Valles Caldera National Preserve

Existing Rangeland Condition Report

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for:
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Summary

This report compliments and synthesizes earlier assessments of existing conditions within the Preserve and serves as the baseline for future analyses. The primary sections are: Existing Rangeland Conditions, Lands Potentially Suitable for Livestock and Elk, and Grazing Capacity for Livestock and Elk. Data were compiled and a spatial analysis conducted by a five-person team with skills in GIS, range, botany, soils, and hydrology (see List of Preparers, page 48).

Existing Rangeland Conditions

All forest and grasslands in the Valles Caldera National Preserve were considered in this assessment and a condition rating was applied to sub-basins within the USGS 6th Hydrologic Unit Code (HUC) watersheds. The current analysis found watershed conditions to be stable or improving with the majority of sub-basins receiving a condition rating of medium from a scale of low to high. Four sub-basins encompassing Redondo Creek within the Sulphur Creek Watershed received an overall rating of high. The headwaters of San Antonio Creek are improving, with several stream sections properly functioning. All sub-basins but Rito de los Indios received an overall rating of medium based on the biotic and abiotic upland indicators. This is likely due to the extensive amount of old logging roads within the sub-basins.

Rangelands were thought to be in good condition when the Preserve was established in 2000. However, past activities such as extensive road building, timber harvest, and grazing continue to impact the area. Grazing impacts from livestock have been greatly reduced, but extensive roads continue to impact current water yields by intersecting water off slopes and channeling to main waterways. Sediment in the East Fork Jemez River and San Antonio Creek is still high from road-related impacts and where bank vegetation has yet to grow back. Bank stability is still affected by livestock and elk; however, current monitoring of streams show vegetation is being restored and stream banks are healing, resulting in an increase in stream reaches in proper functioning condition. Bank re-vegetation may be limited on less fertile upland soils and where (non-native) upland vegetation such as Kentucky bluegrass has increased. Watershed-related road impacts are steadily being remedied by culvert replacements, route closures, and decommissioning of old roads.

Lands Potentially Suitable for Livestock and Elk

For the purpose of this analysis, gently sloped areas close to water and producing greater than 250 pounds of forage per acre were considered suitable for sustained use in support of grazing by elk or domestic livestock. While it is recognized that animals will graze on land with a lower production value, these areas will not be used to assign use or determine capacity.

Based on these criteria, approximately 31 percent of the Preserve was found suitable for sustained grazing by domestic livestock, similar to the level identified under the interim grazing program. Elk tend to to require the same proximity to water as domestic livestock. They use forage from steeper slopes and probably better use the grassland inclusions interspersed through out the forest. Steeper slopes supported very little area with adequate forage and proximity to water to support the elk. In fact, the analysis found an almost complete overlap in area suitable for supporting the Preserves elk herd and suitable for sustaining a domestic livestock program. Vegetation management in forested areas may increase forage production but such gains will not be considered significant across the Preserve. Only an estimated 10 percent of forested acres, primarily in the ponderosa pine type, possess the potential to meet or exceed production levels considered suitable for grazing.

Grazing Capacity for Livestock and Elk

Carrying capacity was estimated both by analysis of actual monitoring and livestock use data from the interim grazing program, and by modeling forage production during a typical year. During a typical precipitation year, the grazing of 9,470 to 11,270 animal unit months (AUMs) in combination with herding achieved the goal of staying below 40 percent utilization when averaged over a 4-year period. When analyzed by year, use for all areas during a typical year (with 14 inches of precipitation) was between 30 and 40 percent, except in riparian areas where use slightly exceeded 40 percent. Modeling of forage production provided a similar capacity in support of the capacity estimate based on monitoring.

Capacity is severely reduced during dry years; and the current number of elk may exceed capacity when they remain on the Preserve all year. During years with abundant rainfall the amount of forage will not limit capacity of either elk or livestock.

Capacity was also estimated using a modeling technique that measured the amount of forage produced. While this the technique is considered to be less accurate than actual grazing use monitoring it resulted in estimates close to actual measurements. The model would be a reasonable tool to use when actual data is not available.

Herding was shown to be effective to achieve desired utilization levels and reduce undesirable effects to sensitive resources. The Preserve monitoring indicates utilization from the interim grazing program has achieved greater capacity than traditional rest rotation or rest deferred grazing systems that rely on fences to achieve distribution.

Background

The Preserve has been well-studied: Key information is contained in the Framework and Strategic Guidance document (Framework) developed for the Preserve (Valles Caldera Trust 2003). A bibliography pertinent to the Preserve is contained within the Framework document and also on the Valles Caldera Coalition website (http://www.vallescalderacoalition.org/VCC-Bibliography.htm). Publications and geographical informational systems (GIS) data used for this report are the vegetation survey, mapping, and preliminary ecological assessment of the Preserve by Muldavin and Tonne (2003); utilization data collected by the Trust and the Jornada Experimental Station; botanical monitoring by Barnes (2002 to 2005); Terrestrial Ecosystem Soil survey (USDA Forest Service 2000 and 2006); and a riparian assessment done by the National Riparian Service Team (2002) and Steve McWilliams (2006).

This analysis utilized a wealth of information from various sources. To better use the data now and in future analyses, three databases (to be kept by the Trust) were created. The metadata description is included in Appendix B. The databases are:

- Forage production database containing 12 tables compiling vegetation monitoring data from Barnes (2001 through 2005); plant associations from Muldavin and Tonne (2003); range monitoring data collected by the Trust and Jornada Experimental Range; Natural Resources Conservation Service (NRCS) ecological site production data; Terrestrial Ecosystem Survey (TES) data; and other data.
- Interim TES mapping data extended from Santa Fe National Forest TES mapping (USDA Forest Service [1993] and McWilliams [2000b]).

Climate

The climate is typical for high elevation forests and montane grasslands in northern New Mexico with most precipitation occurring in summer. Winter precipitation is mostly snow. Climate is modified by elevation and topography. Muldavin and Tonne (2003) provide more detail on climate. There are four grassland weather stations on the Preserve. Data from 2004 to 2006 was analyzed in the 2006 range readiness analysis conducted by the Valles Caldera Trust (Trust) (2006). Data show a fluctuation of dry versus wet years recently.

Vegetation

Sixty-five plant associations within 20 mapping units have been described within the Preserve. These plant associations are within the major forest and grassland types of the Preserve, which include high elevation sub-alpine forests, mixed conifer forests, open foothill pine woodlands, high montane grasslands, and valley floor wetlands. This assemblage of plant communities makes the Preserve one the most diverse sites in the southern Rocky Mountains. A non-technical description of the vegetative communities found on the Preserve can be found in the Framework (Valles Caldera Trust 2003); a technical assessment can be found in Muldavin and Tonne (2006). See Appendix A for a summarized caption of the vegetation groups along with existing soils information.

Soil Resources

There are about 20 soil series within 19 soil mapping units that have been mapped for the Preserve by the NRCS. A general overview for soils can be found in Muldavin and Tonne (2003) and also in the interim grazing environmental assessment (Valles Caldera Trust 2002). See Appendix A for an overview of current soils information.

On the surrounding Santa Fe NF, soils were inventoried in 1989 as ecological units in the Santa Fe NF Terrestrial Ecosystem Survey (TES). This survey considers soil genesis in an ecological context and combines the biotic (e.g., vegetation, animals) and abiotic (e.g., rocks, weather, atmosphere) aspects of soils using climate and vegetation to form an ecological unit. These ecological units were extended from the Santa Fe NF into the Valles Caldera National Preserve by the Santa Fe NF Soil Scientist Steve McWilliams (USDA Forest Service 2000). A GIS coverage was developed to depict the soil resource consistent with the surrounding survey. Land management capability class, soil limitations, and interpretations used in the TES were applied to the Preserve (Valles Caldera Trust 2002).

Methods for Determining Condition

In this report “condition” is the term used to reflect ecological health functions associated with land health. The ecological function of the range was evaluated using health indicators derived from site data and inventory. Ecologic function was considered at two scales: site-specific ground data and evaluation at the sub-basin watershed level. Sites were evaluated using procedures to interpret rangeland health indicators similar to the protocol presented in “Interpreting Indicators of Rangeland Health – Version 4” (Pellant et al. 2005). These procedures generally assess how well ecological processes on a site are functioning, and include the abiotic (soil/site stability and hydrologic function) and biotic (biotic integrity) attributes.

The first step for the rangeland health protocol determines the soil and ecological sites represented. The New Mexico NRCS has conducted an ecological site inventory for the various

soils and habitats of New Mexico. These descriptions are available in their Field Office Technical Guide (http://www.nm.nrcs.usda.gov/technical/fotg/section-2/esd.html). Based on the existing soil surveys, the following four ecological sites representing the various soils and conditions found on the Preserve are:

- Site ID: R048BY007NM; Site Name: Mountain Valley
- Site ID: R048BY005NM; Site Name: Mountain Meadow
- Site ID: R048BY002NM; Site Name: Pine Grassland
- Site ID: R048BY001NM; Site Name: Mountain Breaks

The Subalpine Grassland ecological site (R048BY003NM) criteria was used in the past, but the current survey shows that Pine Grassland and Mountain Breaks ecological site descriptions better described the woodland vegetative types (e.g., spruce-fir, mixed conifer, ponderosa pine, etc.).

Pellant et al. (2005) listed 17 qualitative indicators such as rills, water flow patterns, pedestals, and bare ground. Although intensive ground surveys were not conducted, 3 key quantitative assessment indicators were assessed from 672 locatable plots. These plots were collected by Muldavin and Tonne (2003) for vegetation mapping, Barnes (2001-2005) for range monitoring, and USDA Forest Service (2000 and 2006) for TES[1]. Indicators obtained from past surveys were compared to the ecological site descriptions prepared by NRCS (Table 1).

Table 1. Ecological site descriptions for three key variables (in percent)

Ecological Site	Bare Soil	Litter	Grass and Forb
Mountain Meadow	5	30	65
Mountain Valley	22	35	37
Pine Grassland	32	25	33
Mountain Breaks	33	17	27

A rating of 1 to 3, with 1 the lowest and 3 the highest health rating value, was derived for both "abiotic" (site stability and hydrologic function as indicated by the amount of bare soil and plant litter) and "biotic" (biotic integrity as indicated by the amount of ground cover provided by grass and forb species). If percent plant cover reflected or exceeded ecological site description values then a score of 3 was awarded for the biotic category. If litter cover met ecological site description values and bare soil met ecological site description values without exceeding by more than 10 percent, then a score of 3 was awarded[2]. Scores of 2 and 1 were awarded for biotic and abiotic components based both on level of departure from norms and on professional judgment[3].

[1]Terrestrial ecosystem survey (TES) consists of the systematic analysis, classification, and mapping of terrestrial ecosystems. This integrated survey is hierarchical with respect to classification levels and mapping intensities. A terrestrial ecosystem is an integrated representation of the ecological relationship between climate, soil and vegetation.

[2] Even if the plot appeared to meet standards, professional judgment may have given lower scores on selected points.

[3] For instance, a 2 may have been awarded for abiotic if bare soil met standard, but litter did not; however, if litter met standard and bare soil did not then it is more likely that the abiotic component would have received a 1 because percent bare soil was determined to be a more critical attribute.

Both abiotic and biotic ratings were combined into an overall rating[4] for each of the 633 sampling points (Table 2). Note that this process largely relied on professional opinion and judgment though a systematic decision making process was used to assign condition ranks. Final ranks were assigned based on all available site information including litter, bare soil, grass versus forb cover, native plant cover versus non-native plant cover, etc. A specific datum may have swayed the ranks from a 1 to a 2 or a 2 to a 3, or from low to medium or medium to high. Each point and associated site information were evaluated individually during the initial assignment of ranks; follow-up site visits in May 2006 were made to ground truth data and check assumptions. In the majority of cases, the judgments made remotely with database information matched or came close to the existing condition on the ground.

Table 2. Summarized abiotic and biotic ratings and totals

Abiotic Rating	Biotic Rating	Overall Rating for the Point
1	1	Low
2	1	Low
3	1	Low
1	2	Low
2	2	Med
3	2	Med
1	3	Low
2	3	Med
3	3	High

To assess the current condition at the watershed level, the Preserve was divided into sub-basins using ESRI ArcHydro (Map 1). These sub-basins are close to the USGS 7th order HUC watersheds, and ranged from 1,600 to 12,000 acres. The finer sub-basin level was used to better stratify the current conditions and lessen the dilution of data. The upland site-specific data was used in addition to the proper functioning condition (PFC) assessments[5] collected for perennial stream reaches by the Santa Fe NF (USDA Forest Service 2004) and New Mexico Cadre of the Creeks and Community Strategy (McWilliams 2006), stream invertebrate studies by Vieira et al. (2004), and ongoing stream work done by the Trust. The National Riparian Service Team (2001) verified the stream condition (PFC) findings by the Santa Fe NF.

