Preliminary Land Cover Classification for Los Alamos National Laboratory and Los Alamos County, New Mexico

Teralene S. Foxx, Randy G. Balice, and Mary E. Salisbury

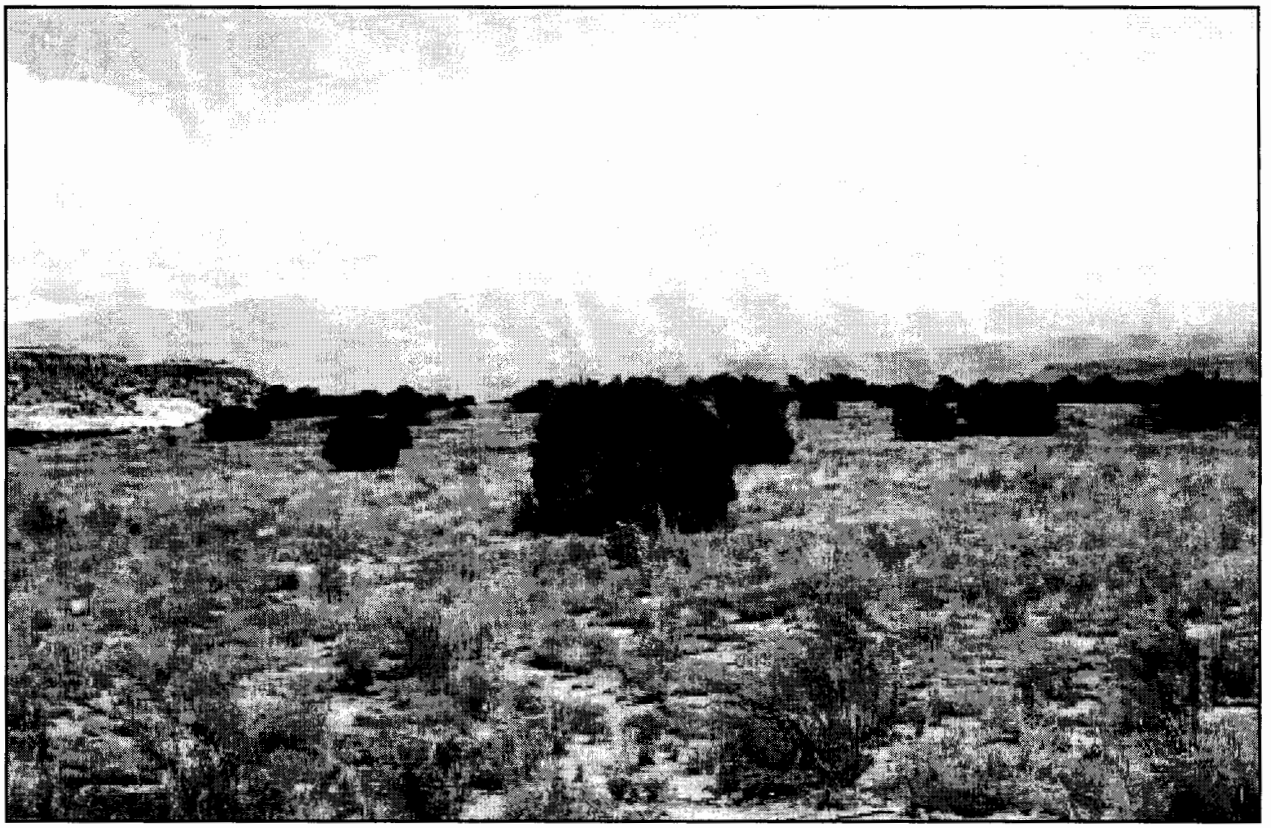

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Table of Contents

Abstract 1
1.0 Introduction 2
2.0 Background 3
3.0 Description of the Area 3
3.1 Geographic Setting 3
3.2 Geologic Setting 5
3.3 Climate 5
3.4 History of Land Use 7
3.4.1 Prehistoric Period (1100 to 1598) 7
3.4.2 Spanish Period (1598 to 1821) 7
3.4.3 Post-Spanish Period (1821 to 1940) 8
3.4.4 World War II and Post World War II Period (1940 to Present) 8
3.4.5 Botanical History 9
4.0 Methods 10
4.1 Methods Used in Vegetation Surveys 10
4.2 Methods Used in Development of Draft Terrestrial Classification 11
5.0 Results 15
5.1 Land Cover Classification and Mapping 15
5.2 Classification Description 15
5.2.1 Classification of Land Used for Human Purposes 15
5.2.2 Riparian and Wetland Systems 16
5.2.3 Unvegetated Lands 18
5.2.4 Terrestrial Systems 18
6.0 Conclusion and Discussion 32
7.0 Acknowledgments 32
8.0 References 33
Appendix A. Working Draft "Keys to Major Land Cover Types in the LANL Vicinity."

Preliminary Land Cover Classification for Los Alamos National Laboratory and Los Alamos County, New Mexico

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Abstract

The major plant cover types of the Los Alamos County, Los Alamos National Laboratory (LANL), and surrounding area are distributed along topographic and moisture gradients. These cover types range from riparian areas along ephemeral streams to mountain grasslands at higher elevations. To date we have identified four terrestrial vegetation classes: forests, woodlands, shrublands, and grasslands. These classes have been further divided into subclasses, regional biomes, cover type groups, cover types, and community types. Cover types include mixed conifer, aspen, ponderosa pine, pinon- juniper woodlands, juniper woodlands, and Rocky Mountain subalpine grasslands. Additional study is needed to further define the cover types within grassland and shrubland classes. We have not yet classified wetland/riparian classes to a sufficient degree. Working Draft Keys also provide a classification for land used for human purposes.

This document provides for a discussion of the preliminary vegetation classification for the County of Los Alamos and LANL. The classification is a detailed description of the Cover Classes used on the draft land cover map that has been produced for LANL by Earth Data Analysis Center, University of New Mexico. This vegetation classification was based on previous qualitative and quantitative field studies, supervised and unsupervised classification for the land cover map, bibliographic references for the area, and 20 years experience with the vegetation of the Jemez Mountains.

This paper represents a preliminary classification that will be further tested through specific error-reduction techniques used in the land cover mapping. We believe that further refinement of this classification will provide a consistent terminology that can be used by researchers for describing the vegetation component of their study sites.

1.0 Introduction

A Habitat Management Plan (HMP) for threatened and endangered species (TES) is a proactive planning tool to provide information about TES to project planners. Such a planning tool is needed so that projects within a facility, such as Los Alamos National Laboratory (LANL), do not come into direct conflict with mandates of the Endangered Species Act of 1973. In the past, surveys for TES were done on a site by site basis and were dependent upon the location of maintenance and construction projects. There was no mechanism for annual surveys of the entire facility. The site by site approach resulted in project delays by last minute discovery of species not known to occur on the facility and by the consultation processes.

In 1995, the Record of Decision (ROD) for the Dual Axis Radiographic Hydrodynamic Test (DARHT) Facility Environmental Impact Statement (EIS) mandated development of a HMP for TES. This requires a site-wide rather than a site by site approach to conservation, protection, and identification of TES and those species of concern (SOC) that occur on or utilize the 112 km^2 (43 mi^2) of the LANL.

Additionally, LANL lands were designated a National Environmental Research Park (NERP) in 1976 based on the "legacy of parks" initiated by President Nixon's 1971 State of the Union Message and subsequent Presidential endorsements. The focus, as with other NERPs, is the "impact of man's activities on his environment; that is, the interaction between man-altered systems and adjacent natural ecosystems." To understand the impact of man's activities on his environment, ecological studies must be conducted.

These two mandates require an understanding of the ecological environments at LANL. Basic to this understanding is identification of the components of the habitats in which TES live. Vegetation components of the habitat influence the ability of organisms to successfully reproduce and forage on a site. Two types of information on vegetation are needed to determine the value of a habitat for a species:

1) plant and associated animal species present on the specific sites and

2) vegetation community patterns within the landscape. To provide these two types of information, the development of a land cover map and a vegetation classification has been one of the efforts of the first year in producing the HMP.

The task to develop a land cover map has resulted in completion of three products. The first is the development of the land cover map from satelite imagery (Koch et al. 1996) and the second is to provide an accompanying vegetation classification describing the homogeneous components within the land cover map extent. The third product is completion of a checklist of plants that are found in these components in the Jemez Mountains (Foxx et al. 1996).

The purpose of this paper is to describe the land use history that influences distribution of plants, to lay out a tentative hierarchial classification of the vegetation in the region based on the New Mexico Natural Heritage Program (NMNHP) classification, and to present a Working Draft Key to the various Cover and Community Types of Los Alamos County and immediate surrounding area.

2.0 Background

Since the early 1970s, vegetation studies at LANL have generally been conducted on a site by site basis and associated with construction projects (see References 7.2). Other studies done for old field succession, fire ecology, habitat typing and wetland monitoring have added to our knowledge (Foxx and Tierney 1996, Foxx and Potter 1979, Barnes 1983, Foxx and Blea-Edeskuty 1995). These studies have resulted in compilation of a list of species that occur in the Jemez Mountains and on the Pajarito Plateau (Foxx and Tierney 1985). This checklist has been revised and is included in this notebook under Foxx et al. (1996). The revised checklist has also been placed in the Geographic Information System (GIS) Database developed by Bennett et al. (1996).

Although much work has been done to compile species lists and to acquire quantitative data on cover, density, and frequency, there has not been a systematic classification of the landscape components of the vegetation within Los Alamos County. However, classification of the landscape components has been accomplished for Bandelier National Monument (BNM) (Allen 1989), and Forest Service personnel have done habitat typing and vegetation classification in portions of the county within the Santa Fe National Forest (Moir and Ludwig 1979).

To understand the vegetation patterns on a landscape level, LANL has worked with Earth Data Analysis Center (EDAC) at the University of New Mexico (UNM) to develop a land cover map (Koch et al. 1996). To understand the elements of the land cover map and the landscape patterns as related to the surrounding area and the State of New Mexico, we have developed this preliminary vegetation classification for Los Alamos County and LANL.

For the mapping and classification, we have extended the boundaries beyond the Laboratory and are using five US Geological Survey 7.5-min. quadrangles (Guaje, Frijoles, White Rock, Puye, and Valle Toledo) as our mapping units. Several studies, such as monitoring elk movements, include areas of BNM, the Santa Fe National Forests, and the privately owned Baca Location. Therefore, a wider view of the area is pertinent. For most of our discussion related to vegetation classification, we will use the county boundaries as our extent. We believe this is necessary because of the following factors: 1) the tops of the Sierra de Los Valles are the watershed sources for the Laboratory and therefore influence the ecology of the Laboratory; 2) land ownership boundaries are artificial and are not barriers to animal and plant movement; and 3) the influence between the Laboratory and its surrounding area is a reciprocal relationship.

