. The target conditions vary depending on the current condition of a site and/or state of the ecosystem (restoration versus maintenance phase).

It should be noted that a particular site may need one to many restoration treatments before the conditions shift and the site is ready for maintenance treatments. The determination that conditions at a particular site have shifted will be based on evaluations of the monitoring data and other relevant ecological information.

Table 5. Resource Target Conditions by Forest Type (Restoration and Maintenance phases).

Forest Type & Monitoring Type Code	Fuel Reduction Goal (restoration phase)	Stand Density by diameter class & species composition (restoration phase)	Fuel Load Distribution (% of landscape) (maintenance phase)	Gap/Patch Size Distribution (% of landscape) (maintenance phase)
Jeffrey Pine (13,739 ac)	30-80% reduction in total dead fuel load	40 - 250 trees/ha all sizes 10 - 80 trees/ha ≥ 80 cm (60-90% pine, 10-30% other)	> 70% of area is 2-10 tons per ac	60-75% 0.1-1.0 ha 10-25% 1.0-10.0 ha 1-5% 10-100 ha 0% 100-600 ha
White Fir (9,238 ac))	60-75% reduction in total dead fuel load	50 - 300 trees/ha all sizes 10 - 80 trees/ha ≥ 80 cm (40-60% fir, 15-40% pine, 0-20% other)	> 70% of area is 10-30 tons per ac	60-75% 0.1-1.0 ha 10-25% 1.0-10.0 ha 1-5% 10-100 ha 0% 100-600 ha
Lodgepole Pine (13,389 ac)	35-55% reduction in total dead fuel load	Unknown density (80-90% pine, 0-10% fir, 0-10% hemlock)	To be determined	To be determined
Red Fir/ W. White Pine (47,827 ac)	60-75% reduction in total dead fuel load	60 - 350 trees/ha all sizes 10 -100 trees/ha ≥ 80 cm (30-70% fir, 20-50% pine, 0-20% other)	To be determined	To be determined
Mountain Hemlock (7,073 ac)	35-55% reduction in total dead fuel load	Unknown density (15-60% hemlock, 0-40% fir, 0-10% pine)	To be determined	To be determined

3.3 Treatment Objectives

To be developed.

4.0 MONITORING DESIGN

The NPS Fire Monitoring Handbook (NPS 2003a) identifies four monitoring levels to guide fire effects monitoring efforts:

Table 6. NPS Fire Monitoring Handbook—Minimum Recommended Standards.

Monitoring Level	**Minimum Recommended Monitoring Standards**
Level 1 – Environmental Monitoring	Weather, fire danger rating, fuel conditions, resource availability, concerns and values to be protected, other biological, geographical or sociological data.
Level 2 – Fire Observation	Reconnaissance—Fire cause, location, size, fuel and vegetation description, potential for spread, current and forecasted weather and fire behavior, resource or safety threats and constraints, logistical information and smoke volume and movement. Fire Conditions— Topographic variables, ambient conditions, fuel model, fire characteristics, smoke characteristics, holding options and resource advisor concerns.
Level 3 – Short-term Change,	This level provides information on burn severity, fuel reduction and vegetative change within a specific vegetation and fuel complex (monitoring type) up to two years postburn, as well as on other variables, according to management objectives.
Level 4 – Long-term Change	Continued monitoring of Level 3 variables to measure trends and change over time. Monitoring frequency is based on sampling at some defined interval (often five and ten years and then every ten years) past the second year postburn monitoring. This monitoring continues until the area is again treated with fire.

Use of Monitoring Levels 1 and 2

The first two monitoring levels provide information to guide fire management strategies for both wildfire and prescribed fires.

Monitoring Goal: *Environmental monitoring and fire observations monitoring provide the basic background information needed for decision-making before, during, and after fire events.*

Monitoring Objectives: *Collect environmental conditions data (fire weather, and resource availability) throughout the fire season as a minimum (The typical fire season for the park occurs between July 10 and October 15). Collect fire observations data (name, location, slope, aspect, spread, intensity, smoke transport and dispersal) for all wildfire and prescribed fires. Use the information collected in a timely manner to adapt to changing conditions and successfully manage each fire.*

Use of Monitoring Levels 3 and 4

Monitoring levels 3 and 4 describe short- and long-term monitoring of the effects of fire on fuels and vegetation to guide wildland fire and can also be applied to mechanical fuel treatments.

Monitoring Goal: *Specific fire-related management objectives guide fire program activities to achieve desired resource target conditions. Vegetation and fuels monitoring provides information needed to determine whether the fuels- and vegetation-related management objectives are being met and to detect any unexpected consequences of prescribed burning or other treatments.*

Monitoring Objectives: *Collect information on fuels and vegetation to determine if specific fire- and fuels-related management objectives have been achieved. Use the information collected to determine if progress is being made towards the desired resource target conditions for each monitoring type as shown in Table 5 on page 22.*

The following sections summarize when, where and how monitoring data will be collected as determined by the type of fire management strategy involved. Table 7 below summarizes the level of monitoring recommended for each Fire Management Strategy used at LAVO. These recommended levels of monitoring are consistent with the NPS Fire Monitoring Handbook (NPS 2003a).

Refer to chapter 3 of the Fire Management Plan for more information about the implementation of these fire management strategies.

Table 7. Recommended Monitoring Levels by Fire Management Strategy.

	Fire Management Strategy			
Monitoring Level	**Wildfire**	**Use of Wildland fire**	**Prescribed Fire**	**Non-Fire Treatment**
Level 1 – Environmental	Yes	Yes	Yes	Yes
Level 2 – Fire Conditions	Yes	Yes	Yes	No
Level 3 – Short-term Change	Maybe	Maybe	Yes	Maybe
Level 4 – Long-term Change	Maybe	Maybe	Yes	Maybe

4.1 Wildfire Monitoring

Field Measurements

The following information will be collected for all wildfires regardless of management strategy: fire name, location, cause, current size, air temperature, relative humidity, wind speed, wind direction, percent slope, aspect, representative Fire Behavior Prediction System (FBPS) fuel model(s) and description, current fire activity (smoldering, creeping, running, torching), rate of spread, direction of spread, flame length, perimeter and area growth, and smoke transport and dispersal. In the event of any fire greater than 100 acres, the burned area will be mapped by severity class with 90 percent accuracy and placed in a GIS layer. For forested areas, severity classes will follow NPS protocols.