The ratings for each upland point (upland rating) and PFC assessments for various segments of perennial streams (riparian rating) were aggregated to determine an overall rating for each of the 28 watersheds that were created during this analysis by further refining the 12-digit HUC[6] (6th order) watersheds into smaller sub-basins or watersheds within the Preserve as follows:

[4] In most instances a score of 1 in either category made the total rating low; however, site-specific factors may have influenced some decisions resulting in different scores (for instance, a site that received a 1 for abiotic and a 3 for biotic might have gotten a total rank of medium because the integrity of the native plant community was intact to a large degree.
[5] There are several guides to the PFC protocol, one of the most recent is Stacey et al. (2006).
[6] Watersheds are mapped using HUCs, as defined by the USGS.

Upland Rating

- If 70 percent or more of sampled upland points within a sub-basin received a high rating, the upland rating for that sub-basin received a high rank.
- If less than 70 percent of sampled upland points received a high rating, but the majority of sampled points were above the rank of low, the upland rating for the sub-basin was determined to be medium.
- To receive a low upland rating, the majority of sampled upland points within a sub-basin had to receive a low rank (there were no areas that met this standard).

Riparian Rating

- If PFC rank within a sub-basin equaled a rating of properly functioning then riparian rating was high.
- If PFC rank within a sub-basin was in a proper functional condition/functioning at risk, proper functioning condition/non-functioning, functioning at risk, or functioning at risk/non-functioning, then the riparian rating was medium.
- If PFC rank within a sub-basin was non-functional, then the riparian rating was low (no sub-basins met this standard).

Overall Watershed Sub-basin Rating

- If upland and riparian ratings were both high, then the watershed sub-basin rating was determined to be high. If the upland rating was high, but no information was available for the riparian rating, then the watershed sub-basin rating was determined to be high based on the existing information.
- If upland and riparian ratings formed some combination of high/medium, high/low, medium/medium, or medium/low, then the watershed sub-basin rating was determined to be medium. If the upland rating was medium, but no information was available for the riparian rating, then the watershed sub-basin rating was determined to be medium based on the existing information.
- If both upland and riparian ratings were low then the watershed sub-basin rating would be determined to be low (no sub-basins met this criteria).

Rangeland Condition

Preserve-wide Rangeland Assessment

Previous Assessments

Past road building and timber harvest activities are very evident in these watersheds. Extensive roads continue to impact current water yields by intersecting water off slopes and channeling to main waterways (McWilliams 2000a; NRST 2002), and depositing large amounts of sediment within the Jemez and San Antonio streams (McWilliams 2000a; USDA Forest Service 2002b; USDA Forest Service 2002a; USDA Forest Service 2003). Livestock and elk grazing have negatively impacted bank stability (NRST 2002). Monitoring during the Trust ownership shows width-to-depth ratios may be improving as cutbanks revegetate (NRST 2002; USDA Forest

Service 2003). Also, the Preserve is replacing culverts, closing routes, and decommissioning old roads to decrease road-related impacts to watersheds.

In their 2001 assessment of the Preserve, the National Riparian Service Team (NRST) identified a number of issues on the Preserve stemming from over 100 years of cumulative influences. Their inspection revealed that a combination of factors was altering the character of the landscape. Upland forests had not only become dense with stands of decadent multi-aged conifers, but the conifers were expanding their range into historical montane grasslands and rapidly converting historic stands of quaking aspen. The NRST suggested that conifer encroachment reduced available water from 0.2 to 0.5 acre-feet per acre, based on observations of Bartos and Campbell (1998) for Utah aspen stands. These reductions in water may have been overestimated, because available water storage on the Preserve is largely influenced by the very porous volcanic geology in the uplands along with extremely high road densities that intercept and channelize subsurface and overland flows (McWilliams 2000a; Muldalvin and Tonne 2003). Though conifer species have increased differences in transpiration over broadleaf species, the net effect of conifer encroachment may be very small compared to the impact of the large road densities (Trombulak and Frissel 2000). Also, hydrologic increases from conifer species may be balanced by the decreases in evaporation moderated by tree shading and higher amounts of duff.

As described in the NRST findings, most riparian segments were maintaining a functional-at-risk rating with an upward health trend, but T-Walk assessment found some stream segments impaired (Valles Caldera Trust 2002). Populations of rainbow and/or brown trout and other species of fish were reproducing in all the major perennial waters across the Preserve (USDA Forest Service 2002a). The NRST found that past grazing and logging operations contribute significantly to the state of the Preserve’s resources; but they also noted that some current uses were impacting resources. Road conditions were slowing or reversing an improving riparian health trend. While no livestock grazing was occurring at the time of their assessment, use by elk was retarding the recovery of riparian areas. Inadequate surface drainage, ditches, stream crossings, stream channel impacts, and increased drainage density were all attributed to the Preserve’s transportation system (NRST 2002).

A riparian assessment was conducted by the Santa Fe NF in 2000 that provided documentation of the structure and function of the riparian/wetland areas. This assessment indicated that past activities had and were impacting watershed conditions (McWilliams 2000). The Valles Caldera Trust requested the New Mexico Cadre of the Creeks and Community Strategy for a reassessment in 2006 using the same protocols that were used in 2000. There were noticeable improvements in riparian structure and function due to changes in vegetation because of increased bank wetting. Several stream segments moved from non-functioning or functioning at risk to a properly functioning condition (McWilliams 2006).

In 2001 Havstad (2002) conducted an ecological rangeland assessment of the Preserve based on a protocol described in “Interpreting Indicators of Rangeland Health” (Pellant et al. 2005). The report stated that much of the rangeland areas on the ranch were classified by the NRCS in good condition in the early 1980s. Many of these areas are stable or have improved over the past 18 years. Sites that have either not improved from fair condition in the 1980s, or maybe even deteriorated since then are the grasslands in the Jaramillo Pasture (Valle Jaramillo located in upper section of the Cerro Pino and Valle Jaramillo sub-basins [see Map 1]) and the terraces on the south end of the Rincon Pasture (upper section of the Headwaters East Fork Jemez River sub-watershed [see Map 1]). These are examples of areas heavily used by large grazing animals throughout the grazing season because of their location (Havstad 2002).

Havstad summarized his assessment based on three broad vegetation categories: mountain meadows (wetland meadows), mountain valleys (upland grasslands), and grazeable woodlands. The assessment was based on 26 monitoring plots and field visits. Havstad found that all of the sites were either as expected or slightly departing from expected, except the Jaramillo pasture and the south end of the Rincon Pasture which departed greatly.

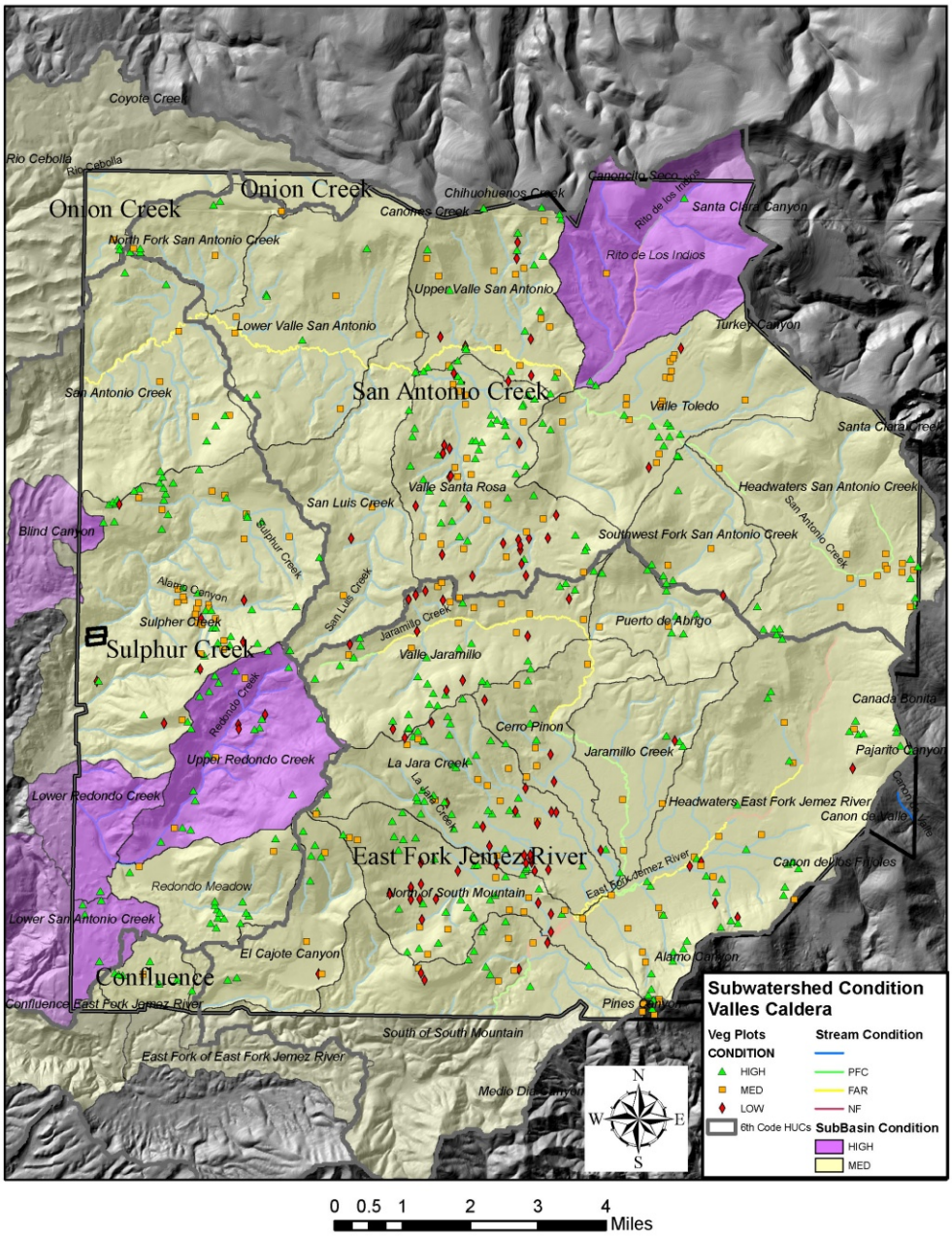
Current Assessment

The quality of water in streams and rivers is an indicator of the health of the watershed and the ecosystem. Therefore it is appropriate to use the watershed as the basic land unit when determining rangeland health. A watershed is an area or region of land that drains into a stream or river. Ridges of higher land separate watersheds from each other. Since the goal is to show changes in water quality resulting from changes in land-use practices, working within a smaller watershed is preferred. To meet this goal, 6th order watersheds (HUC14 watersheds) were subdivided into 44 smaller sub-basins and each of these received an overall rating (Map 1; Tables 9, 10, and 11) (for more details see “Methods for Determining Condition, page 6).

The results of the watershed analysis are grouped within the larger 6th order HUC watersheds. The land area of the Preserve is primarily within five 6th order watersheds. The Preserve’s eastern and northern boundary does not exactly match the 6th order watershed boundaries; therefore, there are small fragments of land that are within the Preserve that slightly overlap into other 6th order watersheds. These fragments are so small that they are grouped and displayed as “various” in Tables 9 and 10.

Sub-basins of the Preserve were evaluated for abiotic and biotic factors that indicate watershed health. These indicators were derived from rangeland health criteria used in Herrick Rangeland Health Criteria (2005) in addition to common watershed health measures such as road density and stream condition measures, such as PFC (Prichard 1998) and stream invertebrate diversity. Results found all sub-basins of the 6th order HUC watersheds to have good to fair condition, with an upward trend. Five sub-basins (11 percent of the acres) were in good (high) condition with stream and upland information indicating slight to no departure from natural conditions. These five sub-basins contain 9,831 acres (11 percent of the total). The remaining basins (89 percent of the acres) were in moderate (medium) condition due to either upland or riparian degraded conditions. These sub-basins contain 80,002 acres (89 percent of the total). None of the basins were rated low.