3.0 Description of the Area

3.1 Geographic Setting

LANL is situated in Los Alamos County in north-central New Mexico, approximately 100 km (60 miles) north-northeast of Albuquerque and 40 km (25 miles) northwest of Santa Fe (Figure 1). The county is approximately 283 km^2 (109 mi^2) and is situated in the Jemez Mountains. The western boundary encompasses some peaks of the Sierra de Los Valles, the mountainous rim of the Valles Caldera, and portions of the table-like extension on the eastern slopes, known as

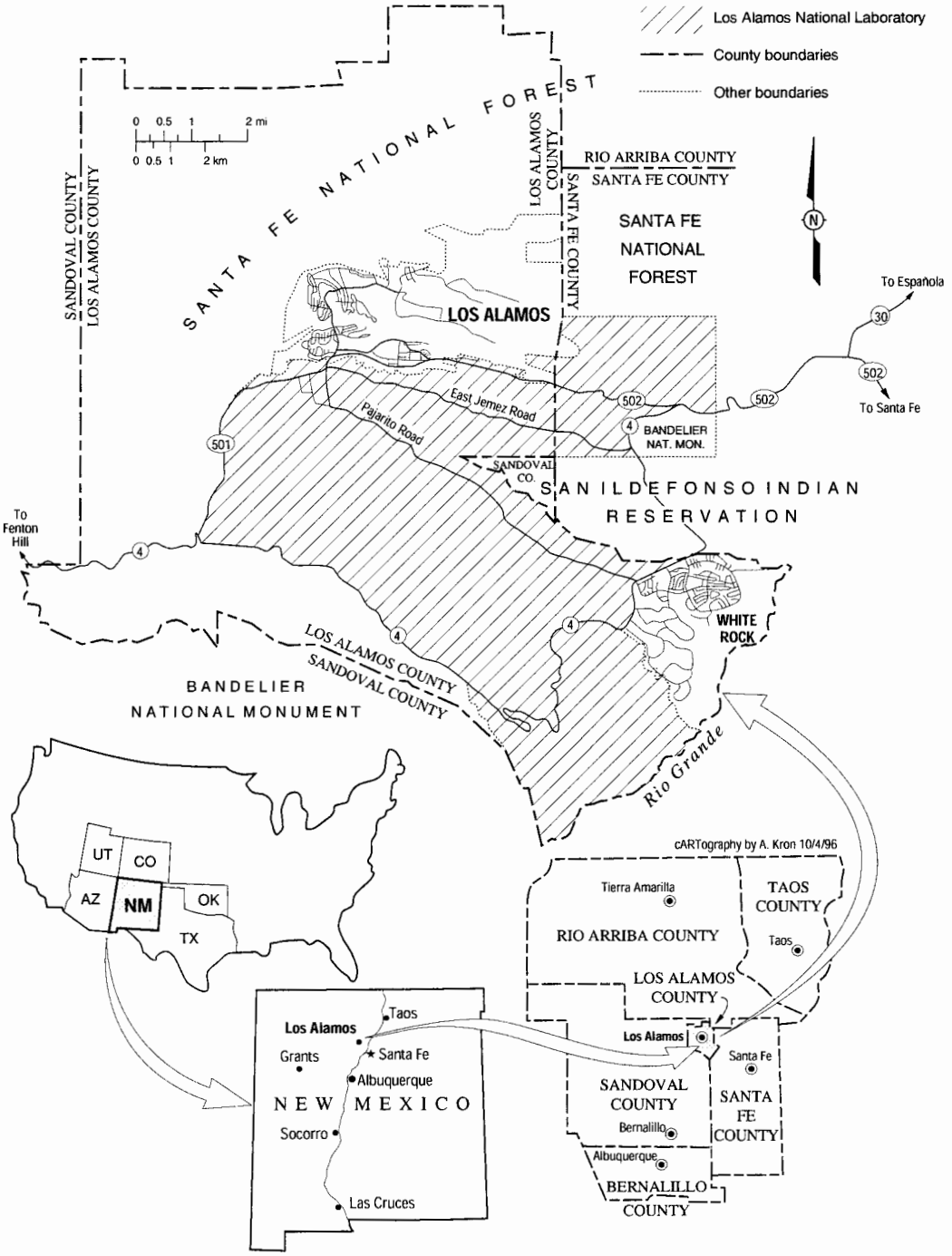


Figure 1. Location of Los Alamos National Laboratory.

the Pajarito Plateau. This plateau extends approximately 16 km (10 miles) from the base of the mountain slopes and ends at the Rio Grande. It is dissected by narrow precipitous canyons separated by finger-like mesas. LANL is located at the base of the Sierra de Los Valles and on portions of the plateau. It comprises 112 km^2 (43 mi^2) of the lands within the county. Because of the rugged topography, most of the facilities are confined to the mesa tops and concentrated in developed technical areas. The remoteness, the lack of development, and the rugged topography provide habitat for a variety of plant and animal species including species listed as endangered or threatened and species of concern under the Endangered Species Act.

Within Los Alamos County, land ownership includes LANL and the communities of Los Alamos and White Rock. Figure 2 shows the land ownership surrounding the Laboratory.

3.2 Geologic Setting

The Jemez Mountains are a remnant of a massive volcano that erupted 1.4 to 1.1 million years ago. Ash from the eruptions laid down 300 m (985 ft) of welded and nonwelded tuff on the eastern flanks. The rim of the collapsed volcano is called the Sierra de Los Valles. The rim has nine peaks including Cerro Grande, Pajarito Mountain, and Caballo Mountain. The tops of the mountains range from 2895 m (9500 ft) to over 3353 m (11,000 ft) in elevation. On the eastern flank of the mountains, an apron-like plateau, the Pajarito Plateau, is formed from a consolidated ash tuff (Burton 1982). Soils for the area have been classified by Nyhan (1979).

The plateau is dissected into canyons and mesas. Only the upper reaches of the canyons have permanent water sources. Below the Laboratory boundaries, the streams have only ephemeral water, flowing during spring snowmelt and during heavy rainstorms in the summer months. Springs and seeps can be found within the Laboratory boundaries and in White Rock Canyon. These water-rich areas, in an otherwise semiarid environment, often have a different and specific flora. Species such as helleborine orchid (*Epipactis gigantea*) are state SOC and others such as the cardinal lobelia (*Lobelia cardinalis)* are of local concern.

3.3 Climate

The area has a temperate mountain climate with four distinct seasons. Springs are dry and windy; summers, warm and often dry in June followed by a rainy season in July and August. July is the warmest month with an average daily high of 27.2 °C (81 °F) and an average daily low of 12.8 °C (55 °F). January is the coldest month with average temperature ranges of a daily high of 4.4 °C (40 °F) to a low of -8.3 °C (17 °F). There is solar heating during the day and rapid radiant cooling at night. The average annual preciptation is 17.6 cm (18.7 in.). Lower elevations near the Rio Grande receive 13 cm (5.1 in.) less and the higher elevations may receive 13 cm (5.1 in.) more. The peak rainfall months are July and August. Most of the winter precipitation falls as snow with an average of 150 cm (59 in.) (Bowen 1990, 1992)

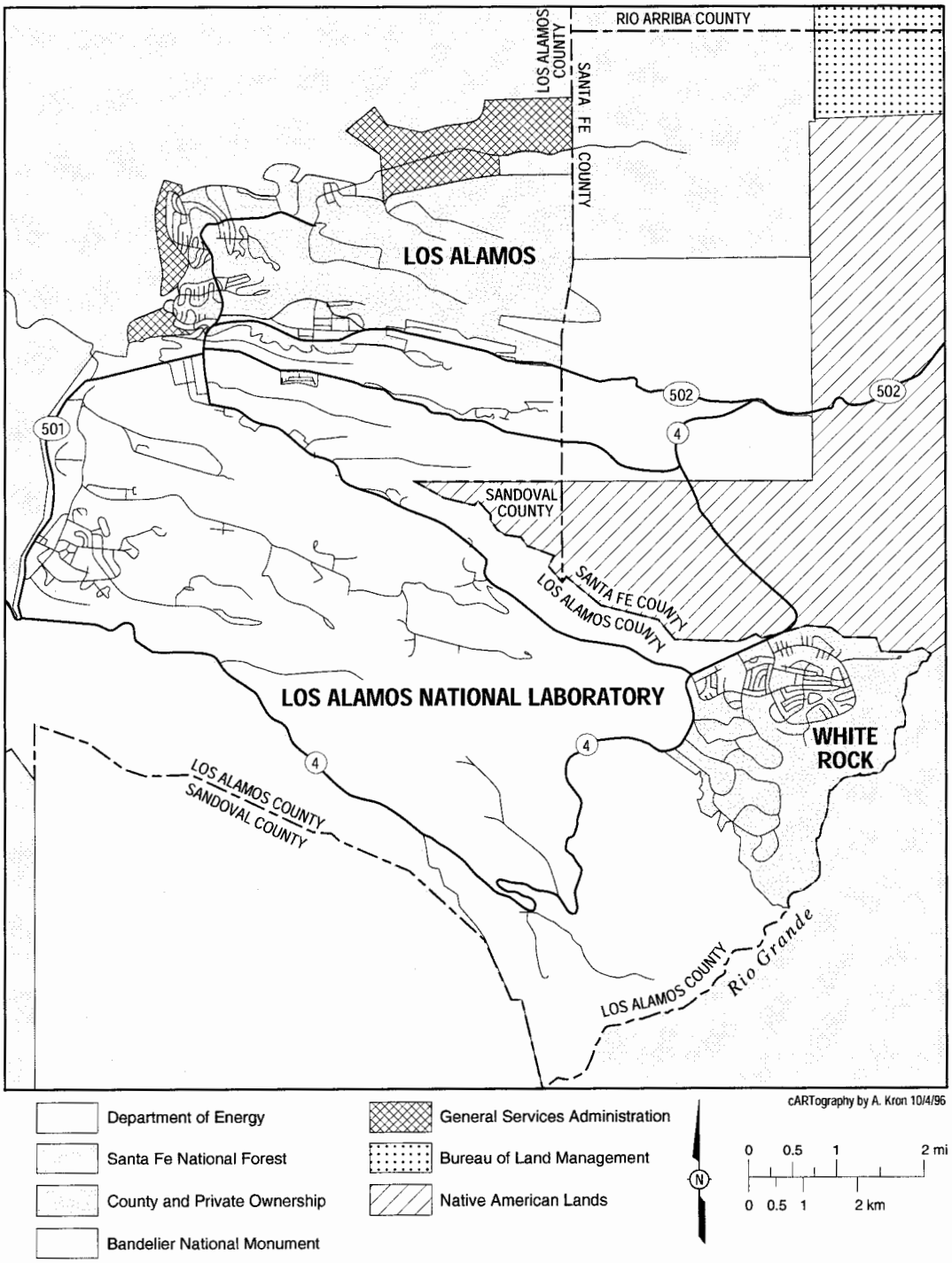


Figure 2. Landownership in the Los Alamos Area.

3.4 History of Land Use

To understand present vegetation patterns, it is important to understand the influence from past human activities. Certain plant species are characteristically found in areas of prehistoric disturbance that were introduced into the area as "camp followers" and are relics of manipulated native species or are part of an introduced ancient crop and weed complex (Yarnell 1958). Clearing areas for agriculture, by both prehistoric inhabitants and early homesteaders, has resulted in a system of abandoned agricultural fields dominated by disturbance species. (Foxx et. al, 1996). Extensive wildfires have turned many hectares of forested land into open grasslands or shrublands (Foxx and Potter 1979). Allen (1989) describes landscape changes throughout the Jemez from various forces, both man-caused and natural. He notes the changes to forests and woodlands brought by grazing, fire suppression, and insect outbreaks.

The history of the land use of the area is long and varied. Foxx and Tierney (1984) described the history of landuse of the Pajarito Plateau from prehistoric to historic times. Allen (1989) also studied the land use and landscape changes.

For our discussion we have divided the land-use changes and landscape modifications into four periods: prehistoric period from 1100 to 1598, the Spanish period from 1598 to1821, post-Spanish period from 1821 to 1940, and World War II (1940) to present. During each of these periods there have been unique influences on the vegetation patterns and the landscape.

3.4.1 Prehistoric Period (1100 to 1598)

According to the present archaeological record, northern New Mexico was inhabited by humans well before the Pajarito Plateau was first settled. After humans arrived in the region, at least several hundred years and several culture phases lapsed before the plateau region was occupied to any extent. Agriculture arrived about 1150 AD with the Pueblo III peoples and lasted until approximately 1500 AD. During this period there were extensive settlements and development of agricultural fields where corn, beans, and squash were grown. Today, remnants of these pueblos and garden plots are scattered throughout the region (Steen 1977, Lange 1959). Associated with these sites are often indicator species such as tomatillo (*Lycium pallidum*).

3.4.2 Spanish Period (1598 to 1821)

With the arrival of the Spanish in the mid-16th century came the introduction of domestic livestock. The impact of small subsistence farms from approximately 1742 through 1821 was primarily in sheep grazing and wood gathering. There is evidence from chronicles of the early explorers that the introduction of domestic livestock profoundly influenced the flora and ecology of the Southwest (Beck 1962, Carlson 1969, Grubbs 1958).

> *In records of his northern New Mexico travels of 1776, Dominguez, a Franciscan priest, mentions trading with Native Americans for several bushels of grass seed. (Chavez 1976).*

3.4.3 Post-Spanish Period (1821 to 1940)

Most of the Pajarito Plateau and the Jemez Mountains were not open to extensive European settlement until after 1821. Prior to that time the area contained only small herds of domestic stock and summer grazing. Two major factors opened the area up for settlement and use: 1) the coming of the narrow gauge railroad (the Chili Line) in 1879 and 2) the Homestead Act of 1882 (Gjevere 1978, Foxx and Tierney 1984).

The building of the railroad opened New Mexico to an influx of Easterners, provided a method of transportation to move goods such as livestock and lumber, and provided access to otherwise remote areas. With the development of the Chili line and the small town of Buckman on the Rio Grande, access roads were developed onto the Pajarito Plateau and large numbers of cattle were introduced into the area. From 1885 through 1887, the Ramon Vigil Grant (an area that basically corresponds to Laboratory lands), had over 3000 head of cattle on 32,000 acres.