Using portable PM2.5 particulate monitors which have already been acquired by the Fire Management Program, institute a long-term smoke monitoring program in Chester and Old Station during the fire season. One 24-hour sample should be taken once a week in each community, beginning in June and continuing throughout the fire season. During fire events a more intense sampling protocol will be used, possibly every day instead of once a week. The MiniVol particulate matter samplers have already been acquired for this purpose, however the filter analysis has not been funded.

An annual report will summarize PM2.5 impacts in Chester and Old Station related to fire incidence. It will report the concentrations of PM2.5 before during and after fire events. Recommendations will be made to evaluate existence and severity of potential impact to air quality in communities near Park and take management actions as necessary.

All fires managed for resource objectives will have a Wildland Fire Decision Support System (WFDSS) analysis prepared. In addition to the data listed above, the following information may be collected for longer duration fires which are managed for resource objectives when qualified fire effects monitors (FEMOs) are available: canopy cover, tree inventory (seedling/sapling/overstory), shrub inventory, non-native plant frequency, dead and down fuels inventory, and photo record.

Timing of Monitoring

Weather conditions for all wildfires will be monitored regularly from the time of discovery/ignition and throughout the duration of the fire. The monitoring frequency will be specified in the planning document.

The most complex fires that are managed for resource objectives will be monitored with permanent sampling plots placed in a safe location in relation to the approaching flame front for pre-burn data. Post-burn data will be collected within one-year post-burn as a minimum; and subsequent years will be monitored as needed.

Monitoring Site Locations

On-site environmental, weather and fire conditions for all wildfires will be monitored as indicated in the planning document.

Vegetation and fuels data will be sampled at a density determined by the Fire Ecologist at the time of the incident, depending on current and predicted fire activity and vegetation/fuel types.

All plot locations will be located using a handheld GPS. In addition, the Fire Ecology Program office will maintain accurate documentation of plot locations for ease of relocation.

Sampling Design

A combination of variable and fixed plots, and planar transects are specified for level 3 and 4 vegetation and fuels monitoring. The Park Fire Ecologist will determine actual design at the time of the WFDSS development.

Intended Data Analysis Approach

The following data summaries will be compiled when fires are managed for resource objectives and the WFDSS specifies long-term data is warranted: Tree density - both grouped by species or dbh grouping, or crown code, live vs. dead; tree height and height to live crown will be used to calculate percent crown; percent canopy cover; percent shrub cover by species, percent live versus dead for shrubs as a group and by species, average height by shrub group and species; tons per acre by fuel class; percent frequency by herbaceous species, and by native and exotic, and rare vs. common.

Data Sheet Examples

See the NPS Fire Monitoring Handbook (NPS 2003a) for examples.

Information Management

Data will be entered, checked for errors, and managed by the Fire Ecology Program staff and supervised by the Fire Ecologist. Original copies of all data will be kept by the Fire Ecology Program office and disseminated as requested. Individual fire monitoring reports will be provided to the park's Fire Management Office within 2-4 weeks of the fire being declared out, depending on the complexity of the event.

Responsible Party

The person in charge of the fire (duty officer or incident commander) is responsible for ensuring that the fire monitoring data is collected, transmitted, acted upon, and filed according to established protocols.

The Fire Ecologist is responsible for collecting, analyzing, and managing vegetation and fuels data collected on fires managed for resource benefits.

Management Implications of Monitoring Results

Monitoring results will be reviewed by the Fire Ecologist each winter. The Fire Ecologist in consultation with Fire and Natural Resource Management Staff will determine if the results of previous burns are acceptable. Acceptable results include meeting the monitoring objectives stated above.

If monitoring results show deviations from desired vegetation conditions, or if resource needs change, the group will determine changes necessary for future activities.

Funding

NFPORS will be the mechanism used for funding all monitoring activities, and the appropriate project account will be charged according to the latest NPS Wildland Fire Management Budget – Business Rules.

4.2 Prescribed Fire Monitoring

Field Measurements

The following information will be collected for all prescribed fires: fire name, location, ignition type (aerial, hand), planned size, air temperature, relative humidity, wind speed, wind direction, percent slope, aspect, National Fire Danger Rating System (NFDRS) fuel model appropriate index (energy release component (ERC) or burning Index (BI)), representative Fire Behavior Prediction System (FBPS) fuel model, rate of spread, direction of spread, flame length, perimeter and area growth, and smoke transport and dispersal.

In addition to the data listed above, the following information will be collected: live fuel moisture (if applicable), dead fuel moisture (1 hour, 10 hour, 100 hour, 1000 hour, litter, duff) as indicated in the site specific burn plan prescriptions, road or sensitive site visibility, smoke column mixing height, smoke transport and dispersal direction. Smoke particulate data may be collected at smoke sensitive locations as indicated in the site-specific burn plan.

To assess short- and long-term fire effects, the protocols found in the NPS Fire Monitoring Handbook (NPS 2003a) will be used. A list of specific protocols will be maintained as part of the monitoring type descriptions.

Timing of Monitoring

All prescribed fires will have the environmental conditions monitored in advance of the planned ignition date. On-site weather and fire conditions monitoring will occur throughout all active ignition phases of each fire on a schedule determined by the burn boss with consultation from the lead monitor (FEMO) assigned to the fire.

All prescribed fires will have short-term and long-term fuels and vegetation data collected prior to the ignition date. Timing of data collection will be coordinated through the Fire Ecologist. Generally, data will be collected at the peak of flowering season. Depending on elevation and aspect, this time may vary from early May through mid-September.

Monitoring Site Locations

On-site environmental conditions for all prescribed fires will be monitored at a representative location within the burn area, as determined by the burn boss with consultation from the lead monitor assigned to the burn.

Permanent sampling points for vegetation and fuels data collected as part of the short-term and long-term monitoring effort will be located using stratified random techniques coordinated by the Fire Ecologist.

No monitoring plots will be established on slopes greater than 50%, or on any areas identified by specialists as having significant resource value (e.g., cultural resource isolated finds).

All plot locations will be located using a handheld GPS. In addition, the Fire Ecology Program office will maintain accurate documentation of plot locations for ease of relocation.