Map 1. Sub-basin condition ratings within 6th order watersheds along with vegetation monitoring plots

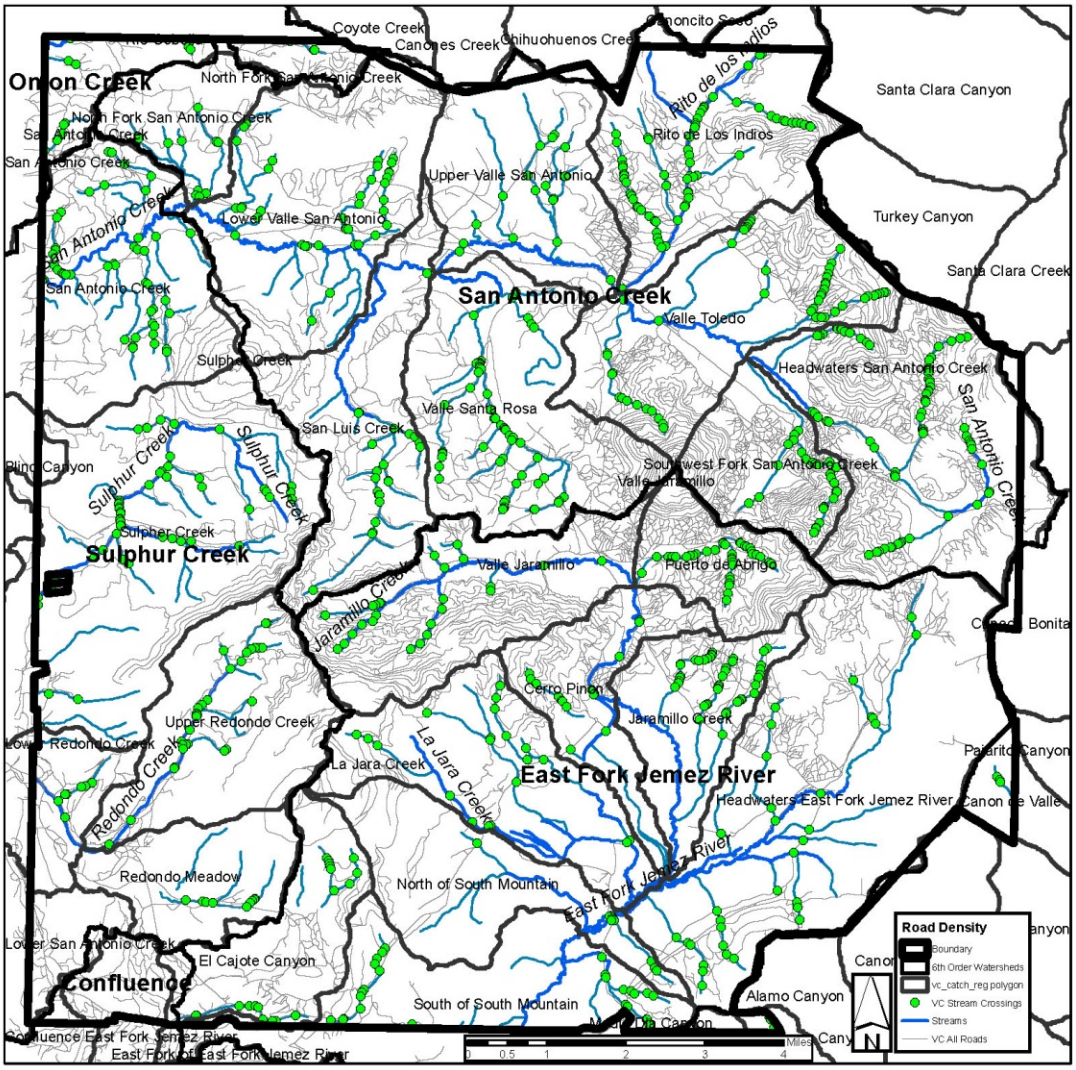


Results for this assessment were similar to the range-specific conclusions in Havstad (2002), even though different measures were used (for the abiotic rating). His assessment was based on site visits, field observations, and data from 26 monitoring plots to address 17 range health indicators. Many of these indicators are qualitative based on field observations such as how many rills or plant pedestals are observed. The data were summarized for three broad ecological types, woodland, upland grassland, and lowland grasslands (wet meadows). This assessment was based on data collected about bare ground, litter, and cover by grasses and forbs (some of the key quantitative indicators used by Havstad). This assessment used 633 plots plus one field trip to verify conclusions. The abiotic and biotic attributes were summarized in a rating of low to high for 44 sub-basins that were totally or partially within the Preserve's boundaries. Each watershed may have more than one vegetation type (for a complete list of the data and results see Tables 9, 10, and 11, and Map 1). With the exceptions of small inclusions, such as those pointed out by Havstad or as indicated by individual plots that received a low rating, all of the sub-basins received a rating of medium or high based on whether bare ground, litter, and plant cover met or exceeded ecological site description values (see Table 1, page 7). No sub-basins received a low rating.

High densities of roads and the number of road stream crossings continue to negatively affect all watersheds and sub-basins, particularly San Antonio Creek and East Fork of the Jemez River Watersheds (see Table 11 and Map 2). Roads can increase and advance the time of peak discharges. Road surfaces, cutbanks, ditches, and culverts all can convert subsurface flow paths to surface flow paths which can be routed directly to stream channels (Jones and Grant 1996). Similar to the findings of Napper (2001), roads—specifically where they cross creeks—are the dominant source of surface erosion in the watersheds. The Forest Service has an objective of limiting road densities to 2.5 miles (or less) of road per square mile in watersheds harboring anadromous fish (Klamath Resource Information System [KRIS], a PC-based computer program, http://www.krisweb.com/index.htm). Road densities of 2.5 miles are also the objective in the neighboring Santa Fe NF (USDA Forest Service 1987).

What appear to be contour lines on Map 2 are roads (there are no contour lines on this map). From 1963 to 1972 timber harvest was primarily by clear-cutting using a jammer logging system that required building numerous roads. These roads broke the forests into narrow, linear patches (Muldavin and Tonne 2003). The Headwaters of San Antonio Creek contained stream sections that were properly functioning, indicating an improvement in watershed conditions. However, due to the number of roads and stream crossings all sub-basins, with the exception of Rito de los Indios, were only rated medium. Four sub-basins within San Antonio Creek Watershed had road densities that exceeded 12 miles of road to the square mile and the number of road stream crossings ranged from 27 to 72. The East Fork of the Jemez River Watershed had three sub-basins that exceeded 12 miles of road to the square mile with the number of road stream crossings ranged from 17 to 40. This spatial analysis was based on existing GIS information and was not verified on the ground; hence, there is expected to be some error, but not of sufficient magnitude.

Map 2. Road densities and road stream crossings within sub-basins and 6th order watersheds



East Fork of the Jemez River Watershed

Previous Assessments

The East Fork of the Jemez River 6th order watershed is dominated by the Preserve's largest valle, Valle Grande, and is the headwaters for the East Fork of the Jemez River. Major tributaries are Jaramillo Creek and La Jara Creek. Because the headquarters is located within this watershed, the area would have been routinely exposed to the earliest seasonal grazing by livestock when cattle were shipped on and off the ranch (Havstad 2002).

East Fork of the Jemez River

Water Quality. A number of water quality issues have been documented on the East Fork of the Jemez over time. Using benthic organisms as an indicator of water quality, this stream was issued a rating of moderately impaired (USDA Forest Service 2002b), and the New Mexico Environment Department (NMED) Surface Water Quality Bureau has documented specific concerns regarding State water quality standards(USDA Forest Service 2002b; New Mexico Environmental Department 2002). Water quality impairments were reported in the year 2000 on the East Fork of the Jemez (along the lower reach below the confluence with Jaramillo Creek) for temperature, total suspended solids, fecal coliform, and stream bottom sediments (Valle Caldera Trust 2002). In its 2002 report, the New Mexico Environmental Department cited two exceedances regarding turbidity between the confluence with the San Antonio and its headwaters, but temperature, fecal coliform, and stream bottom sediments were not cited as concerns (New Mexico Environment Department 2002). Summer water temperatures are generally warm and have exceeded the recommended maximum of 23°C (or 20°C for 4 hour duration). The pH of the stream is neutral to basic and can exceed 8.8. Ammonia and aluminum levels also can exceed water quality standards (Vieira and Kondratieff 2004).

Benthic invertebrate surveys were performed during 2000 (USDA Forest Service 2002b); the dominant organisms found were primarily tolerant ones that can survive in altered aquatic habitat. The East Fork had a low number of taxa (23), probably due to homogeneity of the substrate (fine materials) and thermal consistency (Valle Caldera Trust 2002). Pool habitat had been reduced by high levels of fine sediment, and riffle habitat had excessive amounts of fine materials. Trout spawning habitat throughout this reach had been greatly reduced due to sedimentation (Valle Caldera Trust 2002).

Proper Functioning Condition. Early surveys revealed that this river was not properly functioning for all of the criteria in categories of habitat characteristics and channel condition and dynamics, except pool quality and stream bank condition (USDA Forest Service 2002a) (Table 3). In 2004 a total of 1.8 and 5.2 miles of the East Fork of the Jemez River were classified as "proper functioning condition" and "non-functioning", respectively (USDA Forest Service. 2004). The remainder was classified as "functioning at risk". The NRST rated the lower segment of the East Fork Jemez River below the main access to the Preserve headquarters as functional-at-risk with an upward health trend rather than non-functional (NRST 2002). The East Fork Jemez River Stream Inventory (USDA Forest Service 2002a) noted pool formation concerns, and excessive amounts of long riffles and altered width:depth ratios and stream types. Hydrologists and soil scientists found that high sediment loads, loss of undercut banks, and straightening of channels were causing structural and functional problems to the stream system. Additional discussion reporting details of this inventory can be found in the interim grazing environmental assessment (Valles Caldera Trust 2002).

Table 3. Stream conditions observed on the East Fork Jemez River during early surveys

Factors	Indicators	East Fork Jemez Conditions
Water quality	Temperature; 3-day average	Not properly functioning
	Temperature; 7-day average	Not properly functioning
Habitat characteristics	Sediment	Not properly functioning
	Large woody debris	Not properly functioning
	Pool development	Not properly functioning
	Pool quality	Properly functioning
Channel condition and dynamics	Streambank condition	Properly functioning

The East Fork of the Jemez River was revisited in 2006 and PFC surveys showed that changes are occurring in this stream system (Table 4). The perennial segments of the East Fork have improved from the below the spring to the southern boundary. The installation of an appropriately designed bridge along the headquarters road is likely responsible for the improved conditions. Unlike the lower reaches of the East Fork, the spring area did not appear to be responding to management action over the last 6 years. The intermittent segment below the stock tank and above the non riparian segment appeared to be of concern as well. In 2000 this segment was in properly functioning condition; however, in 2006 this segment was found to be functioning at risk and with a downward trend. Areas of concern around the spring and the intermittent segment below the stock tank seem to be reflective of drought and herbivory as noted by responses associated with the elk exclosure fence (McWilliams 2006).

Table 4. A comparison of PFC results between 2000 and 2006 for the East Fork of the Jemez River.

Stream Segment	2000 PFC Rating	2006 PFC Rating
Segment 1	Functioning At Risk (no trend)	Functioning At Risk (upward trend)
Segment 2	Proper Functioning Condition	Functioning At Risk (downward trend)
Segment 3	Non-Riparian	Non-Riparian
Segment 4a	Functioning At Risk (no trend)	Functioning At Risk (no trend)
Segment 4b	Functioning At Risk (no trend)	Proper Functioning Condition
Segment 5	Proper Functioning Condition	Proper Functioning Condition
Segment 6	Functioning At Risk (upward trend)	Proper Functioning Condition
Segment 7	Not Functioning	Functioning At Risk (upward trend)
Segment 8	Proper Functioning Condition	Proper Functioning Condition

Stream Vegetation. The potential vegetation in the Valle Grande and similar low-gradient stream meadow systems on the Valles Caldera National Preserve is expected to be primarily herbaceous. Primary species were well represented and included mannagrass, water sedge, beaked sedge, silver sedge, and occasional Nebraska sedge in the saturated areas near the stream. Tufted hairgrass is the primary species for the semi-wet areas; Baltic rush may occur throughout. Occasionally, large-stature willows may occur on the outer margins where the fluctuating water table and conditions allow for germination and establishment. Headwaters and steeper stream segments leaving the Caldera are thought to have potential for a combination of herbaceous and woody components such as willows and/or alder. Riparian aspen may also be a component in places. Alder were noted on a few segments, but very few willows were observed. It is unclear whether some past management activity removed the woody component or the woody component was never there. Present browsing of woody species in the area by elk could easily prevent reestablishment if they were part of the system. Shrubby cinquefoil is heavily browsed throughout

the caldera and is generally considered a less palatable shrub than most of the native willows and aspen (NRST 2002).