The Los Alamos homestead era began in 1894 with the establishment of small subsistence farms, which grew beans, grain, and fruit under dry land conditions. The Alamo homestead was filed in 1911 by H. H. Brook. This homestead eventually reached the size of 2.5 km^2 (6.4 mi^2) and produced alfalfa, sorghum, wheat, and "trainloads" of pinto beans. By 1937, 35 farms occupied about 15 km^2 (38.9 mi^2) (Chambers 1974).

The logging industry clear-cut areas of the plateau during the early 1900s. In 1887 the owners of the Ramon Vigil Grant sold the timber rights to H. S. Buckman, who removed lumber from the area until 1903. A newspaper article of December 1903 speculated that Buckman cut 36,000,000 board feet on the 32,000 acre grant. Throughout the early 1900s and into the 1940s, areas adjacent to the Ramon Vigil Grant yielded 17,319,000 board feet of permitted saw log timber (Santa Fe New Mexican 1902).

Development of the plateau for recreation purposes began in 1914. Ashley Pond established the Los Alamos Ranch School in 1917. Areas such as Camp May were established as pack camps, and numerous trails were built for horseback riding (Chambers 1974).

3.4.4 World War II and Post World War II Period (1940 to Present)

Since 1942 the area known as LANL has been under Federal ownership. Since the Laboratory's establishment and the carving of Los Alamos County from Santa Fe and Sandoval Counties, the urban areas of Los Alamos and White Rock have developed. Allen (1989) estimated a 12-fold increase of roads in the Jemez Mountains from 1935 to 1981.

Other factors that have influenced vegetation patterns within the County are landscape changes due to wildfire and long-term fire suppression. Extensive wildfires have burned areas along the slopes of the Sierra de Los Valles and on the upper slopes of the plateau. In 1977, the La Mesa fire burned 6073 ha (15,000 acres) of BNM, Santa Fe National Forest, and LANL property.

Since LANL was removed from private ownership in the early 1940s, there has been little or no urban development, logging, or hunting on Laboratory lands. Essentially, much of the 43 mi^2 has become a natural reserve that supports many plant and animal species including 3 federally listed TES. Although the set-aside provides a unique diversity of plants and animals, active management of ungulate species, timber, and fire is important to sustaining these habitats over the long-term. The HMP is one step in the management of these resources.

3.4.5 Botanical History

Before the 20th century, the Pajarito Plateau and the east side of the Jemez Mountains were largely inaccessible to botanists. Early Spanish chronicler' accounts of the vegetation of the northern Rio Grande (Chavez 1976) seem to indicate that the native composition of the area was much the same as it is now, although the density of most of the species probably has changed greatly.

In 1841, the first trained naturalist entered New Mexico. William Gambel traveled to Santa Fe with a group of trappers and traders. Although he collected plants a few miles into the Santa Fe mountains, Gambel did not survey in the Jemez Mountains. After the American occupation in 1846, naturalists began to work in northern New Mexico. The first arrived with contingents of the US Army and others came later with the US Boundary Survey. Still, the Pajarito Plateau and Jemez Mountains were remote and not until the railroad came to the Rio Grande Valley in the early 1800s were plants collected there for scientific study. As far as we can determine, these first collections were made by Adolf Bandelier when he was living at Cochiti Pueblo. Bandelier's collections were shipped to Dr. George Engelmann, a physician-naturalist, in St. Louis, Missouri, for identification (Lange 1959). A number of plant names in the New Mexico flora have Gambel's or Engelmann's name attached to them.

The Jemez Range and Pajarito Plateau have seen many botanical collectors since the beginning of the 20th century. Among the earliest botanical explorers and authors of this century were E. O. Wooton and Paul Standley, authors of *A Flora of New Mexico* (1915). Later Howard Dittmer, Edward Castetter, and Ora M. Clark mention some plants from this area in their *The Fern and Fern Allies of New Mexico* (1954). Numerous specimens in the herbarium at Bandelier National Monument and the University of New Mexico were collected by Clark. Several students have written master's theses about the botany of our area, and have been mentioned earlier. The early collections and original data from more recent observations have been given in *Flora of New Mexico* by William C. Martin and Charles R. Hutchins (1980). These floristic studies have been summarized as a basic compilation of plant species that have been found in the Jemez Mountains (Foxx and Tierney 1985).

Only recently has there been classification of the landscape components. Other than Allen (1984, 1989), Barnes (1983), and Potter and Foxx (1981), few studies have been specific for the area. Barnes (1983) classified the habitat types in the pinon-juniper woodland of LANL and Bandelier National Monument. Allen (1984, 1989) conducted extensive

studies of the Jemez Mountains. Potter and Foxx (1981) mapped areas of the Cerro Grande. Most other studies are regional in nature. Moir and Ludwig (1979) classified the spruce-fir and mixed conifer habitat types of Arizona and New Mexico. Some of their work was done in the Espanola Ranger Distict of the Santa Fe National Forest.

On the state level, the New Mexico Natural Heritage Program (NMNHP) is engaged in development of a comprehensive classification of vegetation for the State of New Mexico. The purpose of their classification is for conserving and managing the states biological diversity (Muldavin 1994). The system used by the NMNHP incorporates the essential elements of the UNESCO framework with modifications for local characterization of ecosystem. Recently, the Federal Geographic Data Committee issued a standard for Vegetation Classification and Information. The overall objective of this standard was to support the production of uniform statistics on vegetation resources at the national level. The NMNHP can be cross-walked to all of these systems.

4.0 Methods

The proposed classification for LANL has been developed from a variety of sources. However, there are three informational sources that have been most important to the mapping and classification.

1) Previous surveys that have collected qualitative data as to species presence and absence.

2) Previous surveys that have been used to collect quantitative information using the standard vegetation measuring techniques.

3) Unsupervised classification of satellite imagery data for the land cover map (Koch et al. 1996).

4.1 Methods Used in Vegetation Surveys

At LANL, we have established 2 levels of surveys for project review: Level 1 and Level 2. One level is used to collect qualitative data and the other quantitative.

The Level 1 surveys are reconnaissance surveys. These are qualitative surveys that record observations and general species lists for the area. Most of the time the relative dominance of the species have been noted. Prior to the mid 1980s, a number of such surveys were conducted throughout the Laboratory. Generally, the dominant life forms (trees, shrubs, herbs, grasses) were identified by species and a percent cover of the dominant species noted. From species-specific data physiognomic attributes of the dominant vegetation (evergreen, deciduous) can be determined. Additional qualitative surveys were conducted to produce a land cover map (Koch et al. 1996).

Level 2 surveys are quantitative surveys using standard methods to determine vegetation cover, density, and frequency. Techniques have included line intercept methods and circular plots for the overstory component and Daubenmire plots for the understory.

Vegetation surveys have been conducted for Environmental Restoration Operable Units (ER-OU) using the line intercept techniques (Lindsey 1955, Woodin and Lindsey 1954) to measure the overstory components of coniferous forests. Researchers collected data

within 6-m- (20-ft-) wide strips centered on the transect line. Within the strip, the diameter breast heigh (DBH) of trees was measured and all shrub stems were counted. Data gathered included foliar cover, density (trees/acre), and frequency. From these data, an importance index was calculated.

Within the pinon-juniper and riparian areas, the circular plots technique was used to measure the overstory components. A 304.8-m (1000-ft) transect line was placed along the habitat that was to be evaluated. Three circular plots were established along the transect. Data was recorded for all trees within a 9.14-m (30-ft) radius of the center point. Data included species, height, crown diameter, condition, number of stems, diameter, and percent cover. All multistemmed species, such as pinon pine and juniper, were measured for basal diameter. All single-stemmed trees such as ponderosa pine were measured for DBH. Percentage cover for each species was determined by dividing the circle into four equal subplots (quarters) and estimating the cover within each of the subplots.

For the understory component of an area, the quadrat method with a Daubenmire plot of 20 x 50 cm (8 x 20 in.) (Daubenmire 1959) was used for measurement of cryptogamic and herbaceous vegetation, percentage of bare soil and litter, and shrubs with heights of less than 0.9 m (3 ft). We used visual estimates of foliar cover to determine percent cover and species composition, and read quadrats along the transect established for overstory evaluation at 3-m (10-ft) intervals. Quadrats were read until the number of species within the plots had not increased (the species area curve flattened) or a maximum of 100 quadrats had been read along a transect. Figure 3 shows the locations for the quantitative surveys.

All plants were identified using Hitchcock (1950), Martin and Hutchins (1980), Foxx and Hoard (1984, 1995), Tierney and Foxx (1985), and Allred (1993). When necessary, voucher specimens were collected and archived in the herbarium at LANL. Any questionable identifications were confirmed at the University of New Mexico herbarium.

4.2 Methods Used in Development of Draft Terrestrial Classification

The development of a draft classification for LANL had four goals:

1) The classification must be applicable to habitat management.

2) The classification should be consistent with and complimentary to those used by organizations who have lands bordering LANL (e.g. US Forest Service, National Park Service).

3) The classification should be done by State and Federal standards.

4) The classification must represent what is currently present and not based on climax vegetation.

For these reasons, we decided to develop our classification based on the NMNHP system of hierarchical classification. This classification can be translated into the UNESCO system and the newly developed vegetation classification done by the Federal Geographic Data Committee (1996). This classification hierarchy draws upon the UNESCO Framework (Driscoll et al. 1984)

and other classifications from the Southwest including Donart, Sylvester, and Hickey (1978), Brown, Lowe, and Pace (1979), Dick-Peddie (1993) and many habitat type classifications produced by the Forest Service including Moir and Ludwig (1979), and Alexander et al. (1984, 1986). However, our classification is based on present vegetation not habitat types or climax vegetation.

Additionally, the advantage of the NMNHP system is that it has been developed in coordination with the New Mexico Gap Analysis Project and is specific for the ecosystems of the arid and semiarid Southwest. The hierarchical classification is as follows (Muldavin 1994):

I. Class — major physiognomic type (e.g., forest, grassland, etc.);
II. Subclass — moisture and temperature defined subformations;
III. Regional Biome — biogeographically related Series Groups;
IV. Cover Type Groups — sets of morphological, environmentally or floristically relatedcover types;
V. Major Cover Types — sets of Community Types related by at least a common dominant; more or less synonymous with Series without successional implications;
VI. Community Type — fundamental repeated assemblages of species; more or less synonymous with plant association without successional implications;
VII. Phase — floristic variants of Community Types—Typic Phase refers to the modal species composition of the Community Type.

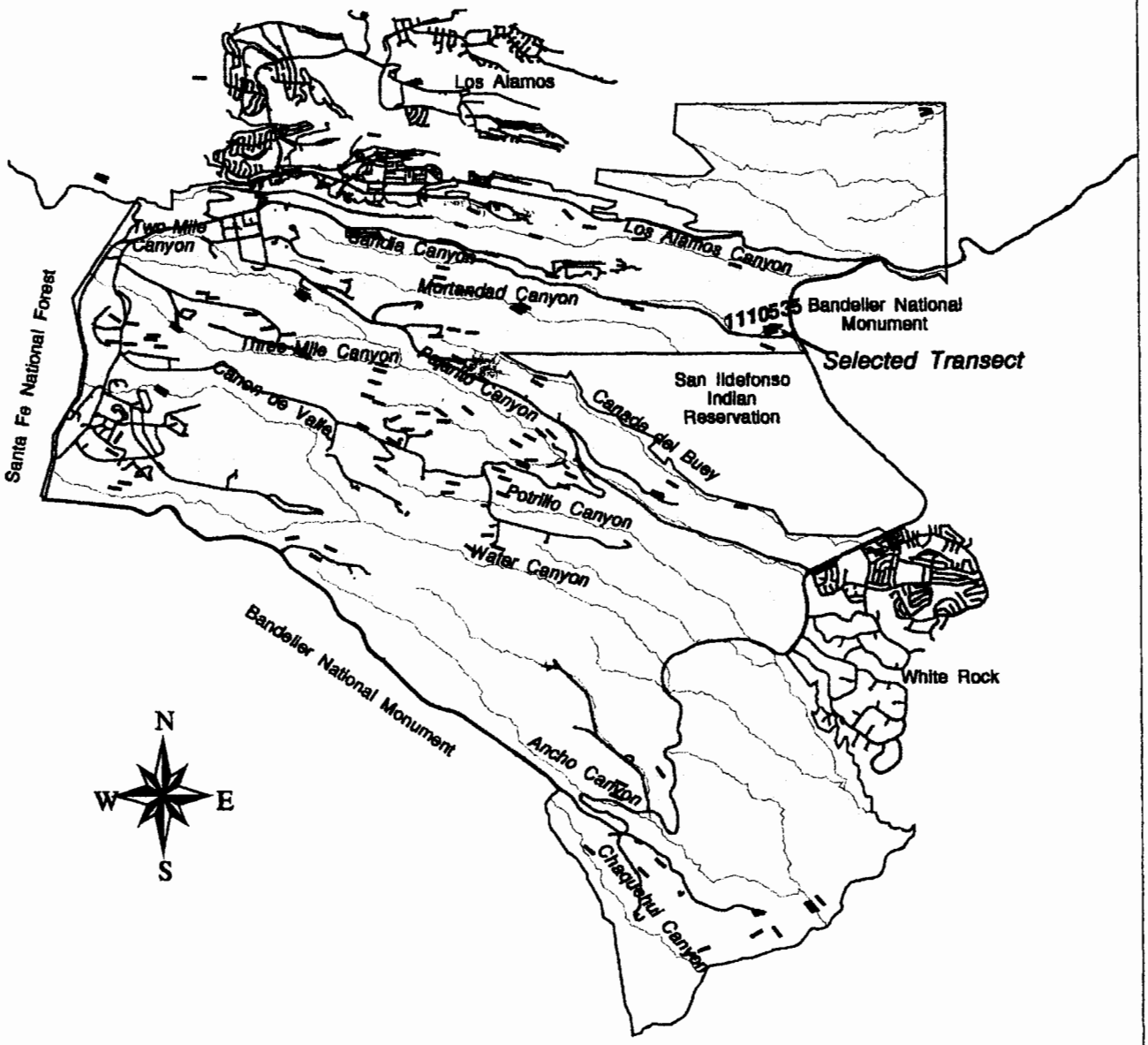
The upper 3 classifications are based on the physiognomic nature of the vegetation and the last two on the floristic nature. The upper 3 classifications are defined by temperature and moisture regimes. The lower levels of the classification are based on floristics. During FY96 we have concentrated on identifying the cover types and community types that are found on LANL and the surrounding area. The land cover map defines the cover types we identified from the spectral classes in satellite imagery. The Working Draft of "Keys to Major Land Cover Types in the LANL Vicinity" (Appendix A) defines the community types for the terrestrial ecosystems, provides a means of consistently identifying sites of human disturbance, and gives a preliminary classification for riparian/ wetland systems.