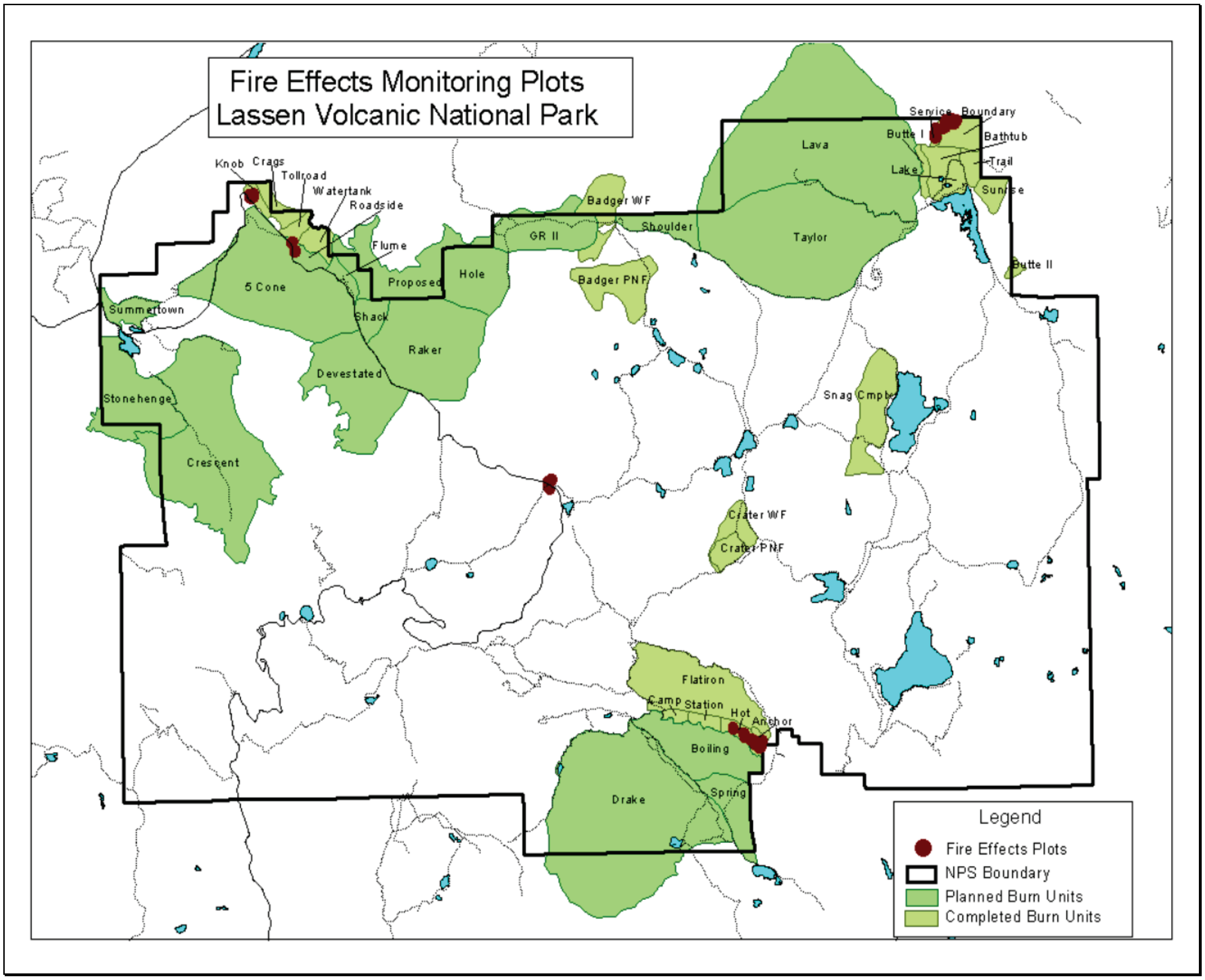

Figure 4. Fire Effects Monitoring Plot Locations.

Sampling Design

Sampling unit shapes and sizes will follow guidelines described in the NPS Fire Monitoring Handbook (NPS 2003a). Pilot sampling is used to refine sample shapes and sizes at the discretion of the Fire Ecologist. Some examples of pilot sampling that has been going on in Lassen:

In almost every monitoring type monitors have been sampling a 5x10 m subsample in Quarter 1 for seedlings, along with sampling all of Quarter 1. In their most recent trip (ABCO plots in Roadside Burn Unit), monitors decided to subsample the 5x10 m belt for all seedlings, and then sample the rest of the quarter for seedlings over 1 year in age. They were getting numbers in the thousands for first year seedlings in the 5x10 area.

The other major pilot sampling effort has been in the shrub belt. Monitors have read the shrub belts in varying widths: 1m, 2m, 3m, 5m and 10m. Usually they sample out to 2m and then again out to 5m. This is the case for all of the PIPO plots in the Timber Crater 1 and 2 burn units. The Fire Ecologist will analyze these data and then choose permanent sampling areas for each variable within each monitoring type.

A minimum sample size will be calculated when the initial 10 plots per monitoring type have been installed. Minimum sample size will be calculated for each objective variable in a monitoring type, based on pre-burn or pre-treatment data and then recalculated post-treatment to determine final sample sizes.

Intended Data Analysis Approach

Data will be analyzed by running minimum sample size equations after all plots have reached one-year post-burn and later if objectives so specify (e.g. after second treatment). Tests will be performed to determine if the data fit a normal distribution or if data are skewed. If normal, and if a change objective is involved, we will use a paired t-test to determine if objectives have been met. If the data is skewed we will consult a statistician for assistance.

Data Sheet Examples

See the NPS Fire Monitoring Handbook (NPS 2003a).

Information Management

Data will be entered, checked for errors, and managed by the Fire Ecology Program staff and supervised by the Fire Ecologist. Program status and results will be recorded in an annual report and issued in January for the previous fiscal year. Original copies of all data will be kept by the Fire Ecology Program office and disseminated as requested.

Responsible Party

The person in charge of the fire (burn boss) is responsible for ensuring that fire monitoring data during the burn is collected, transmitted, acted upon, and filed according to established protocols (e.g. a fire monitor’s report is filed within 2 weeks post-burn).

The Fire Ecologist is responsible for collecting, analyzing, and managing all pre- and post-treatment vegetation and fuels data collected on prescribed fires.

The Lead Biological Technician (Fire Effects), in coordination with the Area Fire Ecologist is responsible for hiring and training seasonal fire effects monitoring staff, collecting field data, storing data electronically, performing data quality checks, and assisting with data analysis as needed.

Management Implications of Monitoring Results

Monitoring results will be reviewed by the Fire Ecologist each winter. The Fire Ecologist in consultation with Fire and Natural Resource Management Staff will determine if the results of previous burns are acceptable. Acceptable results include meeting the monitoring objectives stated above.

If monitoring results show deviations from desired vegetation conditions, or if resource needs change, the group will determine changes necessary for future activities.

Funding

FireProNFPORS will be used to accuire fuels funding for all monitoring activities.The appropriate project account will be charged according to the latest NPS Wildland Fire Management Budget – Business Rules.