Fish. Fish species currently inhabiting the streams in East Fork of the Jemez River watershed include fathead minnows (*Pimephales promelas*), longnose dace (*Rhinichthys cataractae*), Rio Grande sucker (*Catostomus plebeius*), Rio Grande chub (*Gila pandora*), brown trout (*Salmo trutta*), and rainbow trout (*Oncorhynchus mykiss*) (Valles Caldera Trust 2002). There is evidence that the streams within the Preserve were once populated by native Rio Grande cutthroat trout (*Oncorhynchus clarki virginalis*). Museum specimens were collected within the Preserve during the first half of the 20th century (Sublette et. al. 1990). A 1892 report observed that the streams within the Preserve "teemed with mountain trout" (Valle Caldera Trust 2002). The presence of non-endemic rainbow and rainbow-cutthroat trout hybrids, as well as non-native brown trout, will make the establishment and maintenance of pure Rio Grande cutthroat trout populations difficult (NRST 2002).

Jaramillo Creek

Water Quality. Benthic invertebrate surveys were performed during 2000 by Chic Spann, Region 3 Forest Service hydrologist; Steve McWilliams, Santa Fe NF Watershed Program Manager; and Dr. Gerald Z. Jacobi (Valles Caldera Trust 2000). The benthic survey used Jaramillo Creek as the reference site for other streams and was classified as non-impaired. Jaramillo Creek had the largest number of taxa (31) and the most diversity of organisms within the Valles Caldera (benthic organism diversity index was 3.53) (Valles Caldera Trust 2002).

Proper Functioning Condition. Jaramillo Creek, a narrow and deep tributary to East Fork of the Jemez River, is a meandering 1st order stream that predominantly runs through Valle Grande and Valle Jaramillo. A total of 4.3 miles of Jaramillo Creek, starting at the East Fork of the Jemez River, was classified as being in a "proper functioning condition" during early surveys. The remainder of Jaramillo Creek up to the headwaters was classified as "functioning at risk" (USDA Forest Service 2004). Surveys conducted in 2006 revealed that Jaramillo Creek continues to improve with the length of stream channel at risk having been reduced over the intervening 6 years (McWilliams 2006) (Table 5).

Table 5. A comparison of PFC results between 2000 and 2006 for Jaramillo Creek.

Stream Segment	2000 PFC Rating	2006 PFC Rating
Segment 1	Proper Functioning Condition	Proper Functioning Condition
Segment 2a	Functioning At Risk (upward trend)	Proper Functioning Condition
Segment 2b	Functioning At Risk (upward trend)	Functioning At Risk (upward trend)
Segment 2c	Functioning At Risk (upward trend)	Proper Functioning Condition
Segment 3	Proper Functioning Condition	Proper Functioning Condition

Gravel and silt are the dominant bed substrate; some areas have cobbles. The upper headwaters of the Jaramillo Creek consist of seeps and natural wetland areas off of the VC03 road. The dominant substrates of these seeps were mud, silt, and inundated meadow vegetation. Just north of the movie set "ghost town", a clear, cold-water spring emerges from the western hill slope to flow into Jaramillo Creek (site "JC-Spring"). Cobble and sand, and some boulders, dominate the substrate, and aquatic mosses are also present. The spring tributary is shallow, and the tops of most cobbles are exposed (Vieira 2004). In 2006, following an extremely dry winter and spring, Jaramillo Creek was dry for nearly 30 days during the early summer.

Stream Vegetation. Large woody debris was partially submerged in some areas of the upper headwaters of Jaramillo Creek and the riparian zone around the majority of the creek consisted of meadow vegetation, wetland vegetation, and conifers (Vieira 2004). Recent surveys indicate that thin-leaf alder and Bebb's willow have started vegetative reproduction in the upper segment as well (McWilliams 2006).

La Jara Creek

Water Quality. La Jara Creek had a fair diversity of benthic organisms (27 species), but was sampled at a lower frequency than other small creeks.

Proper Functioning Condition. La Jara Creek has been classified as "functioning at risk". Dominant bed substrate includes cobbles and gravel (USDA Forest Service 2004). This stream is higher gradient, with faster current and shallower depth than most lotic systems of the Preserve.

Stream Vegetation. Conifers and aspen are the predominant vegetation in the riparian zone, and the stream is littered with large woody debris. There is anecdotal evidence that Bebb's willow (*Salix bebbiana*) once occurred along La Jara (Willow) Creek (Valles Caldera Trust 2002) although no willow are currently present.

Current Assessment

Condition for this watershed was based on 287 upland vegetation plots plus stream condition data. A total of 67 percent of the watershed is in forest and 55 percent of the forest has a canopy closure greater than 35 percent where forage production is low, usually less than 250 pounds per acre. The range condition is functioning with all nine sub-basins being rated as medium based on length of streams in a proper functioning condition and whether bare ground, litter, and plant cover met or exceeded ecological site description values developed by the NRCS for this area. (Tables 9, 10, and 11, and Map 1).

San Antonio Creek Watershed

Previous Assessments

San Antonio Creek

Water Quality. Water quality in San Antonio Creek was monitored by NMED at two sites located at the mouth of San Antonio Creek and just above San Antonio Campground between April 20, 1998, and March 25, 1999. Both sites showed that turbidity exceeded standards twice during spring runoff and once in the fall. Total organic carbon (TOC) exceeded standards once in the fall at each site and could be attributed to decomposing deciduous vegetation (USDA Forest Service 2003). In 2000, the majority of San Antonio Creek was found not to meet State water quality standards for its designated uses because of temperature, total suspended solids, fecal coliform, and stream bottom sediments (Valles Caldera Trust 2002). However, in 2002 (NMED) found that conditions had improved somewhat, citing only temperature and turbidity as concerns between the confluence with the East Fork of the Jemez River and the headwaters of San Antonio Creek. Water temperature is a crucial parameter for fish health and development. Five stream temperature stations were strategically placed along the length of San Antonio Creek. The stations recorded water temperatures every 4 hours between June 11 and November 24, 2002. The water temperature data were compared to both Forest and NMED standards. The Forest standards classified San Antonio Creek as not properly functioning for salmonid development at all sites except station 5 located near the headwaters. The NMED standards classified two of the five sites

as not properly functioning for water quality (New Mexico Environment Department 2002). Mitigating human-caused elevated stream temperatures should be a focus in the management of San Antonio Creek (USDA Forest Service 2003).

In 2003 NMED found that the stream was generally in accordance with standards based on two sites, although summer water temperatures have exceeded the recommended 23°C maximum (or 20°C for 4 hour duration), the pH of the stream is neutral to basic and often exceeds 8.8, and ammonia and aluminum levels can occasionally exceed water quality standards (Vieira and Kondratieff 2004).

Using benthic invertebrate surveys, San Antonio Creek was rated as slightly impaired (Valles Calder Trust 2000). The dominant organisms found were primarily those tolerant of altered aquatic habitat (Valles Caldera Trust 2002). San Antonio Creek was found to have moderate diversity with 32 species (Vieira and Kondratieff 2004).

Proper Functioning Condition. Early surveys indicated that a total of 6.2 miles, mostly in the upper sections of San Antonio Creek (above confluence with Rio de los Indios Creek) were classified as properly functioning. The remaining 13.3 miles of San Antonio Creek were determined to be functioning at risk (including the section crossing Sulphur Creek Watershed) (USDA Forest Service 2004). The parameters that were not properly functioning included water temperature, relative sediment content in riffles, the density of large woody debris, pool development, width-to-depth ratio, and stream bank condition (Table 6) (USDA Forest Service 2003).

Table 6. Stream conditions on San Antonio Creek prior to 2006 surveys.

Factors	Indicators	San Antonio Creek Conditions
Water quality	Temperature; 3-day average	Site 1 (Battleship): At risk
		Site 2 (La Cueva): Not properly functioning
		Site 3 (Campground): At risk
		Site 4 (Preserve): Not properly functioning
		Site 5 (Rito de los Indios): At risk
Salmonid development	Temperature; 7 day average	Sites 1-4: Not properly functioning
		Site 5: (Properly functioning)
Habitat characteristics	Riffle sediment	Not properly functioning
	Large woody debris	Not properly functioning
	Pool development	Not properly functioning
	Pool quality	Not analyzed due to surveyor error
Channel condition and dynamics	Stream bank condition	Properly functioning
	Width-to-depth ratio	Not properly functioning

Surveys conducted in 2006 showed some improvement in stream condition (Tables 7). San Antonio Creek has shown an increase in riparian wetland species along the bank and an improved rating at the lower end of the stream as it exits the VCNP. The upper end of the San Antonio from the headwaters of the Valle Toledo to below the confluence with the Rito de los Indios was well above the minimum required for PFC, as were the intermittent reaches around and above the stock tank. Several small head cuts associated with bogs above the stock tank have the potential to continue upstream and could pose a future threat to the headwaters (McWilliams 2006).

Table 7. A comparison of PFC results between 2000 and 2006 for San Antonio Creek

Stream Segment	2000 PFC Rating	2006 PFC Rating
Segment 1	Proper Functioning Condition	Proper Functioning Condition
Segment 2	Proper Functioning Condition	Proper Functioning Condition
Segment 3	Non-Riparian	Non-Riparian
Segment 4	Proper Functioning Condition	Proper Functioning Condition
Segment 5	Proper Functioning Condition	Proper Functioning Condition
Segment 6a	Functioning At Risk (upward trend)	Functioning At Risk (upward trend)
Segment 6b	Functioning At Risk (upward trend)	Proper Functioning Condition

Stream Vegetation. The riparian vegetation is not consistent for the entire length of the stream. There are three distinct riparian environments between the mouth and headwaters of San Antonio Creek. Reach 1 has a unique riparian habitat with high diversity. Alder, willow, locust and dogwood are the primary woody streamside vegetation; while water hemlock, grasses, and sedges dominate the herbaceous vegetation. From Reach 2 through 5 the diversity of vegetation decreases. Streamside woody vegetation is primarily comprised of alder and willow, while the herbaceous vegetation is mostly grasses, sedges, horsetail, and rushes (though overall quantity of herbaceous vegetation is severely decreased). From Reach 6 through 11, woody vegetation dramatically decreases, while herbaceous riparian vegetation diversity increases. The only woody vegetation is an occasional patch of cinquefoil. The majority of streamside herbaceous vegetation is sedges, rushes, grasses, buttercups, sorrel, flea bane, dandelion, yarrow, thistle, horsetail (in wetter areas), hair bell, heal-all, clover, spearmint, sunflowers, and scarlet gila. Aquatic vegetation (*Potomogeten*, *Elodea*, *Ceratophyllum demersum*, and algae) was present in the entire stream, but increased in the upper reaches (USDA Forest Service 2003).

In 2000 the Valle San Antonio had up to 85 percent of the bank vegetation comprised of upland species such as Kentucky bluegrass. In 2006 that percentage had been reduced to around 40 percent upland species. Herbivores may slow recovery within the Valles San Antonio and future analysis of changes around elk exclosure fences will be important in quantifying these impacts (McWilliams 2006).

Fish. Fish species currently inhabiting San Antonio Creek include longnose dace and brown trout. There is anecdotal evidence that the East Fork Jemez and San Antonio Creeks were populated by Native Rio Grande cutthroat trout. In a 1892 report “mountain trout” were observed within the Preserve. (Valles Caldera Trust 2002).

Rio de los Indios Creek

Water Quality. Benthic invertebrate surveys were performed during 2000. The benthic survey indicated that the stream reach was non-impaired with 82 percent of the reference attributes (Valles Caldera Trust 2000). Among the running water habitats, small creeks with well developed riparian vegetation (such as Rio de los Indios) were the most diverse with the most number of benthic species (48 total species) (Vieira and Kondratieff 2004).

Proper Functioning Condition. The spring-generated tributary is very shallow, with the tops of most substrates exposed (Vieira and Kondratieff 2004). Temperatures remain cool throughout the summer. Dominant bed substrate includes gravel and cobble; large woody debris can be found throughout the creek channel in the forested reaches.

Rio de los Indio Creek, located in the Rito de los Indios sub-watershed, is a tributary to San Antonio Creek. This small stream is approximately 4 miles long; earlier surveys characterized 2.6

miles as functioning at risk and 1.4 miles as properly functioning (USDA Forest Service 2004). T-Walk's Tarzwell substrate ratio was used to characterize the reference reach above the confluence with San Antonio Creek; the creek was assessed as impaired due primarily to the amount of sands and silts in the gravels.

In 2006 the system had improved and degraded channels had begun to stabilize (Table 8). Rio de los Indios also showed improvement in species composition on the banks and expansion of riparian wetland vegetation both toward the stream and into the floodplain. The entire length of the Rio de los Indios system was considered to be in properly functioning condition or better (McWilliams 2006).