This Working Draft is to be used for guidance of major cover and community types within LANL and the surrounding areas. The keys were designed for homogenous areas of at least 0.405 ha (1 acre). These keys have been developed using information in Allen (1984), Moir and Ludwig (1979), USFW (1988), Muldavin (1994), and the survey data at Los Alamos. Selected quantitative survey data (104 plots), supervised and unsupervised classification data, and qualitative data were examined. Each plot was used to define the community types.

The draft classification contains 10 keys.

- Key A: Key A provides a guidance for classifying areas used for human purposes. Buildings, farms, parking lots, paved or dirt roads, utility corridors, or other man-made structures that are present or dominate the landscape can be classified using this key.

Map 1: Vegetation Transects



Legend

- Selected Transect
- Vegetation Transects
- LANL
- Paved Roads
- Drainages

1:72679

2 0 2 4 6 8 10 12 Kilometers

2 0 2 4 6 8 Miles

LOS ALAMOS NATIONAL LABORATORY
BIOLOGY TEAM, ESH-20 ECOLOGY GROUP
PREPARED: SEPTEMBER, 1996

Figure 3. The locations of transects for the quantitative land cover surveys.

- Key B: Key B provides guidance to the classifying of land that is periodically flooded, supports facultative or obligate hydrophytic plants species, and is characterized by hydric soils. Key B incorporates the riparian/wetland classification (Cowardin 1979).

- Key C: Key C identifies areas that are rock outcrops, talus slopes, or other upland lithosolic areas that do not support vegetation.

- Keys D through J: All other keys are associated classifications of the terrestrial ecosystem on the floristic level including Cover Type and Community Type.

5.0 Results

5.1 Land Cover Classification and Mapping

Three products have contributed to the results presented in this paper. The first is the production of the land cover map (Koch et al. 1996). The second is the development of the preliminary vegetation classification reported in this paper. The third is the revised plant checklist for the Jemez Mountains by Foxx et al. (1996). The following is a detailed discussion of the preliminary classification. The land cover map and the checklist are discussed elsewhere.

5.2 Classification Description

The information in this section corresponds to the classification in Appendix A. There are three sections: Classification of areas of Land Used for Human Purposes which corresponds to Key A of the Working Draft Key, Riparian/Wetland System Classification which corresponds to Palustrine Systems in Muldavin (1994) and Key B of the Working Draft Key; and, Terrestrial System Classification of Vegetation which corresponds to Terrestrial System Classification in Muldavin (1994), the land cover map (Koch et al. 1996), and the Working Draft Keys C through J.

Below we have described each of these classifications.

5.2.1 Classification of Land Used for Human Purposes

To consistently define areas of human disturbance, Key A of the Working Draft has been developed. The land types include archaeological sites, buildings, farms, parking lots, paved and dirt roads, utility corridors, or other man-made structures.

Most of these areas of human disturbance can be pulled up as layers within the GIS ARC/INFO (e.g., road, utilities, residential). In some cases, they will be used to define habitats for TES. Areas of human disturbance generally will not support TES. However, some species such as the Goat Peak pika or bats may actually utilize areas that have undergone disturbance.

Roads: Roads are classified as paved, improved, and unimproved. Improved roads are generally gravel and are maintained by occassional blading. Unimproved roads are rarely bladed.

Utilities: These structures include pipelines, utility poles, and other structures used to supply gas, electricity, or water to facilities and homes. These structures can be aboveground or underground.

Abandoned farmlands: These are areas that have historically been used for agriculture. These areas usually have been cleared of the major cover type and are undergoing successional processes.

Waste ponds: These are water bodies associated with sanitary systems and collection of effluents. They are cement lined.

Industrial facilities: These are facilities within the Laboratory boundaries and are used for research or other activities.

Commercial areas: These are offices, restaurants, and other buildings used for commercial purposes.

Residential areas: These areas are homes, schools, and other buildings.

Archaeological/cultural sites: These areas were used for habitation, farming, ceremonial, or hunting by early residents of the Pajarito Plateau. Cultural sites can include homesteading and World War II sites. These sites are generally protected under the Historic Preservation Act.

5.2.2 Riparian and Wetland Systems

Riparian/Wetland ecosystems are directly associated with wetlands adjacent to rivers (riverine), riverbanks (palustrine) or lakes (lacustrine), e.g., mashes, bogs, and riverbank areas. These systems occur primarily in the canyon bottoms of the Pajarito Plateau and along the banks of the Rio Grande. The riparian/wetland ecosystems of the Plateau include springs, riverbanks, streambanks, outfalls, and marshes.

This classification corresponds to the information in Key B in the Working Draft Key (Appendix A). This key is very tentative and will need further refinement in FY97.

In 1990, the USFW classified the area in accordance with the National Wetlands Inventory 4. This mapping was based upon "The National Wetlands Inventory Classification of Wetlands and Deepwater Habitats of the United States," by Cowardin et al. (1979). The purpose of this inventory was to delineate and identify wetland. The classification was done primarily with infrared aerial photographs. In 1993 to 1995, wetland areas not identified by this survey (outfalls, springs, and small pools) were incorporated into maps by K. Bennett in the Ecology Group, ESH-20. The maps reside in ARC/INFO.

Using information from previous quantitative surveys done at the Laboratory, we have determined only a few riparian and wetland Cover and Community Types. Because of the narrowness of the canyons, spectral identification of the riparian zone was not possible. Therefore, this system will be separately classified. No map layer presently exists.

5.2.2.1 Characterization of Riparian Forests and Shrub Wetlands

From previous surveys, we have determined that Riparian Forest and Shrub Wetlands and Emergent Wetlands Classes are present within Los Alamos County (see References 8.2). For example, Foxx and Tierney (1980, 1984) surveyed Pajarito, Mortandad, Effluent, and Water Canyons. Foxx (1996) tested areas in Ancho and

Chaquehi Canyons for hydric soils and found hydrophytes made up 87.6% of the relative cover. The Riparian Forest and Shrub Wetlands are primarily in the canyons, along ephemeral streams. Emergent wetlands are in areas where canyon bottoms have been dredged, associated with outfalls, or natural springs

Riparian Forest and Shrub Wetlands are characterized by vegetation directly dependent on either ground water and/or flooding. The broadleaf forests are dominated by narrowleaf cottonwood *(Populus angustifolia)*, boxelder (*Acer negundo*), alder (*Alnus oblogifolia, A. tenuifolia).* Evergreen forests include ponderosa pine (*Pinus ponderosa*), white fir (*Abies concolor*), and Douglas fir (*Psuedotsuga menziesii*).

5.2.2.2 Characterization of Emergent Wetlands

Emergent wetlands are dominated by herbaceous species, mostly grass-like species. These cover types may be characterized by cattail (*Typha latifolia*), rush (*Juncus* spp.), or other facultative or obligatory wetland species. Wetlands in Pajarito Canyon have been monitored for 6 years for changes in the species diversity. Other emergent wetlands have been found around outfalls (Foxx and Blea-Edeskuty 1995).

Below we describe some of the species found within the riparian and wetland habitats of these canyons.

Foxx and Tierney (1980, 1984) found understory species in the streamside habitats included Arizona valerian (*Valeriana arizonica*), black-eyed Susan (*Rudbeckia hirta*), cutleaf coneflower (*Rudbeckia laciniata*), western bracken fern (*Pteridium aquilinum*), and Canadian violet (*Viola canadensis*). Common grasses are melic grass (*Melica porteri*) and interior bluegrass (*Poa interior*). They also found a rare larkspur violet (*Viola pedadifida*) within the streamside and moist meadow areas.

Within Guaje and Los Alamos Canyon Banar (1995) found thinleaf alder (*Alnus tenuifolia*), Rocky Mountain maple (*Acer glabrum*), white fir, aspen (*Populus tremuloides*), Douglas fir, limber pine (*Pinus flexilis*), Engelmann spruce (*Picea engelmanni*), and water birch (*Betula occidentalis*). Shrub species in the understory included Gambel oak (*Quercus gambelii*), raspberry (*Rubus strigosus*), wild rose (*Rosa woodsii*), New Mexico locust (*Robinia neomexicana*), gooseberry (*Ribes inerme*)), serviceberry (*Amelanchier utahensis*), and cliffbush (*Jamesia americana*). Common understory species were Richardson's geranium (*Geranium richardsonii*), cutleaf coneflower, and meadow horsetail (*Equisetum arvense).*

Foxx and Tierney (1984) and Foxx (1996) did surveys along the Rio Grande. Within the County and LANL the riparian vegetation has been destroyed by the rising and falling of the backwaters of Cochiti Reservoir. A few netleaf hackberry (*Celtis reticulata*), one-seed juniper (*Juniperus monosperma*), tamarisk (*Tamarix pentandra*), and Russian olive (*Elaeagnus angustifolia*) are found at the edges of the maximum floodpool. Generally only weedy species such as Russian thistle (*Salsola kali),* cocklebur (*Xanthium strumarium*), field sandbur (*Cenchrus pauciflorus*), and summer cypress (*Kochia scoparia*) are found below the maximum floodpool.

Studies have shown that the following species generally occur in the Graminoid Wetlands of the area (Foxx and Tierney 1984, Banar 1995, and Foxx unpublished information). Common species of these wetlands include interior rush *(Juncus interior)* and cattail.

5.2.3 Unvegetated Lands

This information corresponds to Key C of the "Working Draft." Unvegetated lands are primarily associated with rock outcrops, talus slopes, and other upland lithosolic areas that cannot support vegetation. These include cliffs and outcrops of basalt or tuffaceous materials that impart many of the scenic splendors to the Los Alamos region. They also include felsenmeers and talus slopes.

Each of these classes represent specialty habitats to many of our threatened and endangered species and other species of concern, such as the American peregrine falcon, the Goat Peak pika, and the Jemez Mountains salamander.

5.2.4 Terrestrial Systems

Terrestrial systems are not directly associated with river channels (riverine), riverbanks (riparian), or lakes (lacustrine), e.g., marshes, bogs and riverbank areas, commonly referred to as riparian/wetlands. Nor are they heavily influenced by past or present human activity.

Keys D through J in the Working Draft Keys (Appendix A) are associated with the Cover and Community Type classification of the terrestrial systems.

Koch et al. (1996) found that the Forest and Woodland Classes were classified with the greatest accuracy from the supervised and unsupervised classifications of the spectral classes from satellite imagery. He found that the Shrubland and Grassland Classes were the least accurately identified. We believe further study will be required to adequately define the Shrubland and Grassland Cover and Community Types. Below we describe the classification for the Terrestrial Systems.