4.3 Non-Fire Treatment Monitoring

Field Measurements

The following information will be collected for all non-fire treatments: project name, location, treatment objectives, project size, treatment prescription, and methods.

Additional data collection MAY include all or some of the following, based on treatment objectives resource monitoring needs, and available funding: canopy cover, tree inventory, shrub inventory, non-native plant frequency, dead and down fuels inventory, and photo record.

Timing of Monitoring

All non-fire treatments (thinning, shaded fuel breaks, etc.) will have short-term and long-term fuels and vegetation data collected prior to treatment. Timing of data collection will be coordinated through the Fire Ecologist. Generally, data will be collected at the peak of flowering season. Depending on elevation and aspect, this time may vary from early May through mid-September or as necessary for effective project completion.

Monitoring Site Locations

Permanent sampling points for vegetation and fuels data collected as part of the short-term and long-term monitoring effort will be located using stratified random techniques coordinated by the Fire Ecologist.

No monitoring plots will be established on slopes greater than 50%, or on any areas identified by specialists as having significant resource value (e.g., cultural resource isolated finds).

All plot locations will be located using a handheld GPS. In addition, the Fire Ecology Program office will maintain accurate documentation of plot locations for ease of relocation.

Sampling Design

A combination of variable and fixed plots, and planar transects may be used as specified by the Fire Ecologist, depending on monitoring objectives.

Intended Data Analysis Approach

The following data summaries will be compiled for data if collected: tree density - both grouped by species or dbh grouping, or crown code, live vs. dead; tree height and height to live crown will be used to calculate percent crown; percent canopy cover; percent shrub cover by species, percent live versus dead for shrubs as a group and by species, average height by shrub group and species; tons per acre by fuel class; percent frequency by herbaceous species, and by native and exotic, and rare vs. common.

Data Sheet Examples

See the NPS Fire Monitoring Handbook for examples (NPS 2003a).

Information Management

Data will be entered, checked for errors, and managed by the Fire Ecology Program staff and supervised by the Fire Ecologist. Original copies of all data will be kept by the Fire Ecology Program office and disseminated as requested.

Responsible Party

The Fire Ecologist is responsible for collecting, analyzing, and managing vegetation and fuels data collected on non-fire treatment projects in coordination with the project manager (FMO, COR).

Management Implications of Monitoring Results

Monitoring results will be reviewed by the Fire Ecologist each winter. The Fire Ecologist in consultation with Fire and Resource Management Staff will determine if the results of previous burns are acceptable. Acceptable results include meeting the monitoring objectives stated above.

If monitoring results show deviations from desired vegetation conditions, or if resource needs change, the group will determine changes necessary for future activities.

Funding

NFPORS will be used to acquire funding for all monitoring activities, and the appropriate project account will be charged according to the latest NPS Wildland Fire Management Budget – Business Rules.

5.0 NATIONAL FOREST SERVICE MONITORING

FIA (Forest Inventory and Analysis) sample plot locations are based on a systematic sample design consisting of cluster plots placed roughly 3.4 miles apart, one plot every 7,400 acres. The Pacific Northwest Research Station established the FIA grid design as the basis for sampling all forestlands within the State of California. The US Forest Service uses similar plant communities, so data are potentially comparable. The contact at Lassen National Forest is the Fuels Specialist.