Table 8. A comparison of PFC results between 2000 and 2006 for Rio de los Indios

Stream Segment	2000 PFC Rating	2006 PFC Rating
Segment 1	Proper Functioning Condition	Proper Functioning Condition
Segment 2	Functioning At Risk (no trend)	Proper Functioning Condition
Segment 3	Proper Functioning Condition	Proper Functioning Condition

Current Assessment

The San Antonio Creek 6th order watershed is dominated by Valle Toledo and the San Antonio Creek and its tributaries. Condition for this watershed was based on 208 plots. A total of 63 percent of the watershed is in forest and 84 percent of the forest has a canopy closure greater than 35 percent where forage production is low, usually less than 250 pounds per acre.

Range condition is functioning ecologically throughout the watershed with all but one sub-basin being rated as medium. The Rito de los Indios sub-basin was rated as high. Ratings were based on whether or not stream segments were in a proper functioning condition and whether bare ground, litter, and plant cover met or exceeded ecological site description values developed for this area (Tables 9, 10, and 11, and Map 1).

Sulphur Creek Watershed

Previous Assessments

The Sulphur Creek 6th order watershed is dominated by mountainous terrain and forests, except where San Antonio Creek (Valle San Antonio) crosses the watershed at the north end and at Valle Seco (a small valle located within Sulphur Creek sub-watershed). Except the section of San Antonio Creek, no other streams were surveyed as to proper functioning condition. One source of data for stream condition came from benthic invertebrate surveys conducted in 2004.

San Antonio Creek

The lower section of San Antonio Creek within the Preserve is located in the San Antonio sub-watershed of the Sulphur Creek 6th order watershed. San Antonio Creek is approximately 2.5 miles, all of which is functioning at risk. San Antonio Creek was previously described under the San Antonio Creek 6th order watershed.

Sulphur Creek

The acidic Sulphur Creek (5.6 miles long) showed very low benthic diversity (6 species) receiving a rating of "least diverse" (Vieira 2004). Sulphur Creek is a 2nd order stream aptly

named for its high sulfur content. Its acidity (pH of 2 to 4) makes it one of the most unique habitats on the Preserve. Most of the drainage, including Alamo Creek which feeds into Sulphur Creek at lower elevations, is characterized by geothermal activity and sulfur springs. Directly downstream where it runs under the road through a pipe ("SC"), the streambed substrate consisted of cobbles and gravel. A nearby overflow pond was also highly acidic and dominated by aquatic macrophytes and algae ("SC-Pond") (Vieira and Kondratieff 2004).

The length of herbaceous and limited shrub riparian vegetation has increased since 2000. Earlier the riparian/wetland vegetation extended to a point just above the confluence with the Alamo. Today the riparian/wetland vegetation has extended its range to the stock tank at the lower end of the Valle Seco. Acidic deposition along Sulphur Creeks is natural and although this stream has been cited for exceedences regarding conductivity and pH (New Mexico Environmental Department 2002), this stream has been rated as being in Proper Functioning Condition (McWilliams 2006).

Alamo Creek

Alamo Creek is a small stream approximately 2.1 miles in length that feeds into Sulphur Creek at lower elevations. It is characterized by geothermal activity and sulfur springs. The primary substrate of the 1st order tributary was cobble and gravel, and the entire streambed was covered in a white precipitate. This tributary and pools feeding it were geothermally active (Vieira and Kondratieff 2004). The acidic Alamo Bog showed the least benthic diversity (no species) of all sampled (Vieira and Kondratieff 2004). This stream has been rated as being in Properly Functioning Condition (McWilliams 2006).

Redondo Creek

Redondo Creek is approximately 5.4 miles long. A benthic survey in 2004 rated Redondo Creek "most diverse", having the highest number of benthic invertebrate species (39); it was considered the most diverse of any stream on the Preserve (Vieira and Kondratieff 2004). The lowest site sampled was at the Redondo gate along the Preserve's western boundary on the VC02 road, where the cool-water 1st order creek runs predominantly through meadow habitat, with some conifers on hillslopes and riparian vegetation along the banks. Substrate consists of cobble and sand, with CWD (course woody debris) present on the stream bed and along the margins. Riparian vegetation is better developed at upper sites, including 24, the reach above where the VC02 and 03 roads meet and at the Union Building. Cobble and gravel substrate dominate these two upper sites, and CWD is more prevalent than at the Redondo gate site. While temperatures and ammonia levels typically remain at or below water quality standards, aluminum standards were often exceeded (Vieira and Kondratieff 2004). Exceedences for temperature and turbidity have also been documented for Redondo Creek as recently as 2002 (New Mexico Environment Department 2002).

One segment of this stream was rated as Functioning at Risk with an upward trend and two segments were rated as being in Proper Functioning Condition (McWilliams 2006). There are concerns about Redondo Creek within Redondo Meadow below the road junction of VC02 and VC03 and extending for approximately a half mile to the North West end of the meadow. This segment could be a candidate for site-specific action to speed the recovery. The old drill pads have stabilized and the riparian/wetland areas are improving with a robust shrub component.

Current Assessment

Condition for this watershed was based on 127 vegetation plots and 15.6 miles of perennial stream. A total of 88 percent of the watershed is in forest and 81 percent of the forest has a canopy closure greater than 35 percent where forage production is low, usually less than 250 pounds per acre. A total of 12 percent is in grassland with 66 percent of the grassland being dry upland grassland. Small amounts of low and upland grassland can be found in association with Alamo Canyon, Redondo, and Sulphur Creeks; but most of it is found in Valle San Antonio.

These sub-basins, with the exception of San Antonio Creek, have received less livestock use because of the mountainous terrain and lack of waters. Most of the elk concentrate near or within the primary valles outside of this watershed with the exception of San Antonio Creek[7]. Historically an elk herd utilized this side of the Preserve and wintered to the south and west, but elk now concentrate on the east and north sections of the Preserve, which are in or associated with the large grassland valles, and winter to the north and east. This may be due to the lack of hunting on the north and east within Los Alamos or Bandelier National Monument.

Within the Sulphur Creek Watershed, four of seven sub-basins received a high rating; most of these are around Redondo Creek. The remaining three sub-basins received a medium rating. All ratings were based on stream condition and whether bare ground, litter, and plant cover met or exceeded ecological site description values developed by the NRCS for this area (Tables 9, 10, and 11, and Map 1).

Onion, Confluence, and Various Other Watersheds

Current Assessment

The portion of Onion 6th order watershed within the northwest corner of the Preserve is only 1,524 acres; it is dominated by mountainous terrain and forests, virtually all with a canopy greater than 35 percent crown closure resulting in low forage production. All acres were rated as medium (Tables 9, 10, and 11, and Map 1). All ratings were based on whether bare ground, litter, and plant cover met or exceeded ecological site description values developed by the NRCS for this area. Road densities are very low.

The Confluence 6th order watershed within the southwest corner of the Preserve is only 837 acres; it is dominated by mountainous terrain and is entirely forested; 89 percent of the forest has a crown closure greater than 35 percent resulting in very low forage production. All acres were rated as medium (Tables 9, 10, and 11, and Map 1). All ratings were based on whether bare ground, litter, and plant cover met or exceeded ecological site description values developed by the NRCS for this area. Road densities are very low.

There were various small pieces of land that were part of other 6th order watersheds along the east and north boundaries (Map 1). These small parcels equaled 1,065 acres, ranging from 0.5 to 428 acres. Most were woodlands with most having a crown closure greater than 35 percent resulting in very low forage production. These small parcels were not rated.

[7] Meeting with New Mexico Game and Fish Department, May 15, 2006, between Darrel Waybright, Steve Kohlmann, James Biggs (Las Alamos Lab), Anton Jackson, and Keith Menasco.

Table 9. Rangeland condition ratings for sub-basins grouped by watershed

Sub-basin	Acres	Overall Watershed Rating	Upland Rating	Riparian Rating
Confluence [HUC 13020202020040] [1]				
Confluence East Fork Jemez River	101	MED	MED	MED
East Fork of East Fork Jemez River	736	MED	HIGH	MED
East Fork Jemez [HUC 13020202020030]				
Cerro Pinon	2,183	MED	MED	MED
El Cajote Canyon	2,454	MED	MED	
Headwaters East Fork Jemez River	8,772	MED	MED	MED
Jaramillo Creek	2,354	MED	MED	HIGH
La Jara Creek	3,778	MED	MED	HIGH
North of South Mountain	3,035	MED	MED	MED
Puerto de Abrigo	1,783	MED	HIGH	
South of South Mountain	3,108	MED	MED	MED
Valle Jaramillo	3,930	MED	MED	MED
Onion Creek [HUC 13020202010030]				
Rio Cebolla	1,524	MED	MED	
San Antonio Creek [HUC 13020202020010]				
Headwaters San Antonio Creek	5,385	MED	MED	HIGH
Lower Valle San Antonio	4,962	MED	MED	MED
North Fork San Antonio Creek	1,616	MED	MED	MED
Rito de los Indios	4,080	HIGH	HIGH	HIGH
San Luis Creek	3,818	MED	MED	MED
Southwest Fork San Antonio Creek	2,024	MED		HIGH
Upper Valle San Antonio	3,431	MED	MED	MED
Valle Santa Rosa	4,779	MED	MED	
Valle Toledo	4,379	MED	MED	HIGH
Sulphur Creek [HUC 13020202020030]				
Blind Canyon	136	HIGH	HIGH	
Lower Redondo Creek	1,117	HIGH	HIGH	HIGH
Lower San Antonio Creek	817	HIGH	HIGH	
Redondo Meadow	2,115	MED	HIGH	MED
San Antonio Creek	4,267	MED	HIGH	MED
Sulphur Creek	7,370	MED	MED	HIGH
Upper Redondo Creek	3,676	HIGH	HIGH	HIGH
Various Small Parcels Along North and East Edge of Boundary	1,065			

[1]These are the 6th Order, 12 digit watersheds.

Table 10. Amount of acres within various vegetation types within each sub-basin grouped by watershed within the Preserve

Sub-basin	Vegetation Types					Total Acres
	Crown Closure		Mountain Meadow	Mountain Valley	Riparian	
	<35%	>35%				
Confluence [HUC 13020202020040] [1]						
Confluence East Fork Jemez River	11	90				101
East Fork of East Fork Jemez River	79	657				736
East Fork Jemez [13020202020020]						
Cerro Pinon	264	802	800	191	125	2,183
El Cajote Canyon	342	1,965		147		2,454
Headwaters East Fork Jemez River	699	3,524	1,528	2,880	254	8,772
Jaramillo Creek	147	775	308	1,001	123	2,354
La Jara Creek	423	1,773	1,071	232	279	3,778
North of South Mountain	213	1,806	557	359	99	3,035
Puerto de Abrigo	134	1,402	247		1	1,783
South of South Mountain	160	2,063	437	349	99	3,108
Valle Jaramillo	564	2,526	615		225	3,930
Onion Creek [13020202010030]						
Rio Cebolla	183	1,327			14	1,524
San Antonio Creek [13020202020010]						
Headwaters San Antonio Creek	429	3,651	90	1,113	102	5,385
Lower Valle San Antonio	572	2,634	349	1,279	128	4,962
North Fork San Antonio Creek	247	1,009		359	1	1,616
Rito de los Indios	408	2,979	51	460	187	4,080
San Luis Creek	455	2,223	148	862	131	3,818
Southwest Fork San Antonio Creek	73	1,117	84	689	1	2,024
Upper Valle San Antonio	620	1,722	274	697	119	3,431
Valle Santa Rosa	603	2,733	556	841	45	4,779
Valle Toledo	355	2,017	623	1,299	87	4,379
Sulphur Creek [13020202020030]						
Blind Canyon	1	135				136
Lower Redondo Creek	159	916			42	1,117
Lower San Antonio Creek	129	688				817
Redondo Meadow	539	1,451		117	8	2,115
San Antonio Creek	382	2,624	265	884	112	4,267
Sulphur Creek	1,169	5,385		555	260	7,370
Upper Redondo Creek	805	2,755		6	110	3,676
Various Small Parcels Along North and East Edge of Boundary	179	886				1,065

[1]These are the 6th Order, 12 digit watersheds.