5.2.4.1 Hierarchical Classification for Terrestrial Forests

On the Pajarito Plateau, within the Sierra de Los Valles, and within the boundaries of LANL, terrestrial ecosystems are represented by forests, woodlands, shrublands, and grasslands. These are cold temperate forests and woodlands. Table 1 provides an outline of the hierarchical classification for the Forest Class after Muldavin (1994). Below we describe each element of the Forest Class we have defined for Los Alamos County.

Table 1. Hierarchical Classification for Terrestrial Forests.

I. Forest Class
II. Cold Temperate Forest Sub-Class
III. Rocky Mountain Subalpine Forest Regional Biome
IV. Subalpine Conifer Forest Cover Type Class
V. Cover Classes
Engelmann spruce (*Picea engelmannii*)
Subalpine fir (*Abies lasiocarpa*)

IV. Subalpine Broadleaf Forest
  V. Cover Class
    Aspen (*Populus tremuloides*)
III. Rocky Mountain Montane Forest
IV. Rocky Mountain Upper Montane Conifer Forest
  V. Cover Class
    Douglas fir (*Pseudotsuga menziesii*)
    White fir (*Abies concolor*)
IV. Rocky Mountain Lower Montane Conifer Forest
  V. Cover Class
    Ponderosa pine (*Pinus ponderosa*)

I. Forest Class

The forests of the region can be placed in the Rocky Mountain Montane Forest regional biome. These are forests of mid-elevations dominated by cold-tolerant species associated with the Rocky Mountain biogeographic province.

There are two major Cover Type Groups represented: The Rocky Mountain Upper Montane Conifer Forest and the Rocky Mountain Lower Montane Conifer Forests.

The Rocky Mountain Lower Montane Conifer Forest is dominated by rounded-crown conifers which form open to closed canopies. This Group is represented by the ponderosa pine Cover Type. Sometimes low-statured conifers such as pinon pine (*Pinus edulis*) and junipers and broad leaf shrubs or trees of Gambel oak can be found in the subcanopy.

II. Cold Temperate Forest Sub-Class

Forest of mid-elevations dominated by cold-tolerant species.

III. Rocky Mountain Montane Forests Regional Biome

Forests of mid-elevations dominated by cold-tolerant species associated with the Rocky Mountain biogeographic province.

IV. Rocky Mountain Upper Mountain Conifer Forests Cover Type Group

The Rocky Mountain Upper Montane Conifer Forests are dominated by conical crowned conifers which generally form closed canopies (occasional open canopies do occur). The major cover types within our area are Douglas fir and white fir. For the land cover map, we have called the varying mixtures of these cover types as a Mixed Conifer and have further classified them into various community types in our Working Draft Land cover key (Appendix A).

V. Mixed Conifer Cover Type

Mixed Conifer Cover Type comprises approximately 6449 ha (15, 924 acres) of Los Alamos County. The cover type primarily occurs at elevations of 2438 to 2896 m (8000 to 9500 ft). Within the Laboratory boundaries there are 31.8 ha (759 acres) most of which are along the stream channels within the canyons and along the north facing slopes of the upper canyons. Figure 4 is an example of the Mixed Conifer Cover Type.

This cover type is generally found on steep and rocky terrain. At these elevations, mean annual precipitation is 50.8 cm (20 in.), although, in favorable years, it may exceed 88.9 cm (35 in.) according to Tuan et al. (1973).

Within this cover type we have identified nine different community types. They include three Douglas fir, one Engelmann spruce, and three white fir dominated types.

Douglas fir types
Pseudotsuga menziesii/Populus tremuloides
Pseudotsuga menziesii/Quercus gambelii
Pseudotsuga menziesii/Muhlenbergia montana

Engelmann spruce types
Picea engelmanii/Populus tremuloides

White fir types
Abies concolor/Populus tremuloides
Abies concolor/Robinia neomexicana
Abies concolor/Quercus gambelii.

The mixed conifer forests within the county have been logged or burned. There is evidence of fire in the late 1800s and early 1900s (Allen 1989). A fire in 1954 on the eastern slopes of the Sierra de Los Valles was within both Ponderosa Pine and Mixed Conifer Cover Types. Allen (1989) found that the higher elevation mixed conifers on north-facing slopes have a 15 to 25 year surface fire regime, with patchy crown fires. South-facing slopes have a 10 to 8 year interval. The highest fire frequencies are 5 years with return intervals of 5 to 25 years.

Figure 4. An example of Mixed Conifer Cover Type.

Logging has been conducted within the Santa Fe National Forest during the Buckman era and also within the last 20 years. Pajarito Mountain Ski area was begun in 1957 and since that time has extended across the northern-facing slopes of the mountain in this cover type.

The following trees, shrubs, herbs, and grasses are found in this cover type.

Trees: Ponderosa pine, Douglas fir, limber pine, and white fir.

Shrubs: Common shrubs are ninebark (*Physocarpus monogynus*), wild rose, Gambel oak and cliff bush. Other shrubs include Utah serviceberry, bearberry (*Berberis repens*), red-osier dogwood (*Cornus stolonifera*), ocean spray (*Holodiscus dumosus*), inkberry (*Lonicera involucrata*), mock-orange (*Philadelphus microphyllus*), and western black chockcherry (*Prunus virginiana* var. *melanocarpa*).

Grasses and grass-like plants: western wheatgrass (*Agropyron smithii*), bearded wheatgrass *(A. subsecundum),* slender wheatgrass (A. *trachycaulum*), redtop (*Agrostis alba*), pine dropseed (*Blepharoneuron tricholepsis*), Arizona fescue (*Festuca arizonica*), sheep fescue (*F. ovina*), thurber fescue (*F. thurberi*), June grass (*Koeleria cristata*), common timothy (*Phleum pratense*), and inland bluegrass (*Poa interior*).

V. Aspen Cover Type

The Aspen Cover Type makes up approximately 459 ha (1, 134 acres) of Los Alamos County. Within the Laboratory boundaries there are only 7.2 ha (18 acres). Figure 5 is an example of the Aspen Cover Type.

At the higher elevations within the county, aspen is interspersed within the mixed conifer. At lower elevations, within Laboratory boundaries, it is found in the upper canyons, primarily where areas were burned by the 1977 La Mesa fire.

Aspen is considered a fire dependent species and is indicative of previous fire regimes within the mixed conifer type. Allen (1989) found aspen groves bordering the montane grasslands of the upper peaks of the Sierra de Los Valles. He found that the groves consisted of clones of large extent, covering several hectares. Many of the older decadent trees were found to be 80 to 120 years old. He also found damage from deer and elk browsing. In some stands Engelmann spruce was becoming dominant and in others white fir. On Cerro Grande, Allen (1984) found aspen regeneration within a single clone dated to 1847, 1908, and 1941. Aspen invades areas of disturbance such as along the slopes of the ski hill (Foxx and Tierney 1985).

We have identified three different Aspen Community Types. They include

Populus tremuloides/Athryrium filix-femina
Populus tremuloides/Bromus marginatus, and
Populus tremuloides/Bromus ciliatus.

Allen (1989) identified the soils beneath the aspens as thick mollisols.

Figure 5. An example of Aspen Cover Type.

IV. Rocky Mountain Lower Montane Conifer Forest Cover Type Group

The Rocky Mountain Lower Montane Conifer Forest is dominated by rounded-crown confiers which form open to closed canopies. This series group is represented by the Ponderosa Pine Cover Type. Sometimes low-statured conifers such as pinon pine and junipers and broad leaf shrubs or trees of Gambel oak can be found in the subcanopy.

V. Ponderosa Pine Cover Type

The Ponderosa Pine Cover Type comprises approximately 8,783 ha (21,693 acres) of Los Alamos County. This cover type is found primarly in elevational zones of 2134 to 2438 m (7000 to 8000 ft). Narrow bands of ponderosa-dominated areas are found in many canyon bottoms to 1981 m (6500 ft). Below 1981 m (6500 ft) scattered pines can be found in canyons to the Rio Grande at 1646 m (5400 ft).

Figure 6 is an example of the Ponderosa Pine Cover Type.

Within the Ponderosa Pine Cover Type we have identified 5 community types. They include

Pinus ponderosa/Quercus gambelii
Pinus ponderosa/Quercus undulata
Pinus ponderosa/Blephoneuron tricholepis
Pinus ponderosa/Bouteloua gracilis and
Pinus ponderosa/Muhlenbergia montana..

The ponderosa pine forest of the Pajarito Plateau and the Sierra de Los Valles has been influenced by factors of logging in the early 1900s, homesteading in the late 1800s, grazing from the 1600s to the 1940s, and development of Laboratory facilities.

Within the Laboratory boundaries, the Ponderosa Pine Cover Type was logged in the early 1900s and since the 1940s has had little or no timber management. Much of the lumbering activity by H. H. Buckman in the early 1900s was within the Laboratory boundaries. The presence of stumps, cleared areas, and the remnants of a sawmill, called the Phillips Mill, are all indicative of the lumbering activities.

Several large homesteads were established in the Ponderosa Pine Cover Type in the late 1800s. The Homestead Act of 1862 granted quarter sections of land to any bonafide settler who had occupied a site for 5 years. On the Laboratory, homesteads were most important after 1894. Homesteads claimed earlier in the 1800s were used mainly as summer grazing areas. Development of these homesteads required cutting trees and developing agriculture fields where they grew beans and hay. At the time the area was purchased for the Manhattan Project, the owners were forced to abandon these homesteads. These old fields have been invaded by ponderosa pine (Foxx and Tierney 1996) and are a plant community association within the Ponderosa Pine Cover Type.

Figure 6. An example of the Ponderosa Pine Cover Type.

Some portions of the Ponderosa Pine Cover Type were burned in the 1977 La Mesa fire. Much of that area is now a shrub/ grassland cover type. However, small portions along State Route 502 were replanted in 2-year-old ponderosa pine stock.

The following shrubs, herbs, grasses, and grass-like plants characterize this cover type:

Shrubs: Bearberry (*Arctostaphylos uva-ursi*), buckbrush (*Ceanothus fendleri*), Colorado barberry (*Berberis fendleri*), and Gambel oak.

Herbs: Yarrow (*Achillea lanulosa*), Rocky Mountain nodding onion (*Allium cernuum*), pussytoes (*Antennaria parvifolia*), spreading dogbane (*Apocynum androsaemifolium*), wormwood (*Artemisia ludoviciana*), yellow ragweed (*Bahia dissecta*), Indian paintbrush (*Castilleja integra*), golden aster (*Chrysopsis villosa*), wavyleaf thistle (*Cirsium undulata*), and dayflower (*Commelina dianthifolia*),

Grasses and grasslike-plants: Slender wheatgrass, western wheatgrass, redtop, little bluestem (*Schizachyrium scoparium*), big bluestem (*A. gerardii*), blue grama (*Bouteloua gracilis*), yellow nutsedge (*Cyperus esculentus*), Junegrass, mountain muhly (*Muhlenbergia montana*), and Indian grass (*Sorghastrum nutans*).

Inclusions within the Ponderosa pine cover type include abandoned agricultural fields. Some plants typical of these grasslands are Harvard three-awn (*Aristida barbata*), wormwood (*Artemisia carruthii*), false tarragon (*Artemisia dracunculus*), yellow ragweed, golden aster, Bigelow rabbitbrush (*Chrysothamnus nauseosus* subs. *bigelovii*), Bermuda grass (*Cynodon dactylon*), trailing fleabane (*Erigeron flagellaris*), and evening-primrose (*Oenothera coronopifolia*).

5.2.4.2 Hierarchical Classification for Terrestrial Woodlands

The woodlands of the Pajarito Plateau are generally at elevations lower than 2100 m (7000 ft). The mesas near White Rock and Pajarito Acres are covered with pinon and juniper. Table 2 provides an outline of the hierarchical classification for terrestrial woodlands (Muldavin 1994). Below we describe each element of the Woodland Classes identified in Los Alamos County.

Table 2: Hierarchical Classification of Woodland Class (Muldavin 1994).

I. Woodland
II. Cold Temperate Woodland
III. Rocky Mountain/Great Basin Lower Montane—Foothill Woodland
IV. Rocky Mountain/Great Basin Closed Conifer Woodland
Pinon pine (*Pinus edulis*)
IV. Rocky Mountain/Great Basin Open Conifer Woodland (Savannah)
One-seed Juniper (*Juniperus monosperma*)

I. Woodland Class

Woodlands are characterized by trees less than 10 m (33 ft) tall, usually forming moderately closed to very open canopies (less than 60% canopy cover). This class may include some closed-canopied woodland types (greater than 60% canopy cover), but the tree species are low in stature (pgymy conifers such as pinon pine). The class excludes open-canopied vegetation dominated by species that are generally considered tall statured (for example, ponderosa pine forest).