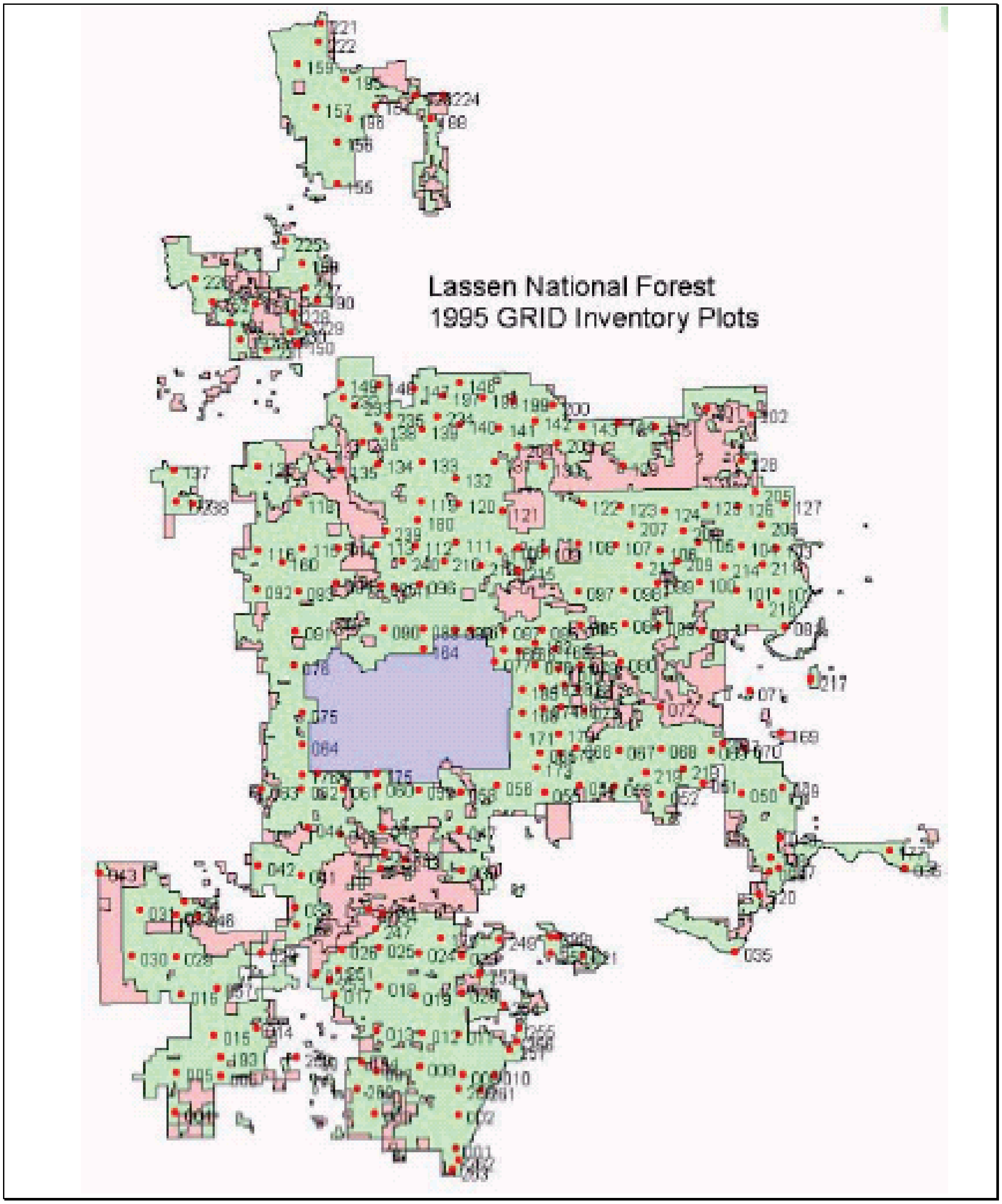

Figure 5 Lassen National Forest FIA Plot Layout

6.0 AIR QUALITY MONITORING

LAVO is on the boundary of three air basins, Mountain Counties, Northeast Plateau, and Sacramento Valley (SV). Located near the northern end of the SV, the park is potentially exposed to pollutants transported from the SV and other areas. The SV air basin (SVAB) includes nine counties and portions of two others. Emissions in the SV are dominated by sources in the Sacramento metropolitan area, at the southern end of the SV (Alexis et al. 1999).

Since 1980, population growth in the SV has been more rapid than in many other parts of California, partially offsetting the effects of emission-control programs (Alexis et al. 1999). The Mountain Counties air basin (MCAB) includes the western slope of the Sierra Nevada, an area with relatively low population (~1% of the state total) and emissions (~ 3% of the state total; CARB 1998b). The Northeast Plateau is also an area of low population and emissions (CARB 1998b). The principal species of concern are ozone precursors (NO_x and ROG) and PM. SO_2 emissions are not high.

LAVO is located within Lassen, Shasta, Tehama, and Plumas counties. Major point sources are not numerous in these counties or in other nearby counties. Sources within Lassen, Shasta, Tehama, and Plumas counties that emit at least 100 tons/year of ROG, NO_x, PM_{10}, or SO_2 are located near the communities of Chester, Quincy, Wendel, Burney, Redding, Anderson, and Red Bluff. As of 1996, stationary sources accounted for 9% of ROG emissions, 14% of NOx emissions, and 4% of PM_{10} emissions in Lassen, Shasta, Tehama, and Plumas counties (CARB 1998b). Mobile sources dominate NO_x emissions, while area sources (road dust, construction, and farming operations) dominated PM emissions.

At Lassen CASTNet monitors Ozone hourly and dry deposition; NPS monitors O_3, IMPROVE monitors PM_{10} and $PM_{2.5}$ (See Figure 6 for locations). The CASTNet dry-deposition monitoring site located within LAVO began operating July 25, 1995. The monitoring instrument measures ambient concentrations of gases and particles, and EPA uses a computer model to calculate the dry-deposition rates from the measurements. An NADP site was installed in 2000 to monitor wet deposition.

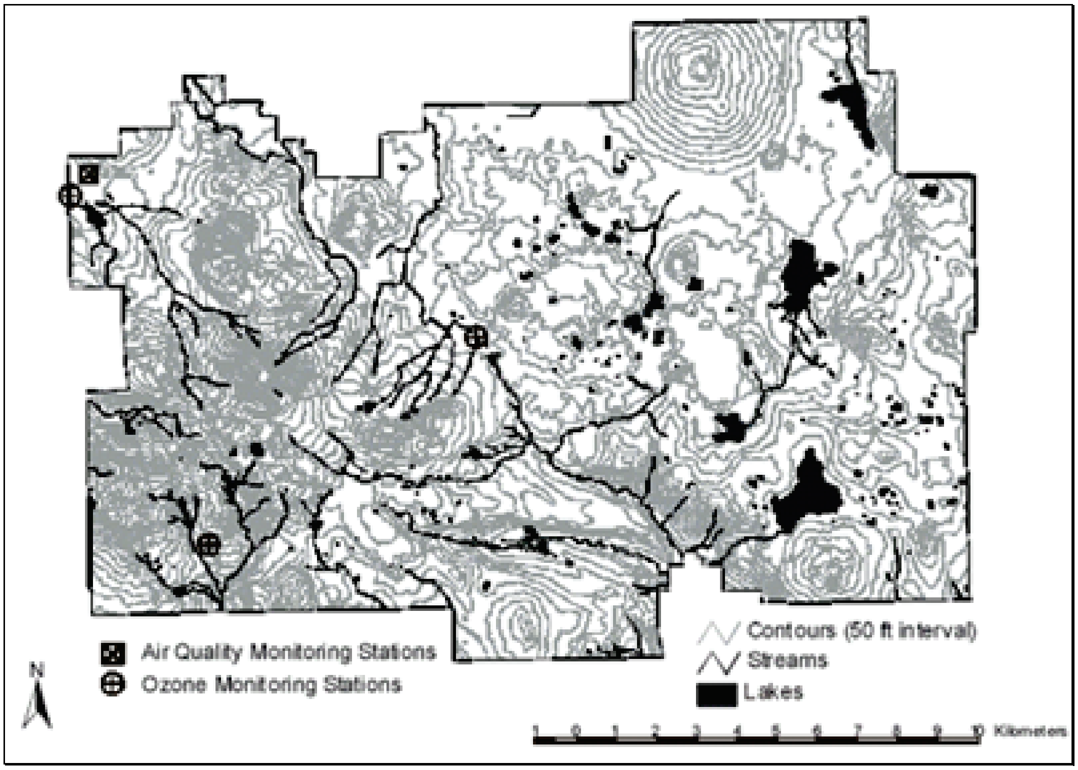

Figure 6. Locations of air quality and ozone monitoring stations at LAVO. Also shown is the hydrography and major contours.

7.0 OTHER MONITORING AND RESEARCH

Fire severity maps are created for all large fires greater than 200 acres through the National Burn Severity Mapping Project, which is a joint program between the National Park Service and USGS (http://burnseverity.cr.usgs.gov/). These data are used to assess spatial patterns of canopy mortality and to serve as long-term references for landscape change. Additionally, the Forest Service's Fire Remote Sensing Program in Sacramento recently completed (2011) dNBR burn severity maps for all fires in Lassen >50 acres in size back to 1982. These data are being used to evaluate recovery in different burn severities over time.