Table 11. Vegetative plot information for each sub-basin grouped by watershed

Sub-basin	Acres/ [# of Plots]	Upland % of Plots			Abiotic % of Plots			Biotic % of Plots			Riparian [2]	Benthic [3]	Road Density (miles/ square mile)	Road Stream Crossings (#)
		Low	Med	High	Low	Med	High	Low	Med	High				
Confluence [13020202020040] [1]														
Confluence East Fork Jemez River	101 [0]	0	0	0	0	0	0	0	0	0	FAR (inferred)	MI	7	0
East Fork of East Fork Jemez River	736 [8]	0	12.5	87.5	0	0	100	0	12.5	87.5	FAR (inferred)	MI	11	0
East Fork [13020202020020]														
Cerro Pinon	2,183 [16]	25	37.5	37.5	12.5	18.8	68.8	18.7	25	56	PFC	NI-MI/MD	12	17
El Cajote Canyon	2,454 [12]	8.3	33.3	58.3	8.3	16.6	75	0	41.6	58.3			8	19
Headwaters East Fork Jemez River	8,772 [55]	9	25.4	65.4	5.4	25.4	69	1.8	16.3	81.8	FAR, PFC	MI/MOD	6	33
Jaramillo Creek	2,354 [8]	12.5	37.5	50	12.5	37.5	50	0	25	75	PFC	NI/MD	8	43
La Jara Creek	3,778 [68]	29.4	16.1	54.4	5.8	32.3	61.7	19.1	7.3	73.5	PFC	MI/MOD	5	20
North of South Mountain	3,035 [48]	25	20.8	54.1	25	10.4	64.5	10.4	12.5	77	FAR, NF	MI/MOD	3	10
Puerto de Abrigo	1,783 [10]	0	20	80	0	10	90	0	10	90			24	40
South of South Mountain	3,108 [17]	23.5	29.4	47	17.6	23.5	58.8	11.7	11.7	7.4	FAR, PFC	MI/MOD	3	27
Valle Jaramillo	3,930 [53]	22.6	20.7	56.6	20.7	22.6	56.6	3.7	3.7	92.4	PFC, FAR	NI/MD	16	25
Onion Creek [13020202010030]														
Rio Cebolla	1,524 [3]	0	33.3	66.6	0	0	100	0	33.3	66.6			8	13
San Antonio Creek [13020202020010]														
Headwaters San Antonio Creek	5,385 [23]	0	56.5	43.4	0	34.7	65.2	0	52.1	47.8	PFC	SI/MOD	16	72

Sub-basin	Acres/ [# of Plots]	Upland % of Plots			Abiotic % of Plots			Biotic % of Plots			Riparian [2]	Benthic [3]	Road Density (miles/ square mile)	Road Stream Crossings (#)
		Low	Med	High	Low	Med	High	Low	Med	High				
Lower Valle San Antonio	4,962 [10]	0	40	60	0	30	70	0	30	70	FAR	SI/MOD	6	38
North Fork San Antonio Creek	1,616 [8]	0	37.5	62.5	0	25	75	0	25	75	FAR	SI/MOD	5	11
Rito de los Indios	4,080 [6]	0	16.6	83.3	0	16.6	83.3	0	16.6	83.3	PFC	NI/MD	12	72
San Luis Creek	3,818 [7]	14.2	42.8	42.8	14.2	42.8	42.8	0	42.8	57.1	FAR	SI/MOD	8	23
Southwest Fork San Antonio Creek	2,024 [10]	10	20	70	10	20	70	0	20	80			24	27
Upper Valle San Antonio	3,431 [35]	20	31.4	48.5	14.2	22.8	62.8	8.5	25.7	65.7	FAR, PFC	SI/MOD	6	17
Valle Santa Rosa	4,779 [81]	24.6	25.9	49.3	19.7	23.4	56.7	18.5	17.2	64.1			9	56
Valle Toledo	4,379 [28]	7.1	57.1	35.7	7.1	42.8	50	3.5	46.4	50	PFC	SI/MOD	13	53
Sulphur Creek [13020202020030]														
Blind Canyon	136 [1]	0	0	100	0	0	100	0	0	100			1	0
Lower Redondo Creek	1,117 [1]	0	0	100	0	0	100	0	0	100	PFC	-/MD	8	7
Lower San Antonio Creek	817 [4]	0	0	100	0	0	100	0	0	100			8	0
Redondo Meadow	2,115 [17]	0	11.7	88.2	0	5.8	94.1	0	5.8	94.1	FAR	-/MD	5	10
San Antonio Creek	4,267 [14]	0	28.5	71.4	0	14.2	85.7	0	28.5	71.4	FAR, PFC	SI/MD	6	46
Sulphur Creek	7,370 [64]	10.9	35.9	53.1	10.9	14	75	1.5	34.3	64	PFC	-/LD	6	56
Upper Redondo Creek	3,676 [26]	11.5	11.5	76.9	11.5	3.8	84.6	0	19.2	80.7	PFC	-/MD	6	30

[1]These are the 6th Order, 12 digit watersheds.
[2] Proper functioning condition rating: PFC = proper functioning condition; FAR = functioning at risk; NF = nonfunctioning.
[3] Level of diversisty of benthic organisms: NI = nonimpaired; MI = modereately impaired; SI = slightly impaired; MD = most diverse; MOD = moderately diverse; LD = least diverse.

Lands Potentially Suitable for Livestock and Elk

Analysis Protocol for Determining Suitability

Lands suitable for assigning use for sustainable grazing by livestock, elk, and other wildlife were identified based on forage productivity, slope, and distance to water. Suitability was determined within 14-digit HUC watersheds (6th order), further stratified by ecological sites[8]. Small inclusions such as administrative sites, springs, and headwaters are included at this time, but would be considered for exclusion when actual grazing decisions are made.

The Preserve is primarily within five 6th order watersheds. The Preserve's eastern and northern boundary does not exactly match the 6th order watershed boundaries; therefore; there are small parcels (from less than an acre to 428 acres) of land that fall within various other 6th order watersheds. In Tables 9 and 10 these various parcels are named "various".

The following factors were used to determine suitability:

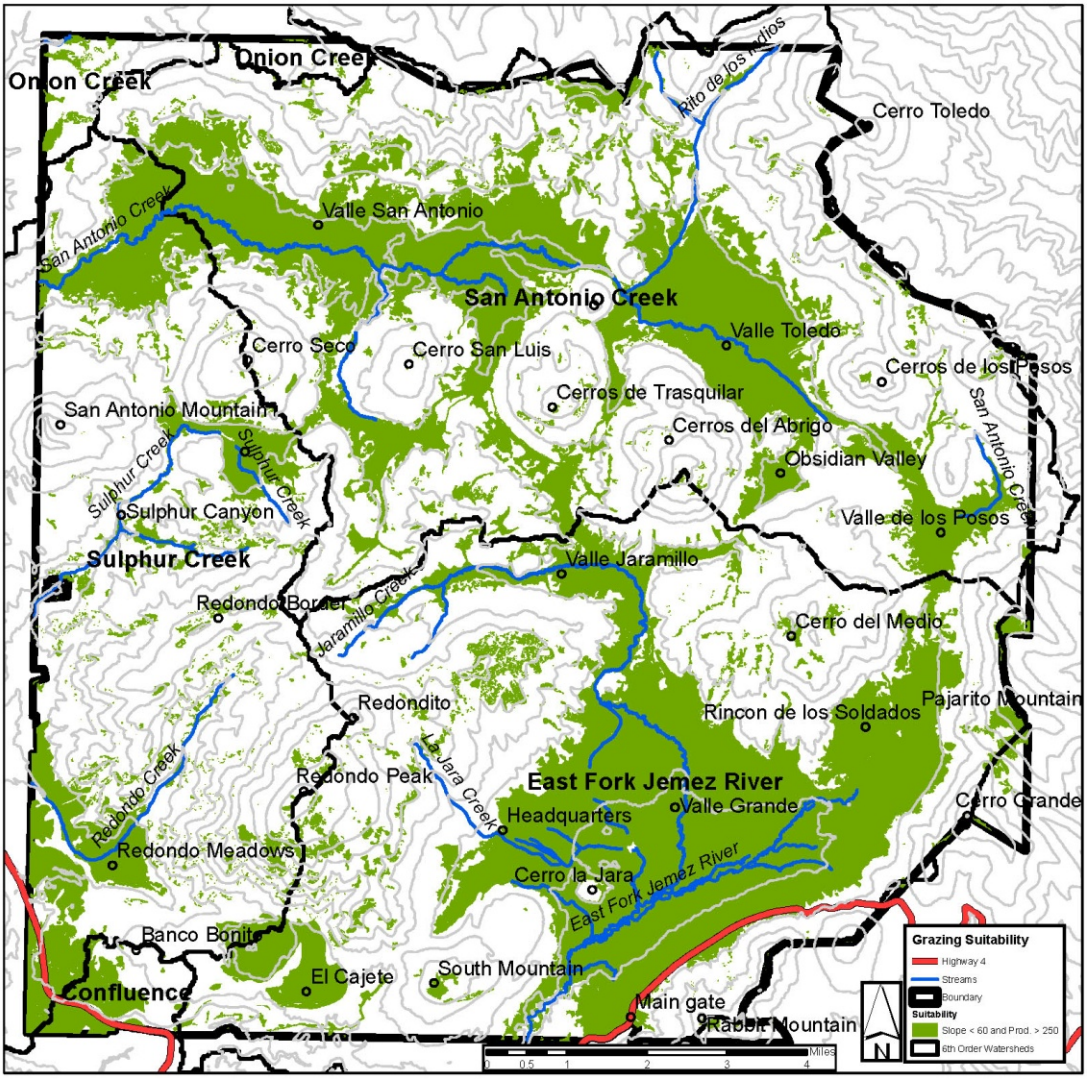
- A minimum production of 250 pounds of forage per acre was required to be considered suitable. Production was determined from 5 years of monitoring data collected by the Jornada Experimental Range Station supplemented with TES data.
- Percent slope of 0 to 30 percent was considered suitable for domestic livestock, elk, and other wildlife; 31 to 60 percent was considered suitable for elk and other wildlife, but not livestock. Areas greater than 60 percent were not considered suitable for livestock or elk.
- All lands farther than one mile from permanent water were considered unsuitable in the near future. All perennial streams and stock tanks were included in this analysis; however, current condition of stock tanks was not considered.

Suitability for livestock and elk grazing was modeled at two levels: One level identified those acres that have long-term potential (potential capacity); water was not considered and some of these acres may not be suitable without future water development. The other level restricted the suitable acres to those that are currently suitable with access to streams or stock tanks, or could be made suitable with maintenance or repair (full capacity).

Potential Capacity

The Preserve consists of 88,972 acres. A spatial suitability analysis indicates that a total of 26,072 (29 percent) acres are potentially suitable for forage use by livestock, elk, and other wildlife; and 1,450 acres, situated on greater than 30 percent slopes but less than 60 percent slopes, are suitable only for elk and other wildlife (Table 12 and Map 3). The bulk of the suitable acres are found in the East Fork of the Jemez River and the San Antonio Creek Watersheds, 45 and 39 percent, respectively. Mountain Meadow and Mountain Valley ecological sites throughout the various watersheds make up the majority of the suitable habitat (67 percent).

[8] Ecological site – Land with a specific potential natural community and specific physical site characteristics, differing from other kinds of land in its ability to produce vegetation and to respond to management.



Map 3. Land considered suitable for grazing based on percent slope (<60%) and forage production per acre (≥250 lbs)

Table 12. Suitability based only on slope and minimum of 250 pounds/acre forage production

Watershed (6th Order)	Ecological Sites	Acres Producing >250 Pounds/Acre 0–30% Slope	31–60% Slope	Total Acres
Onion Creek [HUC 13020202010030]	Woodland <35% Canopy Closure	110	0	110
	Riparian	3	0	3
	Total	113	0	113
San Antonio [HUC 13020202020010]	Woodland <35% Canopy Closure	1,879	372	2,251
	Woodland >35% Canopy Closure	128	10	138
	Mountain Meadow	1,657	42	1,699
	Mountain Valley	5,809	101	5,910
	Riparian	579	26	605
	Total	10,052	551	10,603
East Fork Jemez River [HUC 13020202020020]	Woodland <35% Canopy Closure	1,048	245	1,293
	Woodland >35% Canopy Closure	479	54	533
	Mountain Meadow	4,872	52	4,924
	Mountain Valley	4,465	37	4,502
	Riparian	1,001	7	1,008
	Total	11,865	395	12,260
Sulphur Creek [HUC 13020202020030]	Woodland <35% Canopy Closure	809	260	1,069
	Woodland >35% Canopy Closure	1,057	142	1,199
	Mountain Meadow	218	10	228
	Mountain Valley	1,218	16	1,234
	Riparian	257	22	279
	Total	3,559	450	4,009
Confluence [HUC 13020202020040]	Woodland <35% Canopy Closure	81	1	82
	Woodland >35% Canopy Closure	331	18	349
	Total	412	19	431
Various	Woodland <35% Canopy Closure	71	35	106
	Total	71	35	106
Totals by Eco-sites	Woodland <35% Canopy Closure	3,998	913	4,911
	Woodland >35% Canopy Closure	1,995	224	2,219
	Mountain Meadow	6,747	104	6,851
	Mountain Valley	11,492	154	11,646
	Riparian	1,840	55	1,895
Grand Totals		26,072	1,450	27,522

Full Capacity

Table 13 displays acres when, in addition to slope and a minimum of 250 pounds of forage production, the distance from water is considered.