The woodlands of the Plateau are considered Cold Temperate Woodlands. In our area the Rocky Mountain/Great Basin Lower Montane woods are associated with the Rocky Mountain biogeographic province. These woodlands are generally dominated by moderately cold-tolerant, drought-tolerant, evergreen needle-leaved conifer species.

There are two cover type groups that can be found in the area: Rocky Mountain/Great Basin Closed Conifer woodlands and Rocky Mountain/Great Basin Open Conifer Woodlands (Savannah).

II. Cold Temperate Woodland

Woodlands of mid and upper elevations of mountainous regions dominated by cold to very cold winters and generally cool to mildly warm summers.

III. Rocky Mountain/Great Basin Lower Montane Foothill Woodland

These woodlands exist in lower elevations of mountainous and hill regions primarily associated with Rocky Mountain biogeographic provice, but with some important elements from the Great Basin province. These woodlands generally are dominated by moderately cold-tolerant and drought-tolerant evergreen needle-leaved conifer species.

IV. Rocky Mountain/Great Basin Closed Conifer Woodland Cover Type Group

These woodlands are dominated by rounded-crown, low-statured conifers that form moderately closed to moderately open canopies (>60% canopy cover). The major cover type is pinon pine. One-seed juniper is a common canopy associate. Oaks such as Gambel oak, wavyleaf oak (*Q. undulata),* and gray oak *(Q. grisea*), or other shrubs such as mountain mahogany (*Cercocarpus montana*) and big sagebrush (*Artemisia tridentata*) are common. Common grasses are blue grama.

V. Pinon-Juniper Woodland Cover Type

The Pinon-Juniper Woodland Cover Type comprises 3,553 ha (8,776 acres) of Los Alamos County. The lower elevations of the LANL are dominated by this cover type with a total 2704 ha (6,762 acres). Figure 7 is an example of the Pinon-Juniper Woodland Cover Type.

Within this cover type we have identified seven community type associations. They include

Pinus edulis-Juniperus monosperma/ Chrysothamnus nauseosus, Fallugia paradoxa,
Pinus edulis-Junipers monosperma/ Cercocarpus montana,
Pinus edulis-Juniperus monosperma/ Artemisia tridentata,
Pinus edulis-Juniperus monosperma/ Bouteloua gracilis,
Pinus edulis-Juniperus monosperma/ Muhlenbergia montanus
Pinus edulis-Juniperus monosperma/ S. scropulorum and
Pinus edulis-Juniperus monosperma/bare.

Figure 7. An example of the Pinon-Juniper Woodland Cover Type.

These woodlands were influenced primarily by grazing and homesteading activities until 1942 when they were purchased for the Manhattan Project. Since that time there has been no logging, little influence from fire, and only small areas urbanized.

IV. Rocky Mountain/Great Basin Open Conifer Woodland (Savanna) Cover Type Group

These woodlands are dominated by rounded-crown, low-statured conifers that form moderately oepn to very open canopies (25% to 50% canopy cover). This type group can include very open canopied stand (10% to 25%) in the broad ecotone to grassland commonly referred to as savanna. Major cover types are one-seed juniper. The undergrowth is predominantly grass and dominated by warm season grasses such as blue grama. Shrub species such as wavyleaf oak, snakeweed (*Gutierrezia sarothrae*), big sage, and rabbitbrush (*Chrysothamnus nauseosus*) are well represented.

V. Juniper Woodlands Cover Type

The Juniper Woodland Cover Type is dominated by one-seed juniper. In the draft map we have not pulled-out this cover type, although from experience we know it exists and is primarly at the lower elevations below the scarp of White Rock Canyon at elevations from 1620 m to 1950 m (5400 ft to 6500 ft). During the next iteration of the map, we expect to have pulled this cover type out, probably primarily from the grassland cover type.

From previous survey data and data collected by Barnes, we have identified the following community type associations:

Juniperus monosperma/basalt scarp
Juniperus monosperma/tuff scarp
Juniperus monosperma/Chrysothamnus nauseosus-Fallugia paradoxa
Juniperus monopserma/Quercus undulata
Juniperus monosperma/Artemisia tridentata
Juniperus monosperma/Bouteloua curtipendula
Juniperus monosperma/Bouteloua eriopoda
Juniperus monosperma/Bouteloua gracilis.

This cover type is often found in relatively undisturbed locations, along the slopes of White Rock Canyon. Interspersed within this type are springs that provide ribbons of riparian vegetation. Much of the area was used prehistorically and has an abundance of petroglyphs (Lilienthal and Hoard 1995).

The following trees and shrubs have been found in this community (Foxx and Tierney1984).

Trees and shrubs: Bigelow sage (*Artemisia bigelovii*),wormwood, sand sagebrush (*Artemisia filifolia*), fringed sagebrush (*A. frigida*), big sagbrush, fourwinged saltbush (*Atriplex canescens*), mountain mahogany, rabbitbrush, sticky rabbitbrush (*C. viscidiflorus*), green jointed-fir (*Ephedra viridis*), winterfat (*Eurotia lanata*), Apache plume (*Fallugia paradoxa*), cliff fendlerbush (*Fendlera rupicola*), wavyleaf oak, and skunkbush (*Rhus trilobata*), wax currant (*Ribes cereum*), New Mexico locust, wild rose.

Grasses and graminoids: A number of grass species have been identified from the slopes of White Rock Canyon including little bluestem, side-oats grama (*Bouteloua curtipendula*), black grama (*B. eriopoda*), blue grama, hairy grama (*B. hirsuta),* galleta (*Hilaria jamesii*), ring muhly (*Muhlenbergia torreyi*), false buffalo-grass (*Munroa squarrosa),* Indian rice-grass (*Oryzopsis hymenoides*), muttongrass (*Poa fendleriana),* inland bluegrass, spike dropseed (*Sporobolus contractus*), sand dropseed (S. *cryptandrus*), and needle-and-thread grass (*Stipa comata*).

Forbs: A variety of forbs have been identified including the plains blackfoot (*Melampodium leucanthum*), sego lily (*Calochortus nuttallii*), buffalo gourd (*Cucurbita foetidissima*), lark spur (*Delphinium virescens*), and Wright's verbena (*Verbena wrightii*).

Within the cover type there have been identified (Foxx and Tierney 1984) microhabitats, such as the talus-slopes, that support characteristic vegetation. This habitat is found in shallow sandy soils between piles of basalt rubble on steep slopes. The lip-fern (*Cheilanthus* sp.), cliff-brake fern (*Pellaea limitanea*), and the fringed sagebrush are common at the base of the cliffs. These rocky patches also support narrow leaf hoptree (*Ptelea trifoliata* subsp. *angustifolia*) and cliff fendlerbush (*Fendlera rupicola).* Within these talus slopes the *Oreohelix* spp. snail is found.

5.2.4.3 Hierarchical Classification of Shrubland Class.

The Shrubland Class was not well identified in the land cover map produced in FY96. Further accuracy assessments will be required to further define the large area we call grass/shrub/savannah.

Key I of the Working Draft Key (Appendix A) relates to the present information available on shrublands within the county.

In this section, we only describe the definitions of the shrubland and some of the elements of the shrublands, we believe occur on the Pajarito Plateau. Table 3 shows the hierarchical classification for shrubs developed by Muldavin for the State.

Table 3: Hierarchical Classification of Shrublands (Muldavin 1994).

I. Shrubland
II. Mesophytic Shrubland Sub-Class
III. Rocky Mountain Montane Shrub and Interior Chaparral Regional Biome
IV. Rocky Mountain Deciduous Scrub Cover Class Group
IV. Broadleaf Evergreen Interior Chaparral Cover Class Group
III. Plains-Mesa Sand Scrub Regional Biome
IV. Plains-Mesa Broadleaf Sand-Shrub Cover Type Group
II. Xerophytic Shrubland Regional Biome
III. Great Basin Desert Shrub
IV. Great Basin Microphyllous Desert Shrub Cover Class Group
IV. Great Basin Droadleaf Deciduous Desert Shrub Cover Class Group

I. Shrubland Class

Shrublands are dominated by shrubs 0.5 to 5 m (1.5 to15 ft) tall, forming canopies greater than 25%.

The shrublands within the area are within the Mesophytic or Xerophytic Shrublands subclasses. These shrublands are primarily dominated by moderately to very cold tolerant shrubs and moderately to very drought tolerant species including Gambel oak, mountain mahogany, and wavyleaf oak. Within the Mesophytic Shrubland subclass, the Rocky Mountain Montane Deciduous Scrub is the only cover type identified in this region. Xerophytic shrublands have two cover type groups applicable to the Plateau: The Great Basin Microphyllous Desert Shrub and the Great Basins Broadleaf Deciduous Desert Shrub.

II. Mesophytic Shrubland Sub-Class

We believe the Rocky Mountain Montane Deciduous Shrubs Cover Type groups are found in some of the burned areas and are primarly dominated by Gambel oak. More study will be required to better refine the cover type and/or inclusions of this type into the Ponderosa Pine and Pinon-Juniper Cover Types.

II. Xerophytic Shrubland Sub-Class

Xerophytic Shrublands are dominanted by very drought tolerant species. These species are generally found at lower elevations of the Plateau.

Xerophytic Shrublands are represented by Great Basin Desert Shrub Cover Type Group. Within that cover type group some Great Basin Microphyllous Desert Scrub cover types are found in the lower elevations near the community of White Rock and within White Rock Canyon. These shrubby areas are dominated by big sagebrush.

In general, shrublands within Los Alamos County and LANL are small and result from disturbance. In most cases they will be termed inclusions within the larger cover type (Pinon-Juniper or Juniper Woodlands). These shrubland inclusions may have resulted from disturbances such as fire, cultural and historic sites, and mechanical disturbances such as road building. Figure 8 shows a typical shrubland resulting from a wildfire.

We believe many of the shrubland types will be inclusions within the Forest or Woodland Cover Types. Additional study will be required to better define this class within the County.

5. 2. 4. 4 Hierarchical Classification of Grassland Class

Koch et al. (1996) found that the Grassland Class was not accurately identified from the satellite imagery. Additional field surveys are needed to better define the Cover and Community Types.

The information presently available has been incorporated into Key J of the Working Draft (Appendix A).

Figure 8. An example of typical shrubland resulting from a wildfire.

Table 4 shows the hiearchial classification for grasslands for the State of New Mexico (Muldavin 1994). Below we discuss elements of this grassland classification that appears to occur on the Pajarito Plateau. In FY97 we will further define the Grassland Class for the County of Los Alamos.

Table 4: Hiearchical Classification of Grasslands (Muldavin 1994).

I. Grassland
II. Mesophytic Grassland Subclass
III. Rocky Mountain Subalpine and Montane Grassland Regional Biome
IV. Rocky Mountain Subalpine Grassland
IV. Rocky Mountain Montane Grassland
III. Plains-Mesa-Foothill Grassland Regional Biome
IV. Short Grass Steppe Cover Class Group
IV. Mid-Grass Praire Cover Class Group
IV. Tall Grass Praire Cover Class Group
II. Xerophytic Grassland
III. Great Basin Desert Grassland Regional Biome
IV. Great Basin Foothill-Piedmont Grassland Cover Type Group
IV. Great Basin Lowland/Swale Grassland Cover Type Group

I. Grassland Class

Grasslands are dominated by herbaceous graminoid species. Shrubs comprise less than 25% canopy cover. Most of the grasslands of the Plateau are not grazed and are true to structural descriptions.

Grasslands of the Plateau and Sierra de Los Valles are in the Mesophytic Grassland Sub-Class. Mesophytic grasslands are dominated by cold tolerant and moderately drought-intolerant species. The grasslands are primarily found at high elevations, at the tops of the mountain tops and at low elevations within the pinon-juniper and juniper woodlands.

Those of the higher elevation are within the Rocky Mountain Subalpine Grasslands, Rocky Mountain Montane Grassland Formation. Those at lower elevations are within a Short Grass Steppe Formation.

IV. Rocky Mountain Subalpine Grassland cover Type Group

These high-elevation grasslands are dominated by dense stands of grasses, sedges and rushes, trees and shrubs are rare. This type of grassland is found primarily along the peaks of the Sierra de Los Valles. They are dominated by *Danthonia* spp. and various fescues and sedges.