There were 347 fuels inventory plots established throughout the park in 1998 and 1999 as part of a fuels mapping program. Each plot contains two to four Brown's Transects to quantify surface fuel load, height to live crown estimates, and various qualitative information on fuel type and forest type. These plots were GPS'd and monumented in the field so there is an opportunity to use the data for long-term fuels monitoring. The plots are being re-located and re-measured as they burn. They are particularly useful in the backcountry where FMH monitoring plots are lacking. In 2010 and 2011, many of these plots were relocated and re-measured

A recent study to examine post-fire aspen regeneration in groves burned by prescribed fires from 1998 to 2006 was just completed in collaboration with the University of Arizona (Dr. Ellis Margolis). The results indicate that the density of new sprouts after fire were variable but generally low, except for in a few of the more severely burned transects. However, in growth rates were very low due to intensive browsing pressure and relatively few have grown to exceed >150 cm in height after 11 years. Monitoring of several unburned aspen groves in the Northwest Gateway Zones 1 and 2 is ongoing. The results to date over a 12 year period show continued decline of live aspen overstory with minimal regeneration and increases in conifer density and fuel load. They recommend either higher intensity fire to restore aspen and/or a targeted mechanical restoration approach to offset the low rates of disturbance and high conifer densities in these stands.

Dr. Carl Skinner and colleagues at the Pacific Southwest Research Station in Redding, CA completed a study in 2009 documenting historic frequency and extents of fires in persistent, seral shrub fields near Manzanita Lake. Comparing fire scar records sampled from spatially distributed remnant old pines in the shrubfields and adjacent forests stands, they found less frequent but more synchronous (widespread) fires in the shrubfields than adjacent forested stands. There was low synchrony of large fire years in the park with studies in surrounding landscapes, likely due to the geologically fragmented nature of the study area. They concluded that relatively infrequent and hotter fires have historically maintained a significant component of early seral shrub fields in these areas.

There are two ongoing research projects in the park conducted in collaboration with Dr. Alan Taylor and colleagues from Penn State University. The objectives of the first project are to (a) quantify historical spatial patterns of high severity fires using a combination of historic aerial photos and tree and shrub dates, and (b) use fire behavior modeling to predict areas across the landscape that have an inherently high probability of high intensity fires today due to terrain, fire weather, and fuels. A side product from this research is a the development of a new and improved (higher accuracy) set of canopy fuels layers for the park (Pierce et al. In Press). A second study examines demography and disturbance history of old-growth pine in the Butte Lake area, which will have field work completed in 2012.

The Penn State group also recently completed a study of post-fire regeneration following the 1985 Badger Fire near the northern boundary. Regeneration in this lodgepole forest has been very slow and patchy. They found that distance to seed source was the most important factor determining post-fire tree regeneration over climate and fire severity. Lodgepole in this area are not serotinous and areas far from live trees have recovered more slowly.

Recent Publications:

Margolis, EQ and C.A. Farris. 2011. Post-fire quaking aspen regeneration response. Final report for DSCESU Agreement #H2623050831. National Park Service

Pierce, A.D. and A.H. Taylor. 2011. Fire severity and seed source influence lodgepole pine (*Pinus contorta var. murranana*) regeneration in the southern cascades, Lassen Volcanic National Park, California. Landscape Ecology 26:225-237

Pierce, A.D., C.A. Farris, and A.H. Taylor. 2012 (In Press). Use of Random Forests for modeling and mapping forest canopy fuels for fire behavior analysis in Lassen Volcanic National Park, California, USA. Forest Ecology and Management, volume TDB.

Skinner, C.N. 2009. Fire history of sparsely treed shrub fields in the vicinity of Manzanita Lake, Lassen Volcanic National Park. Final CESE Report for Project #LAVO-00811. National Park Service.

8.0 LITERATURE CITED

(Agee et al., 1978). Agee, J.K., R.H. Wakimoto, and H.H. Biswell. 1978. Fire and fuel dynamics of Sierra Nevada conifers. Forest *Ecology and Management* 1:255-265.

(Agee 1993). Agee, J.K. 1993. *Fire Ecology of Pacific Northwest Forests*. Island Press, Washington, D.C.

(Agee 1994). Agee, J.K. 1994. Fire and weather disturbances in terrestrial ecosystems of the eastern Cascades. *In*: Assessment, edited by P. F. Hessburg. Vol. 3 of Eastside forest ecosystem health assessment. General Technical Report PNW-GTR-320. Portland, OR: U.S. Forest Service, Pacific Northwest Research Station.

(Anderson 1999). Anderson, M.K. 1999. The fire, pruning, and coppice management of temperate ecosystems for basketry material by California Indian tribes. *Human Ecology* 27:79-113.

(Beaty and Taylor 2001). Beaty, R.M., and A.H. Taylor. 2001. Spatial and temporal variation of fire regimes in a mixed conifer forest landscape, Southern Cascades, California, USA. *Journal of Biogeography* 28:955-966.

(Bekker and Taylor 2001). Bekker, M.F. and A. H. Taylor. 2001. Gradient analysis of fire regimes in montane forests of the southern Cascade Range, Thousand Lakes, Wilderness, California, USA. *Plant Ecology* 155:15-28.

(Bennett and Kunzman 1985). Bennett, P. S. and M. Kunzman. 1985. Effects of Heating on Artifacts: A Brief Report of Work Conducted at the Western Archeological and Conservation Center, Tucson. Draft, National Park Service, Cooperative Park Studies Unit, University of Arizona, Tucson Arizona.

(Bock and Bock 1977). Bock, C. E., and J. H. Bock. 1977. Patterns of post-fire succession on the Donner Ridge Burn, Sierra Nevada. In Proceedings of the symposium on the environmental consequences of fire and fuel management in Mediterranean ecosystems, technical coordination by H. A. Mooney and C. E. Conrad, 464–69. General Technical Report WO-3. Washington, DC: U.S. Forest Service.

(Bolsinger 1989). Bolsinger, C. L. 1989. Shrubs of California's chaparral, timberland, and woodland: Area ownership and stand characteristics. Resource Bulletin PNW-RB-160. Portland, OR: U.S. Forest Service, Pacific Northwest Research Station.

(Brown and Smith, 2000). Brown, J.K. and J.K. Smith (eds.). 2000. Wildland Fire in Ecosystems: Effects of Fire on Flora. United States Department of Agriculture, Forest Service, Rocky Mountain Research Station. Ogden, Utah. General Technical Report. RMRS-GTR-42-Vol. 2.

(Burel and Baudry 2003). Burel, F and J. Baudry. 2003. Landscape ecology: concepts, methods and applications. Plymouth (UK): Science Publishers. 362p.

(CEPA 2004a). California Environmental Protection Agency. Air Resources Board. Smoke Management Program. < http://www.arb.ca.gov/smp/smp.htm > (19 April 2004).

(CEPA 2004b). California Environmental Protection Agency. Air Resources Board. Prescribed Burning and Smoke Management Fact Sheet. < http://www.arb.ca.gov/smp/progdev/pubeduc/pbfs.pdf > (19 April 2004).