Table 13. Suitability based on slope, minimum of 250 pounds/acre forage production, and <1 mile from water

Watershed (6th order)	Ecological Sites	Acres < 1 Mile From Water Producing >250 Pounds/Acre		Total Acres
		0–30% Slope	31–60% Slope	
Onion Creek [HUC 13020202010030]	Woodland <35% Canopy Closure	110	0	110
	Riparian	3	0	3
	Total	113	0	113
San Antonio [HUC 13020202020010]	Woodland <35% Canopy Closure	1,872	365	2,237
	Woodland >35% Canopy Closure	128	10	138
	Mountain Meadow	1,657	42	1,699
	Mountain Valley	5,809	101	5,910
	Riparian	579	26	605
	Total	10,045	543	10,588
East Fork Jemez River [HUC 13020202020020]	Woodland <35% Canopy Closure	939	146	1,085
	Woodland >35% Canopy Closure	479	54	533
	Mountain Meadow	4,872	52	4,924
	Mountain Valley	4,465	37	4,502
	Riparian	1,001	7	1,008
	Total	11,756	296	12,052
Sulphur Creek [HUC 13020202020030]	Woodland <35% Canopy Closure	742	224	966
	Woodland >35% Canopy Closure	719	135	854
	Mountain Meadow	218	10	228
	Mountain Valley	1,218	16	1,234
	Riparian	257	22	279
	Total	3,154	406	3,561
Confluence [HUC 13020202020040]	Woodland <35% Canopy Closure	3	0	3
	Woodland >35% Canopy Closure	4	2	6
	Total	7	2	9
Various	Woodland <35% Canopy Closure	29	7	36
	Total	29	7	36
Totals by Eco-sites	Woodland <35% Canopy Closure	3,695	742	4,437
	Woodland >35% Canopy Closure	1,330	201	1,531
	Mountain Meadow	6,747	104	6,851
	Mountain Valley	11,492	153	11,645
	Riparian	1,840	54	1,894
Grand Totals		25,104	1,254	26,359

Perennial streams and all stock tanks were considered. Acres beyond 1 mile from water were considered unsuitable. The difference between when distance from water is not considered and when acres located beyond 1 mile from water are excluded is only 1,163 acres (4 percent of the total), all of which are in the woodland ecological sites (indicating the Preserve has a fairly even distribution of waters). All acres beyond 1 mile from water are accounted for in the woodland ecological site, with 57 percent being in the woodland site with greater than 35 percent canopy cover. Stock tanks are of greater importance in woodland areas. For this assessment all tanks regardless of condition were included as a water source; many are non-functional or only have water available in years with average or above moisture. When stock tank condition is included as part of an annual range-readiness assessment, less water will make more acres unsuitable.

Grazing Capacity

Forage Production Methodology

Data used to estimate forage production and grazing capacity came from four main sources: (1) mapped vegetation associations of the Preserve (Muldavin and Tonne 2003); (2) forage stand delineation and attribution database created by Photo Science, Inc., in 2005; (3) TES conducted by the Forest Service in 2000; and (4) forage utilization data collected by Jornada Experimental Range Station for 2003 through 2005. When the TES, Muldavin and Tonne (2003) plant associations, and the forest stand delineation spatial layers were intersected they produced over 2 million individual mapped polygons.

Photo Science, Inc. (2005) mapped general vegetation types across the Preserve emphasizing forest stand delineation and attribution (ESRI GIS personal geodatabase). The amount of forage that a site can produce, which is partly dependent on tree crown closure, was one of the data elements also provided.

The Forest Service completed the TES covering the Preserve in 2000. TES consists of the systematic analysis, classification, and mapping of terrestrial ecosystems. A terrestrial ecosystem is an integrated representation of the ecological relationship between climate, soil, and vegetation. Muldavin and Tonne's (2003) plant associations were the basic units for estimating forage production values; however, TES was used to classify some monitoring sites as upland versus lowland mountain meadow or mountain valley ecological sites based on soil characteristics. TES potential forage production estimates were based on modeling, not on actual growth measurements; and some potential TES forage figures were greatly inflated compared to data derived from actual clipping and weighing of plant growth. Therefore, potential TES forage figures were considered in conjunction with data from Muldavin and Tonne (2003) in upland woodland sites only where there were no monitoring data.

The Jornada's forage production estimates were based on 3 consecutive years (2003 through 2005) of monitoring data collected at 41 permanent plots. Data were collected in 2002, but the fall data were not available at the time of this analysis. After reviewing the 2002 production information, it was determined that the addition of these data would not have made a significant difference in the estimates.

The estimates derived from the monitoring data were thought to be more accurate and representative of existing conditions than the estimated potential production recorded for TES or estimated forage production estimated for ecological sites by the NRCS. Jornada forage utilization monitoring data were collected from 2002 through 2005 in the spring prior to livestock use and again in the fall following use. Herbaceous species (total biomass) were clipped, air dried, and weighed within paired plots—one within an ungulate exclosure and one in the open. The protocol and clipping results can be accessed on the Jornada's web site, http://usda-ars.nmsu.edu/data-info/data_index.htm.

Muldavin (NMNHP at the University of New Mexico) determined vegetation associations (Muldavin and Tonne 2003) which were then mapped across the Preserve in 2005. The map was based on aerial photography from 2000 and Landsat satellite imagery from 1999 and 2001, and was designed to serve natural resources management planning activities at an operational scale of 1:24,000 with 6-meter pixels. There are 20 map units distributed among forest, shrubland, grassland, and wetland ecosystems. Each map unit is defined following a vegetation classification that was developed for the Preserve based on 348 ground plots. Data from ground plots were also sources of data for forage production when monitoring plots were absent. A forage value was calculated for each of the 20 vegetative associations (basic mapping unit).

Where vegetation associations identified by Muldavin and Tonne (2003) had utilization monitoring plots, forage production was calculated by grouping the plots to derive a minimum, typical, and maximum forage value based on actual forage weights. The typical forage was what would be available in most years with an average amount of moisture, but was not calculated as an "average" that included all production values. Because the ecosystems on the Preserve have great potential to increase production during wet years, the average would be skewed by the higher than expected production estimates. Typical forage was derived by calculating the average production excluding the extremes.

Where monitoring points were not available, an estimate of the typical forage production was obtained from TES data based on frequency of TES plots for a given amount of forage production as influenced by the dominate species recorded. For clarification, if the highest number of plots recorded produced 125 pounds of dry forage, and these plots had the dominant species found within this plant association, then 125 pounds per acre was used as the typical or assigned value for a given plant association. The high and low values for plant associations without monitoring plots were calculated using an average increase or decrease recorded from the monitoring plots located in other plant associations between a wet and dry year. For example if a monitoring plot (where forage was actually clipped and weighed) had a 90 percent increase from typical on a wet year it was assumed that the other vegetation types would have the same magnitude of increase. The master table used to attribute forage values for a GIS layer consisting of TES soil units and plant associations from Muldavin and Tonne (2003) was prepared which would lead to capacity estimates across the Preserve (Table 14).

Table 14. Forage production values for each of the plant associations mapped on the Valles Caldera National Preserve

Plant Associations	Monitoring Points	Forage Production					
		Typical		High		Low	
		Grazable Woodland	Mountain Meadow/ Mountain Valley	Grazable Woodland	Mountain Meadow/ Mountain Valley	Grazable Woodland	Mountain Meadow/ Mountain Valley
Spruce-Fir Forest and Woodland (Dry Mesic)		75	150	143	287	7	14
Spruce-Fir Forest and Woodland (Moist Mesic)		75	150	143	287	7	14
Forest Meadow		150	NA	287		14	
Mixed Conifer Forest and Woodland (Dry Mesic)	2	125	889	239	1,952	11	182
Mixed Conifer Forest and Woodland (Moist Mesic)		125	125	239		11	11
Blue Spruce Fringe Forest		125	125	239	239	11	11
Aspen Forest and Woodland (Dry Mesic)		125	802	239	2,298	11	41
Aspen Forest and Woodland (Moist Mesic)	2	125	844	239	2,298	11	6
Ponderosa Pine Forest	1	250	933	478	1,935	23	378
Gambel Oak-Mixed Montane Shrubland		150	150	287	287	14	14
Upper Montane Grassland	5	1,119	1,119	3,513	3,513	495	495
Lower Montane Grassland	20	875	1,016	2,368	3,520	144	106
Wet Meadow	8	1,504	1,504	4,464	4,464	400	400
Wetland	3	1,504	1,504	4,464	4,464	400	400
Montane Riparian Shrubland		1,667	1,667	5,503	5,503	210	210
Sparsely Vegetated Rock Outcrop		40	40	76	76	4	4
Felsenmeer Rock Field		25	NA	48		2	
Roads-Disturbed Ground		125	125	239	239	11	11
Open Water		0	0	0		0	0
Post-Fire Bare Ground		250	NA	478		23	

Since previous assessments were based on three broad ecological sites—mountain valley, mountain meadow, and grazeable woodland (a combination of pine grassland and mountain breaks)—production estimates for each of the 20 vegetation mapping units were summarized by ecological sites within each plant association. The ecological site information was generated using NRCS soil mapping units, but the scale of this mapping was coarse and likely contained errors. Muldavin and Tonne (2003) mapped on a smaller scale and ground-truthed map units, increasing accuracy. Hence, some meadow ecological sites were reported as being within the forested plant associations when under normal circumstances mountain valley and mountain meadow sites would not occur in these areas. Typical forage production values were adjusted to more accurately reflect actual conditions.

An average production coefficient was derived for each ecological site within each 6th order watershed. This coefficient was calculated based on a weighted average of the various production rates recorded in each site. For example, a watershed would have five ecological sites and each of these sites would be divided into slope break and distance from water classes. Each of these classes would have different average forage production values and each separate class would have a given amount of acres that was determined suitable for grazing. A weighted average would weight each production estimate by the amount of acres containing a particular forage value to estimate forage production for the ecological site (e.g., woodland with less than 35 percent canopy closure, mountain meadows, etc.).

Grazing Animal Carrying Capacity Methodology

The capacity was calculated two ways: (1) by assessing the current grazing program to see how well stocking rates from 2001-2005 have met the Preserve's objectives, and (2) by modeling forage production and then calculating the number of animal unit months (AUMs) that the forage should be able to carry and still meet the Preserve's objectives.

Forage Modeling Methodology

The amount of grazing animals that an area can support depends not only on the amount of forage produced, but the access to that forage as determined by availability of water and amount of slope or steepness of the terrain. Livestock prefer to use land that is generally flat and close to water. Even if there is abundant forage far away from water or on steep slopes, livestock will use it only after forage closer to water or on flatter ground is depleted, which can lead to overgrazing and lack of sustainability in some areas. The formula used for calculating available forage is [40 percent of available forage] x [distance to water factor] x [slope factor], and is similar to what has been used for past range assessments on the Preserve (Table 15).

Table 15. Factors used to determine amount of forage available

Distance to Water	Weight Factor	Percent Slope	Weight Factor
0–0.5 mile	1.0	0–10%	1.0
0.5–1 mile	0.7	11–30%	0.7
> 1 mile	Non-Suitable	31–60%	0.4
		> 60%	Non-Suitable

Land was not considered suitable for livestock or elk under the following conditions:

- Forage production was less than 250 pounds per acre[9].
- Slope was greater than 60 percent for elk, 30 percent for livestock.

Capacity Estimates

Capacity Estimates Based on Monitoring of 2002-2005 Grazing Program

Modeling can closely estimate capacity; however it is not as effective as monitoring actual stocking rates and the resulting effects on the forage resource. An environmental assessment and a decision was made in 2002 for an interim grazing program that would allow livestock stocking rates not to exceed 2,000 animal units[10] (AUs) over a 4-month period based on estimated forage production along with an adaptive monitoring program that had a target utilization rate for all herbivores not to exceed 40 percent utilization of grasses for the following four ecological sites:

- Grazeable Woodland – forests located on the mid-slopes surrounding the valles.
- Mountain Valley – the upland dry grasslands between the woodlands and the wet bottomlands.
- Mountain Meadow – wet meadow grasslands adjacent to the riparian areas.
- Riparian – grasslands within 150 feet on either side of the perennial streams.

The areas included for the interim grazing program were primarily the grasslands found in the valles and the surrounding woodland consisting of approximately 18,000 acres. These land areas are essentially the same acres that were found to be suitable for grazing based on slope and minimum production values (250 pounds/acre) in a typical year (see Lands Potentially Suitable for Livestock and Elk, page 28).