This cover type was extensively studied by Allen (1989) and is called a Montane Grassland in his classification (Figure 9). It is confined to nine peaks of the Sierra de Los Valles, including Pajarito Mountain. These mountains are the sources of the watersheds extending on to LANL. The Subalpine Grasslands are found in a distinctive landscape pattern on the upper, south-facing slopes and their existence has been cited in local lore and references for several hundred years. He found that there has been extensive invasion of conifers, primarily ponderosa pine and Douglas fir. He attributes the invasion to fire suppression and the reduction of grasses by grazing of sheep in the late 19th and early 20th century.

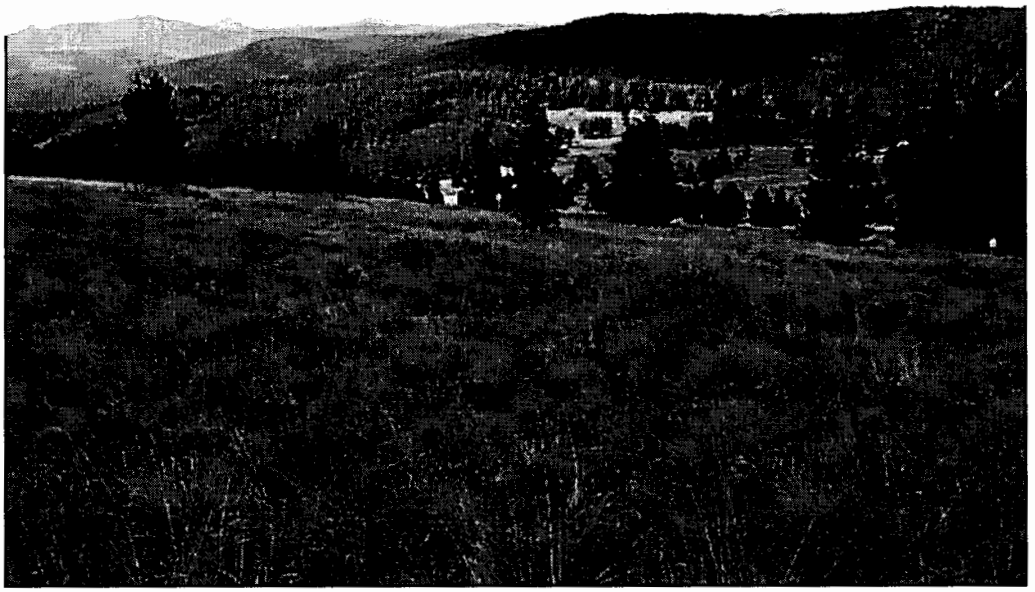


Figure 9. An example of Montane Grassland.

IV. Rocky Mountain Montane Grassland Cover Type Group

These are mid to high elevation grasslands dominated by dense stands of grasses, sedges, rushes, with few trees and shrubs. The major cover types include mountain muhly.

III. Plains-Mesa-Foothill Grassland Regional Biome

These grasslands are found on the mesas and lower slopes of the Sierra de Los Valles. The primary cover type is called a Short Grass Steppe.

IV. Short Grass Grassland cover Type Group

The short grass grasslands that occur at lower elevations will require additional field studies to determine community types. There are a variety of species that occur between 2400 m (8000 ft) and 1620 m (5400 ft). At upper elevations, associated with mixed conifer and ponderosa pine, mountain muhly, and pine dropseed are common. Little bluestem is scattered throughout. At lower elevations, within the Pinon-Juniper Woodland, blue grama is the dominant grass species.

Within these short grass grasslands, there are disburbance grasslands that have been created by extensive wildfires and restoration efforts. We have identified a sheep fescue *(Festuca ovina)* community type as a disturbance type resulting from reseeding after the La Mesa fire in 1977. This species is common in areas of high intensity crown fires that reduced the overstory canopy to zero

percent during the La Mesa fire (Foxx 1996). Within these fire disturbed areas species such as big bluestem have increased in abundance.

Another disturbance community type are old fields. These grasslands have developed in the abandoned and fallow fields of the early homesteaders (Foxx et al. 1996). They are primarily in the Ponderosa Pine Cover Type and are approximately 60 years fallow.

Considerable work and study must be done in the lower elevation grasslands to further determine if there are additional cover types and to determine the community type.

6.0 Conclusion and Discussion

To date we have tentatively identified the land cover types for Los Alamos County and LANL. We believe the classification for the forest and woodland types is more accurate and more representative of the area. However, further accuracy assessments must be done to better define the grassland and shrublands classes. A separate classification of riparian and wetland systems is necessary because of the narrowness of the canyons and lack of definition of spectral classes within the canyons for these systems. NMNHP is developing a classification for riparian areas that will be helpful in the classification of these canyon bottom systems (Muldavin personal communication).

Regardless of these limitations, this classification scheme will provide a consistent way of naming of the vegetation. Many TES and SOC occur within the Forest and Woodland Classes where we presently have the highest accuracy of classification. The land cover map, vegetation classification, and checklist of plants will enhance the use of the GIS and associated database for future Habitat Evaluation Procedures (HEP) and Eco-toxicological modeling.

In FY97, we will examine potential habitats for more defined characteristics such as downed woody components. The habitat definitions for species such as the Jemez Mountain Salamander and the Mexican spotted owl may include a downed woody component. Defining these characteristic will help identify actual and potential habitats.

7.0 Acknowledgements

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APPENDIX A
WORKING DRAFT

Key to Major Land Cover Types in the LANL Vicinity

These keys are to be used as guidance for the identification of major types of land cover at Los Alamos National Laboratory and the surrounding areas. They are designed for homogenous areas that are at least 0.405 hectares (1.0 acre) in total area or are significant linear features.

1. Building, farms, pavement, paved or dirt roads, utility corridors, or other engineered structures are present and dominant components of the landscape.

- Use Key A (Land Used for Human Purposes)

1. Man-made structures are absent. Landscape is in a seminatural state, intrusions by man are relatively minor.

- Go to 2

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2. Land is at least periodically flooded, supports facultative or obligate hydrophytic plant species, is characterized by hydric soils; *or* the vegetation composition is influenced by nearby water; *or* the effects of past flooding are evident.

- Use Key B (Wetlands and Riparian Zones)

2. The land is variable but not as above.

- Go to 3

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3. Land is covered by <7 percent vegetation *or* ≥20 percent rock or bare ground.

- Use Key C (Unvegetated Lands)

3. Land is covered by ≥7 percent vegetation *and* <20 percent rock or bare ground.

- Go to 4

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4. Land is vegetated by an open woodland. *Juniperus monosperma* is the only tree species present, or *Pinus edulis* may be present with <7 percent coverage.

- Use Key D (*Juniperus monosperma* Woodlands)

4. Vegetation structures are variable. Combinations of tree species are not as above.

- Go to 5

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5. Land is forested or wooded. Trees are ≥5 m (16 ft) tall with coverage ≥12 percent.

- Go to 6

5. Land is not forested or wooded. Vegetation otherwise.

- Go to 9

6. Dominant trees are *Pinus edulis* or *Juniperus monosperma*. Other tree species are <7 percent in combined coverage.

- Use Key E (*Pinus edulis-Juniperus monosperma* Woodlands)

6. Trees other than *Pinus edulis* or *Juniperus monosperma* are present with ≥7 percent combined coverage.

- Go to 7

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7. *Pinus ponderosa* is present with ≥7 percent coverage. *Pinus edulis* or *Juniperus monosperma* may be present, but other tree species are absent or are present with <7 percent coverage.

- Use Key F (*Pinus ponderosa* Forests)

7. Tree species other than *Pinus ponderosa*, *Pinus edulis*, or *Juniperus monosperma* are present with ≥7 percent cover.

- Go to 8

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8. *Pseudotsuga menziesii*, *Abies concolor*, or *Picea engelmannii* are present with ≥7 percent coverage. *Populus tremuloides* may be present or absent.

- Use Key G (Mixed Conifer Forests)

8. *Populus tremuloides* is present with ≥20 percent coverage. *Pseudotsuga menziesii*, *Abies concolor*, or *Picea engelmannii* are absent or present with <7 percent coverage.

- Use Key H (Aspen Forests)

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9. Shrub species with ≥12 percent cover are present.

- Use Key I (Shrublands)

9. Shrub species are absent *or* with <12 percent cover.

- Use Key J (Grasslands)

Key A: Land Used for Human Purposes. Buildings, farms, parking lots, paved or dirt roads, utility corridors, or other man-made structures are present and the dominant feature of the landscape. These features may essentially be linear in shape. Natural vegetational and geomorphic processes are secondary to man's activities.

1. Structure is a road or other transportation corridor, including road cuts and embankments.
   - Go to 2

1. Structure is not a road.
   - Go to 4

---

2. Road is paved.
   - Paved road

2. Road is not paved.
   - Go to 3

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3. Road is improved
   - Improved Road

3. Road is not improved or is abandoned.
   - Unimproved road

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4. Structure is a powerline, pipeline, or other utility.
   - Go to 5

4. Structure is not a utility supply system.
   - Go to 6

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5. Utility system is above the ground surface.
   - Exposed utility

5. Utility is beneath the ground surface. Land is cleared regularly.
   - Buried utility

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6. Landscape is a farm, an agricultural system, or a prehistoric settlement.
   - Go to 7

6. Landscape is urban or industrial. Not agricultural.
   - Go to 9

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7. Landscape is a prehistoric settlement.
   - Archaeological Site

7. Landscape is a farm or other agricultural systems.
   - Go to 8

8. Farm is active.

- Active Farm

8. Farm is inactive.

- Abandoned farm

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9. Land use is predominantly for industrial purposes, including LANL research facilities and other light industry.

- Go to 10

9. Land use is not predominantly industrial. Structures are for residential or commercial purposes.

- Go to 11

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10. Structure is a shallow water body with nonearthen walls.

- Waste pond

10. Structure is a building or other associated facility.

- Industrial facility

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11. Land use is predominantly for commercial purposes, including offices and restaurants.

- Commercial

11. Land use is predominantly for residential purpose.

- Residential

Key B: Wetlands and Riparian Zones. Land is at least periodically flooded, supports facultative or obligate hydrophytic plant species, is characterized by hydric soils; *or* the vegetation composition is influenced by nearby water; *or* the effects of past flooding are evident. These are marshes, lakes, rivers, streams, gallery forests, and other communities strongly influenced by the presence of water.

1. Land is vegetated with ≥30 percent cover.
   - Go to 2

1. Land is not vegetated or plant cover is <30 percent.
   - Go to 9

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2. Vegetation is dominated by *Acer negundo*, *Populus angustifolia*, *Populus fremontii*, or other riparian tree species.
   - Go to 3

2. Hydrophytic or riparian tree species are not present or present only as accidentals.
   - Go to 5

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3. Vegetation is dominated by *Populus angustifolia*.
   - POAN Riparian Forest

3. Vegetation is not dominated by *Populus angustifolia*.
   - Go to 4

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4. Vegetation is dominated by *Populus fremontii*.
   - POFR Riparian Forest

4. Vegetation is not dominated by *Populus fremontii*.
   - Other riparian forest

---

5. *Salix* spp., *Tamarix* spp., *Alnus tenuifolia*, or other obligate or facultative hydrophyte shrub species are present with ≥30 percent cover.
   - Go to 6

5. Obligate or facultative hydrophyte shrub species are absent or present with <30 percent cover. *Carex* spp., *Typha* spp., *Scirpus* spp., or other obligate or facultative hydrophyte species are present with ≥30 percent cover.
   - Go to 8

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6. Vegetation is dominated by *Salix* spp.
   - Willow Wetland

6. Vegetation is various, but not dominated by *Salix* spp.
   - Go to 7

7. Vegetation dominated by *Tamarix* spp.

- Tamarisk Wetland

7. Vegetation is various, but not dominated by *Tamarix* spp.

- Shrub Wetland

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8. Vegetation is dominated by *Typha* spp.

- Cattail Meadow

8. Vegetation is dominated by *Carex* spp., *Scirpus* spp., or other species.

- Rush/Sedge Meadow

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9. Area is <75 percent stones, boulders or bedrock *and* is exposed for ≥50 percent of the year.

- Sandbars/mudflats

9. Substrate is various, but the land is covered by water >50 percent of the year.

- Go to 10

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10. Water is contained in a channel and flows, at least slowly.

- Go to 11

10. Water is not contained in a channel, and is standing or flows very slowly.

- Go to 13

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11. Water is relatively fast flowing over a high gradient. The substrate consists of rock, cobbles, or gravel with some patches of sand.

- Go to 12

11. Water is relatively slow moving over a low gradient. The substrate is mainly sand and mud.

- River

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12. The channel contains flowing water throughout the year.