(Crandell 1972). Crandell, D.R. 1972. *Glaciation near Lassen Park, northern California*. Washington (DC): U.S. Geological Survey, *Professional Paper 800-C*, pp. C179-188.

(Deal 2001). Deal, K. 2002. *Fire Effects to Lithic Artifacts*. Paper prepared for Cultural Resources Protection and Fire Planning, January 22-26, Tucson, Arizona.

(Dickman and Cook 1989). Dickman A. and S. Cook. 1989. Fire and fungus in a mountain hemlock forest. *Canadian Journal of Botany 67:2005-16*.

(DOD 1978). United States Department of Defense. 1978. *Environmental Planning in the Noise Environment*. Technical Manual 5-830-2. NAVFAC P-970.

(DOI 2001). United States Department of the Interior, National Park Service. 08 June 2003. *Conservation Planning, Environmental Impact Analysis and Decision Making*. Director's Order #12 and Handbook.

(DOI 2002). United States Department of the Interior, National Park Service, Fire Effects Monitoring Handbook. < http://www.nps.gov/fire/fmh/FEMHandbook.pdf > (18 April 2002).

(DOI 2004a). United States Department of the Interior, National Park Service, NPS Visitation Database Reports. < www2.nature.nps.gov/NPstats/npstats.cfm > (02 April 2004).

(DOI 2004b). United States Department of the Interior, National Park Service, NPS Economic Impact Estimates and Reports. < http://www.prr.msu.edu/yayen/nps/npsselect.cfm > (05 April 2004).

(FEIS 2004a). *Arctostaphylos patula*. In: Fire Effects Information System. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory. <http://www.fs.fed.us/database/feis/ > (27 May 2004).

(FEIS 2004b) *Ceonothus velutinus*. In: Fire Effects Information System. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory. < http://www.fs.fed.us/database/feis/ > (27 May 2004).

(Garth 1939). Garth, T. R. 1939. Atsugewi Ethnography. Unpublished manuscript.

(Garth 1978). Garth, T.R. 1978. Atsugewi. *In* Robert F. Heizer (ed.), *Handbook of North American Indians, Volume 8: California*. Washington DC, Smithsonian Institution.

(Haecker 2001). Haecker, C.M. 2001. *Effects of Fire on Historic Structures and Historic Artifacts*. Paper prepared for Cultural Resources Protection and Fire Planning, January 22-26, Tucson, Arizona.

(Hann and Bunnell 2001). Hann W. J. and D.L. Bunnell. 2001. Fire and land management planning and implementation across multiple scales. Int. J. Wildland Fire. 27 p.

(Hann and Bunnell 2001). Hann, W.J. and D.L. Bunnell. 2001. Fire and land management planning and implementation across multiple scales. Int. J. Wildland Fire 10:389-403.

(Hann et al. 2003). Hann, W., D. Havlina, A. Shlisky, et al. 2003. Interagency and The Nature Conservancy fire regime condition class website. USDA Forest Service, US Department of the Interior, The Nature Conservancy, and Systems for Environmental Management. < http://www.frcc.gov > (25 February 2004).

(HUD, 1991). United States Department of Housing and Urban Development. 1991. *The Noise Guidebook.*

(Johnson 1978). Johnson, J.J. 1978. Yana. *In*: Robert F Heizer (ed.) *Handbook of North American Indians, Volume 8: California* Washington DC, Smithsonian Institution.

(Kane 1975). Kane, P.S. 1975. *The glacial geomorphology of the Lassen Volcanic National Park area*. Berkeley (CA): University of California, Geography Department, Ph.D. Thesis. 224 p.

(Kauffman and Martin 1989). Kauffman, J.B. and R.E. Martin. 1989. Fire behavior, fuel consumption, and forest-floor changes following prescribed understory fires in Sierra Nevada mixed conifer forests. *Canadian Journal of Forest Research* 19:455-462.

(Keeley and Keeley 1993). Keeley, J.E. and S.C. Keeley. 1993. Chaparral. Pages 165–208 *in* M. G. Barbour and W. D. Billings, editors. North American terrestrial vegetation. Cambridge University Press, Cambridge, UK.

(Keeley and Stephenson 2000). Keeley, J. E. and N. L. Stephenson. 2000. Restoring natural fire regimes to the Sierra Nevada in an era of global change. Pages 255-265 in Cole, D. N., and S. F. McCool, compilers. Wilderness Science in a Time of Change conference – Volume 5: Wilderness ecosystems, threats, and management; 1999 May 23-27 Missoula MT. Proceedings RMRS-P-15-Vol-5. Ogden, UT: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

(Kilgore 1973). Kilgore, B.M. 1973. The ecological role of fire in Sierran conifer forests: its application to national park management. *Quaternary Research* 3:496-513.

(Leiberg 1902). Leiberg, J. B. 1902. Forest conditions in the northern Sierra Nevada, California. Professional Paper 8, Series H, Forestry, 5. Washington, DC: U.S. Geological Survey.

(Leopold et al. 1963). Leopold, A.S., S.A. Cain, C.M. Cottam, I.N. Gabrielson, and T.L. Kimball. 1963. Study of wildlife problems in national parks: in national parks and wildlife management in the national parks. Transactions of the North American Wildlife and Natural Resources Conference 28: 28-45.

(Norman and Taylor, in press). Norman, S. and A.H. Taylor. In press. Variation in fire-return intervals across a mixed-conifer forest landscape. In: Proceedings of fire in California ecosystems: Integrating ecology, prevention and management. Nov. 17-20, 1997, San Diego, CA.

(Norman and Taylor 2003.). Norman, S. P. and A. H. Taylor. 2003. Tropical and north Pacific teleconnections influence fire regimes in pine-dominated forests of northeastern California, USA. *Journal of Biogeography* 30(7): 1081-1092.

(NPS 1999). United States Department of the Interior, National Park Service. Lassen Volcanic National Park Resources Management Plan. On file at the Division of Resource Management, Lassen Volcanic National Park.

(NPS 2003a). United States Department of the Interior, National Park Service, Fire Effects Monitoring Handbook. < http://www.nps.gov/fire/fmh/FEMHandbook.pdf > (18 April 2003).

(NPS 2003b). United States Department of the Interior, National Park Service. Lassen Volcanic National Park General Management Plan. On file at the Division of Resource Management, Lassen Volcanic National Park. xxx p.

(Olson 1994). Olson, R.D. 1994. Lassen National Forest fire history. Unpublished report on file with Lassen National Forest, Susanville, CA.

(Parker 1991). Parker, A.H. 1991. Forest environment relationships in Lassen Volcanic and Yosemite National Parks, California, USA. *Journal of Biogeography* 18:543-552.

(Pickett and White 1985). Pickett, S.T.A. and P.S. White (eds.) 1985. The Ecology of Natural Disturbance and Patch Dynamics. Academic Press: New York.

(Pickett et al. 1989). Pickett, S.T.A., Kolasa, J. Armesto, J.J. and Collins, S.L. 1989. The ecological concept of disturbance and its expression at various hierarchical levels. *Oikos* 54: 129–136.

(Pinder et al. 1997). Pinder, J.E., G.C. Kroh, J.D. White, and A.M.B. May. 1997. The relationships between vegetation type and topography in Lassen Volcanic National Park. *Plant Ecology* 131:17-29.

(Riddell 1978). Riddell, F.A. 1978. Maidu and Konkow In, Robert F Heizer (ed.) *Handbook of North American Indians, Volume 8: California* Washington DC, Smithsonian Institution.

(Sampson and Jespersen 1963). Sampson, A. W., and B. S. Jespersen. 1963. California range brushlands and browse plants. Extension Service Manual 33. Davis: University of California, Division of Agricultural Sciences, California Agricultural Experiment Station.

(Schultz 1954) Schultz, P.E. 1954. *Indians of Lassen Volcanic National Park and Vicinity* Mineral, CA. Loomis Museum Association, Lassen Volcanic National Park.

(Show and Kotok. 1924). Show, S. B., and E. I. Kotok. 1924. The role of fire in California pine forests. U.S. Department of Agriculture Bulletin 1294.

(Skinner and Chang 1996). Skinner, C.N., and C.R. Chang. 1996. *Fire regimes past and present. Sierra Nevada Ecosystem project: final report to Congress, II, Assessments and scientific basis for management options,* pp. 1041-1069. University of California Davis, Center for Water and Wildland Resources, Davis CA.

(Strong 1973). Strong, D. H. (1973) These happy hunting grounds: a history of the Lassen region. Loomis Museum Associates, Red Bluff, CA.

(Taylor 1990a). Taylor, A.H. 1990. Habitat segregation and regeneration patterns of red fir and mountain hemlock in ecotonal forests, Lassen Volcanic National Park, California. *Physical Geography* 11:36-48.

(Taylor 1990b). Taylor, A.H. 1990. Tree invasion in meadows of Lassen Volcanic National Park, California. *Professional Geographer* 4:457-470.

(Taylor 1993). Taylor, A. H. 1993. Fire history and structure of red fir (*Abies magnifica)* forests, Swain Mountain Experimental Forest, northeastern California. *Canadian Journal of Forest Research* 23:1672-1678.

(Taylor 1995). Taylor, A.H. 1995. Forest expansion and climate change in the mountain hemlock (Tsuga mertensiana) zone, Lassen Volcanic National Park, California, USA. *Arctic and Alpine Research* 27:207-216.

(Taylor 1997). Taylor, A H. 1997. Vegetation Dynamics and Change in Lassen Volcanic National Park. Draft Report prepared under cooperative agreement 4000-9-8004. Report on file at Headquarters Office, Lassen Volcanic National Park, Mineral, CA.

(Taylor 2000). Taylor, A.H. 2000. Fire regimes and forest changes in the mid and upper montane forests of the southern Cascades, Lassen National Park, California, USA. *Journal of Biogeography* 27:87-104.

(Taylor and Halpern 1991). Taylor, A.H., and C.B. Halpern. 1991. The structure and dynamics of *Abies magnifica* forests in the southern Cascade Range, USA. *Journal of Vegetation Science* 2:189-200.

(Taylor and Solem 2001). Taylor, A.H. and M.N. Solem. 2001. Fire regimes and stand dynamics in an upper montane forest landscape in the southern Cascades, Caribou Wilderness, California. Journal of the Torrey Botanical Society 128(4):350-361.

(Thomas and Agee 1986). Thomas, T.L. and J.K. Agee. 1986. Prescribed fire effects on mixed conifer forest structure at Crater Lake, Oregon. *Can. J. For. Res*. 16(5):1082-87.

(Turner et al. 1993). Turner, M. G., W. H. Romme, R. H. Gardner, R. V. O'Neill, and T. K. Kratz. 1993. A revised concept of landscape equilibrium: Disturbance and stability on scaled landscapes. *Landscape Ecology* 8: 213–27.

(USBLS 2004). United States Bureau of Labor Statistics. Unemployment rates by county, February 2003 – January 2004 averages. < http://www.bls.gov/lau/maps/twmcort.pdf > (5 April 2004).

(USCB 2004). United States Census Bureau. Census 2000 Fact Sheet. < http://factfinder.census.gov > (02 April 2004).

(USDA 2001). United States Department of Agriculture, Forest Service. Wildland Fire Suppression Chemicals Toxicity and Environmental Issues and Concerns. < http://www.fs.fed.us/rm/fire/The_Environment.html > (06 June 2001).

(USDA, 2000a). United States Department of Agriculture, Forest Service, Pacific Northwest Research Station. July 2000. Smoke Exposure at Western Wildfires. Research Paper. PNW-RP-525.

(USDI and USDA 2001). United States Department of the Interior and the United States Department of Agriculture, Interagency Federal Wildland Fire Policy Review Working Group. 2001. Review and update of the 1995 federal wildland fire management policy. < http://www.nific.gov/fire_policy/index.htm > (11 February 2004).

(West 2003). West, G.J. 2003. Pollen record of late Pleistocene-Holocene vegetation and climate history, Lassen National Park, California. G. JAMES. Pp. 40-41 *In*: G.J. West and N.L. Blomquist (eds.), Proceedings from the 20th Annual Pacific Climate (PACLIM) Workshop, April 6-9, 2003, Pacific Grove, CA.

(White et al. 1995). White, J.D., G.C. Kroh, and J.E. Pinder III. 1995. Mapping forest species at Lassen Volcanic National Park, California using Landsat Thematic Mapper data and a geographical information system. *Photogrammetric Eng. & Remote Sensing* 61:299-305.

(White and Pickett 1985). White, P.S., and S.T.A. Pickett. 1985. Natural disturbance and patch dynamics: an introduction. *In*: S.T.A. Pickett and P.S. White (eds.), The Ecology of Natural Disturbance and Patch Dynamics, Academic Press, New York, pp.3–13.

(Wilken 1967). Wilken, G. C. 1967. History and fire record of a timberland brush field in the Sierra Nevada of California. Ecology 48:302–4.