- Permanent stream

12. The channel contains flowing water for only part of the year.

- Intermittent stream

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13. Water body is ≥2 m (6.6 ft) deep, *or* ≥8 ha (20 acres) in area.

- Lake

13. Water body is not as above.

- Go to 14

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14. Substrate is sand, mud, gravel, or other natural material. Shoreline was not created or enhanced by man.

- Natural pond

14. Ultimate substrate is either a natural or synthetic material that was emplaced or improved by man. Shoreline was created or enhanced by man.

- Impoundment

Key C: Unvegetated Land. The land is covered by <7 percent vegetation *or* • 20 percent rock, bare ground, or open water. The land is not developed for industrial, urban, agricultural, residential, or other cultural purposes.

1. Slopes are ≥70 percent.
   - Go to 2

1. Slopes are <70 percent.
   - Go to 3

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2. Substrate is a volcanic tuff.
   - Tuffaceous cliff

2. Substrate is a basalt.
   - Basalt cliff

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3. Rocky substrate is relatively continuous rock.
   - Go to 4

3. Rocky substrate is cobbly or bouldery *or* soils may be present.
   - Go to 5

4, Substrate is a volcanic tuff.
   - Tuffaceous outcrop

4. Substrate is a basalt.
   - Basalt outcrop

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5. Land is above 2400 m (8000 ft) in elevation. Bouldery and cobbly outcrop is on a hillslope.
   - Felsenmeer

5. Land is below 2400 m (8000 ft) in elevation.
   - Go to 6

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6. Out crop is on a lower-slope position.
   - Go to 7

6. Position is various. Soils or nonsoils may be present.
   - Unvegetated disturbed

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7. Substrate is a volcanic tuff.
   - Tuffaceous talus

7. Substrate is a basalt.
   - Basalt talus

Key D: *Juniperus monosperma* Woodlands. The landscape is a seminatural, open or closed woodland. The dominant tree species is *Juniperus monosperma*. Other tree species are <7 percent in combined coverage.

1. Slopes ≥15 percent and boulders or rock outcrop 20 percent.
   - Go to 2

1. Slopes and ground surface are otherwise.
   - Go to 3

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2. Rock outcrops are predominantly basalt.
   - JUMO basalt scarp

2. Rock outcrops are tuffaceous or other than basalt.
   - JUMO tuff scarp

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3. Shrub species with ≥7 percent cover are present.
   - Go to 4

3. Shrub species are absent *or* with <7 percent cover.
   - Go to 6

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4. Arroyos with *Chrysothamnus nauseosus* or *Fallugia paradoxa* present with ≥7 percent combined cover.
   - JUMO/CHNA-FAPA

4. *Chrysothamnus nauseosus* or *Fallugia paradoxa* absent or with <7 percent combined cover.
   - Go to 5

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5. *Quercus undalata* ≥7 percent cover. *Artemisia tridentata* may or may not be present.
   - JUMO/QUUN

5. *Quercus undalata* <7 percent cover. *Artemisia tridentata* ≥7 percent cover.
   - JUMO/ARTR

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6. *Bouteloua curtipendula* ≥7 percent cover.
   - JUMO/BOCU

6. *Bouteloua curtipendula* absent or present with <7 percent cover.
   - Go to 7

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7. *Bouteloua eriopoda* ≥7 percent cover. *Bouteloua gracilis* may or may not be present.
   - JUMO/BOER

7. *Bouteloua eriopoda* is absent or with <7 percent cover. *Bouteloua gracilis* is present with ≥7 percent cover.
   - JUMO/BOGR

Key E: *Pinus edulis-Juniperus monosperma* Woodlands. The landscape is a seminatural, open or closed woodland. The dominant tree species are *Juniperus monosperma* and *Pinus edulis*. Other tree species are <7 percent in combined coverage.

1. Slopes are ≥15 percent and boulders or rock outcrops are ≥20 percent.
   - Go to 2

1. Slopes and ground surface otherwise.
   - Go to 3

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2. Rock outcrops are predominantly basalt.
   - PIED-JUMO basalt scarp

2. Rock outcrops are tuffaceous or other than basalt.
   - PIED-JUMO tuff scarp

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3. Shrub species with ≥7 percent cover are present.
   - Go to 4

3. Shrub species are absent *or* with <7 percent cover.
   - Go to 8

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4. Oaks are present with ≥7 percent cover.
   - Go to 5

4. Oaks are absent or with <7 percent cover.
   - Go to 6

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5. *Quercus undulata* is the dominant oak species.
   - PIED-JUMO/QUUN

5. *Quercus gambelii* is the dominant oak species
   - PIED-JUMO/QUGA

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6. Arroyos with *Chrysothamnus nauseosus* or *Fallugia paradoxa* are present with ≥7 percent combined cover.
   - PIEN-JUMO/CHNA-FAPA

6. *Chrysothamnus nauseosus* or *Fallugia paradoxa* are absent or with <7 percent combined cover.
   - Go to 7

7. *Cercocarpus montana* is present with ≥7 percent cover. *Artemisia tridentata* may or may not be present.

- PIEN-JUMO/CEMO

7. *Cercocarpus montana* is absent or with <7 percent cover. *Artemisia tridentata* is ≥7 percent cover.

- PIEN-JUMO/ARTR

8. *Bouteloua gracilis* is ≥7 percent cover.

- PIED-JUMO/BOGR

8. *Bouteloua gracilis* is <7 percent cover.

- Go to 9

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9. *Muhlenbergia montana* is present with ≥7 percent cover.

- PIED-JUMO/MUMO

9. *Muhlenbergia montana* is absent or present with <7 percent cover.

- Go to 10

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10. *Schizachyrium scoparium* is present with ≥7 percent cover.

- PIED-JUMO/SCSC

10. *Schizachyrium scoparium* is absent or present with <7 percent cover. Large amounts of bare soil are present.

- PIED-JUMO/bare

Key F: *Pinus ponderosa* Forests. The landscape is a seminatural forest. *Pinus ponderosa* is the dominant tree species, being present with cover ≥7 percent. *Juniperus monosperma* and *Pinus edulis* may also be present, but other tree species are absent, occur as accidentals, or are <7 percent in cover.

1. Shrub species, primarily oaks, with ≥7 percent cover are present.

- Go to 2

1. Shrub species are absent *or* with <7 percent cover.

- Go to 3

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2. *Quercus undalata* is the dominant oak species.

- PIPO/QUUN

2. *Quercus gambelii* is the dominant oak species.

- PIPO/QUGA

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3. *Blepharoneuron tricholepis* is present with ≥7 percent cover.

- PIPO/BLTR

3. Vegetation composition is various, but *Blepharoneuron tricholepis* is absent or present with <7 percent cover.

- Go to 4

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4. *Bouteloua gracilis* is present with ≥7 percent cover.

- PIPO/BOGR

4. *Bouteloua gracilis* is absent or present with <7 percent cover.

- Go to 5

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5. *Muhlenbergia montana* is present with ≥7 percent cover.

- PIPO/MUMO

5. *Muhlenbergia montana* may or may not be present. Combined cover of all understory plant species is <7 percent.

- PIPO forest

Key G: Mixed Conifer Forests. The landscape is a seminatural forest. Trees ≥5 m (16 ft) tall with coverage >12 percent are present. Tree species other than *Pinus ponderosa*, *Pinus edulis*, or *Juniperus monosperma* are present with ≥7 percent cover. *Populus tremuloides* may be present or absent.

1. *Pseudotsuga menziesii* is present with ≥7 percent cover and reproducing successfully. *Abies concolor* or *Picea engelmannii* are absent or present as accidentals.

- Go to 2

1. *Pseudotsuga menziesii* is absent or present with <7 percent cover. *Abies concolor* or *Picea engelmannii* are present with ≥7 percent cover or are reproducing successfully.

- Go to 4.

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2. *Populus tremuloides* is present with ≥12 percent cover. *Quercus* spp. are absent or present with <7 percent cover.

- PSME-POTR

2. *Populus tremuloides* is absent or present with <12 percent cover. *Quercus* spp. are present with ≥7 percent cover.

- Go to 3

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3. *Quercus gambelii* is present with ≥7 percent cover. *Muhlenbergia montana* may or may not be present.

- PSME/QUGA

3. *Quercus gambelii* is absent or present with <7 percent cover. *Muhlenbergia montana* is present with ≥7 percent cover.

- PSME/MUMO

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4. *Picea engelmannii* is present with ≥7 percent cover and reproducing successfully. *Abies concolor* is absent or present with <7 percent cover.

- Go to 5

4. *Abies concolor* is present with ≥7 percent cover or reproducing successfully. *Picea engelmannii* is absent or accidental.

- Go to 6

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5. *Populus tremuloides* is present with ≥12 percent cover.

- PIEN-POTR

5. *Populus tremuloides* is absent or present with <12 percent cover. Composition of the understory is variable.

- PIEN forest

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6. *Populus tremuloides* is present with ≥12 percent cover.

- ABCO-POTR

6. *Populus tremuloides* is absent or present with <12 percent cover.

- Go to 7

7. *Robinia neomexicana* is present with ≥7 percent cover.

- ABCO/RONE

7. *Robinia neomexicana* is absent or present with <7 percent cover.

- Go to 8

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8. *Quercus gambelii* is present with ≥7 percent cover.

- ABCO/QUGA

8. *Quercus gambelii* is absent or percent with <7 percent cover. Composition of the understory is variable.

- ABCO forest

Key H: Aspen Forests. The landscape is a seminatural forest. Trees are ≥5 m (16 ft) tall with coverage ≥12 percent are present. *Populus tremuloides* is present with ≥20 percent coverage. *Pseudotsuga menziesii*, *Abies concolor*, or *Picea engelmannii* are absent or present with <7 percent coverage.

1. *Athyrium filix-femina* is present with ≥7 percent cover.

- POTR/ATFI

1. *Athyrium filix-femina* is absent or present with <7 percent cover.

- Go to 2

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2. *Bromus marginatus* is present with ≥7 percent cover. *Bromus ciliatus* is absent or present with <7 percent cover.

- POTR/BRMA

2. *Bromus ciliatus* is present with ≥7 percent cover. *Bromus marginatus* is absent or present with <7 percent cover.

- POTR/BRCI

Key I: Shrublands: Shrub species with ≥12 percent cover are present. Tree species are absent or not present to ≥5 m (16 ft) tall with coverage ≥12 percent. The land is not developed for industrial, urban, agricultural, residential, or other cultural purposes.

1. *Quercus gambelii* is present with ≥7 percent cover.

- QUGA/BLTR

1. *Quercus gambelii* is absent or present with <7 percent cover.

- Go to 2

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2. *Atriplex canescens* is present with ≥7 percent cover.

- ATCA

2. *Atriplex canescens* is absent or present with <7 percent cover.

- Go to 3

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3. *Chrysothamnus nauseosus* is present with ≥7 percent cover.

- CHNA

3. *Chrysothamnus nauseosus* is absent or present with <7 percent cover.

- Go to 4

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4. *Artemisia tridentata* is present with ≥7 percent cover. *Robinia neomexicana* is absent or present with <7 percent cover.

- ARTR

4. *Artemisia tridentata* may or may not be present. *Robinia neomexicana* is absent or present with ≥7 cover.

- RONE

Key J: Grasslands: Shrub species are not present with ≥12 percent cover. Tree species are absent or not present to ≥5 m (16 ft) tall with coverage ≥12 percent. The land is not developed for industrial, urban, agricultural, residential, or other cultural purposes.

1. *Muhlenbergia montana* is present with ≥7 percent cover.

- MUMO

1. *Muhlenbergia montana* is absent or present with <7 percent cover.

- Go to 2

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2. *Bouteloua gracilis* is present with ≥7 percent cover.

- BOGR

2. *Bouteloua gracilis* is absent or present with <7 percent cover.

- Go to 3

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3. Grass species, such as *Danthonia intermedia*, are present with ≥7 percent cover. Elevations are above 2400 m (8000 ft).

- Montane Grassland

3. Grass species, such as *Danthonia intermedia*, are absent or present with <7 percent cover. Elevations are below 2400 m (8000 ft).

- Go to 4

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4. *Festuca ovina* is present with ≥7 percent cover.

- FEOV

4. *Festuca ovina* is absent or present with <7 percent cover.

- Go to 5

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5. *Schizachyrium scoparium* is present with ≥7 percent cover.

- SCSC

5. *Schizachyrium scoparium* is absent or present with <7 percent cover.

- Go to 6

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6. *Agropyron smithii* is present with ≥7 percent cover.

- AGSM

6. *Agropyron smithii* is absent or present with <7 percent cover. Species compositions are various.

- Disturbed grassland