The target utilization rate for all herbivores under the interim grazing environmental assessment (EA) was 40 percent. The EA also included livestock forage allocations of 15 percent in riparian areas and 35 percent for the remaining ecological sites, but due to difficulties in distinguishing livestock use from elk use, these target rates cannot be directly measured. Forty percent is generally accepted by the scientific community to be a physiological threshold where once exceeded, may lead to physiological damage to the plant and ultimately the plant community by not leaving enough residual leaf area for photosynthesis required for carbohydrate production and nutrient storage in roots. Over-use also may not leave enough plant litter on the soil surface required for effective ground cover (Valles Caldera Trust 2002, pages 52-52).

To date the Preserve has taken a conservative approach, stocking less than 700 head of livestock in addition to the existing elk numbers, to allow for adaptive management. The Preserve has also herded animals daily to assure that utilization was not excessive in any one area. The actual livestock numbers and the estimated elk numbers plus the amount of precipitation received during the growing season are shown in Table 16 (U.S. Government Accounting Office 2005).

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[9] The 250 pound per acre threshold was recommended by the Valles Caldera Trust's staff based on professional experience. A minimum analysis was done with a lower threshold and will be discussed in the modeled capacity estimate section.

[10] Animal unit is defined as a 1,000 pound cow with a calf. The size of the cow dictates the amount of forage expected to be consumed in a month.

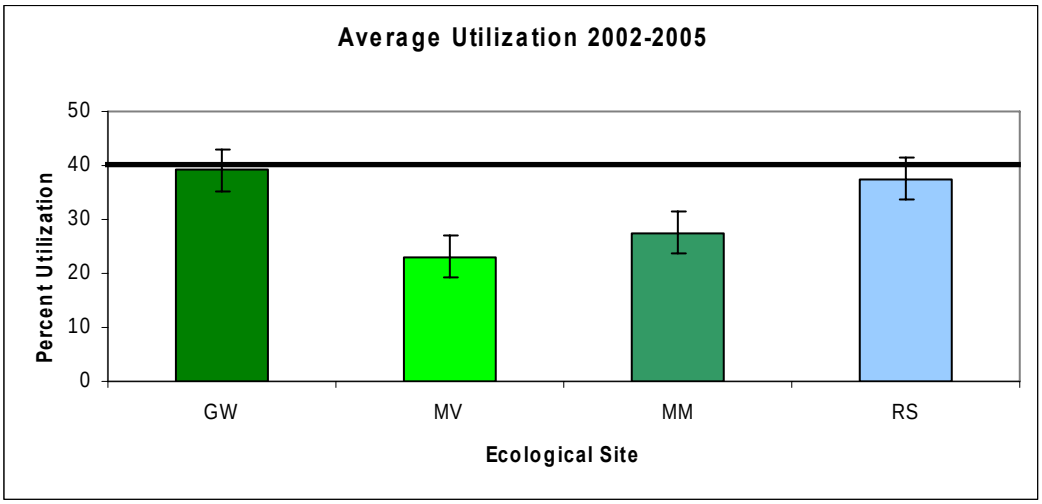
Table 16. Actual stocking levels and growing season precipitation for the years 2002–2005

	2002	2003	2004	2005
Livestock (head)[1]/ [AUMs[1]]	703 [879]	680 [2,270]	666 [2,111]	600 [1,918]
Elk (head)/ [AUMs] [2]	2,000–2,500 [7,200 – 9,000]	2,000–2,500 [7,200 – 9,000]	2,000–2,500 [7,200 – 9,000]	2,000–2,500 [7,200 – 9,000]
Precipitation (inches)	9.10 [4]	14.10	11.80	18.6

[1]AUMs (animal unit months) for livestock are based on 4 months with the exception of 2002 which is based only on 1.25 months of actual use (number of head [AU] times the number of months).
[2] Estimate of elk use during summer and fall months by New Mexico Department of Game and Fish (Kohlmann 2005). AUMs for elk are based on 6 months for each year (number of head x animal unit equivalent (0.6) x 6 months).
[4] Amount of precipitation recorded during the growing season (April 1–October 30) based on Quemazon Snotel site located in Los Alamos County (9,000 feet elevation) north of Parajito Mountian.

Based on monitoring data, existing livestock and elk stocking rates have met or exceeded overall objectives stated for the interim grazing program for the Preserve, except forage allocated to livestock. Using a 4-year averaged utilization rate for each ecological site, the overall use by both livestock and elk were less than 40 percent for each ecological site (Figure 1).

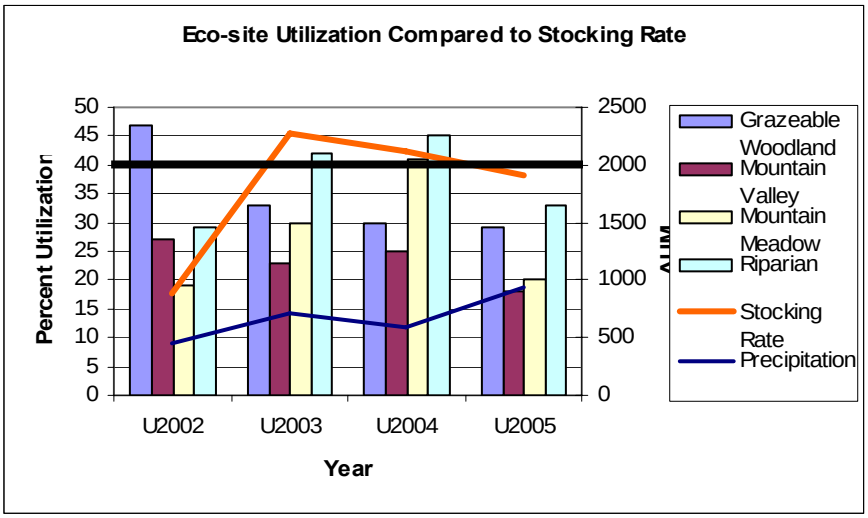
Figure 1. Average utilization by ecological site[1]



[1] GW = grazeable woodland, MV = mountain valley, MM = mountain meadow, and RS = riparian.

When the data is displayed by individual years there are some years and some ecological sites where the 40 percent threshold was exceeded (Figure 2).

Figure 2. Utilization rates by year by ecological site with stocking and precipitation rates



Research is not available to identify why utilization exceeded 40 percent in the grazeable woodland in 2002 or in the riparian in 2003 and 2004. The 40 percent threshold only serves as general guidance; achieving less than 40 percent average use in some years may help forage recover from drought or past use in over-utilized areas. The following are observations thought to be true but there is much that is unknown.

1. With the existing elk numbers, the current livestock stocking of 2,000 to 2,200 AUMs is a good estimate of the carrying capacity for the Preserve under the current herding management when 12 to 14 inches of precipitation is received during the growing season. Protection can be provided to riparian and mountain meadow areas by herding and luring livestock away from riparian and mountain meadow areas. Stocking 2,000 head of livestock annually (the upper limit within the interim grazing assessment), when considered with the existing elk numbers, would likely be unsustainable in meeting the objective to not exceed 40 percent forage utilization.

2. The livestock target forage allocations (15 percent in riparian areas and 35 percent for the remainder of the Preserve) are not useful for monitoring during the grazing season to time livestock movements because of the difficulty of separating livestock use from elk use. However, the proportion of AUMs currently being grazed indirectly indicates that elk are consuming a significant part of this allocation.

3. Livestock use was so light in 2002 that the overuse in the grazeable woodland can probably be attributed to elk (in combination with dry conditions). With moisture being below what would be considered a typical year, a greater number of elk (AUMs) likely remained on the Preserve during the winter. There has been no reoccurrence of this overuse.

4. With forage used primarily by elk (5,000 to 6,250 AUMs) in 2002 (a dryer year), riparian utilization rates remained below 40 percent. Although an increase in moisture occurred, the increase in livestock numbers in 2003 from 879 to 2,270 AUMs increased the use in the riparian corridor (150 feet on either side of the stream) to above 40 percent.

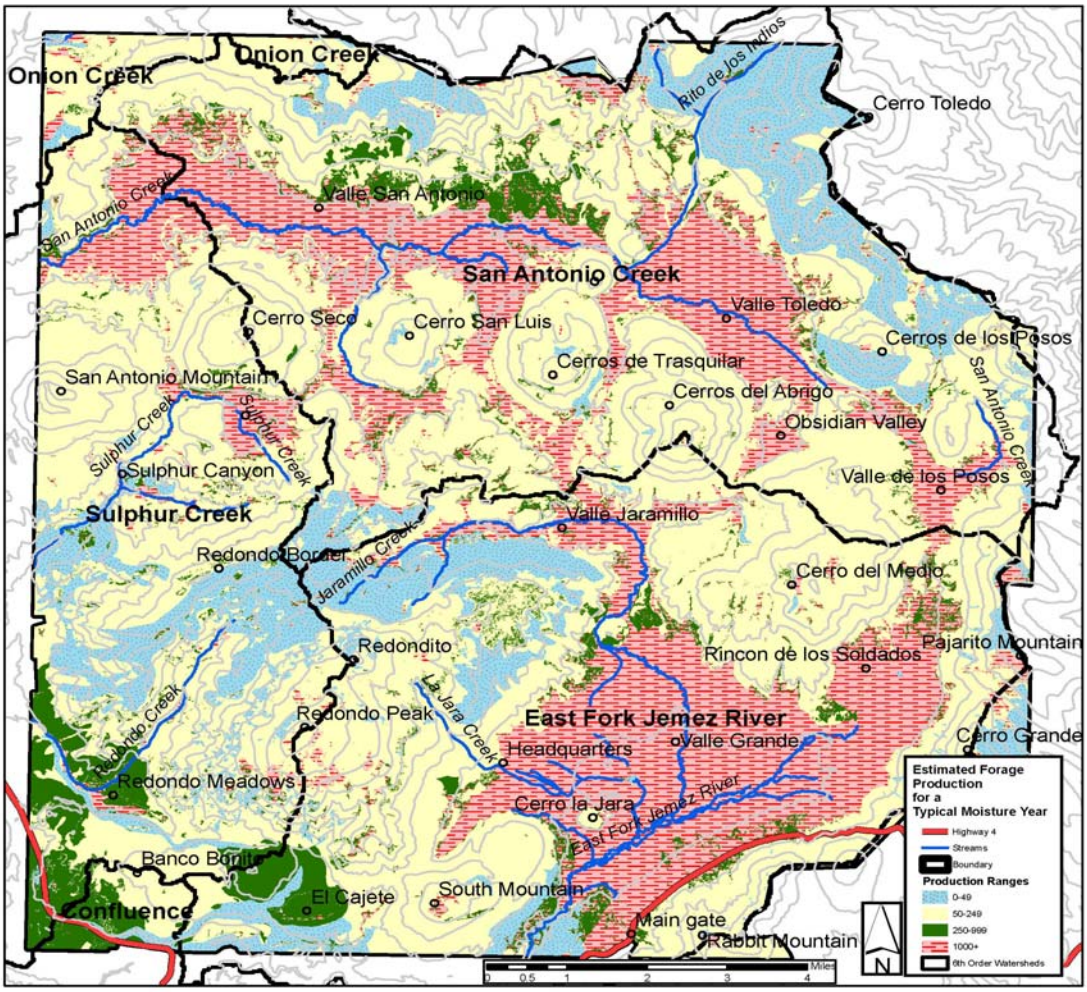
5. Actual use by elk will increase during dry years because more elk remain on the Preserve during the winter. In addition, a decrease in production as a result of climate may further increase the actual percent of forage utilized. With a decrease in moisture from 14.1 to 11.8 inches during the growing season, but essentially keeping the same approximate stocking (both elk and livestock), riparian and mountain meadow exceeded the 40 percent threshold.

6. Increasing the moisture from 11.8 to 18.6 inches showed that the current stocking of 1,918 AUMs of livestock and 5,000 to 6,250 AUMs of elk was well below what the forage could support, and remain below the 40 percent threshold. There was heavy snowfall in 2004/2005; elk moved off the Preserve during that winter which lead to a decrease in elk AUMs and a corresponding decrease in forage utilization in the early spring and late fall. Although carrying capacity increases during wetter years, stocking rates should not necessarily increase to the full extent. The benefits of light grazing are well documented (Holechek et al. 1999).

7. In the EA discussion for elk and livestock, it was stated that forage outside of the areas where livestock were to be stocked was available for elk. However, this is not necessarily true: Elk preference is for the same habitat targeted for livestock grazing—primarily the grasslands associated with the valles and the surrounding woodlands. Any proposal of utilizing more of the grasslands for livestock and expecting elk to move to other habitat would likely fail resulting in overgrazing. A program of vegetation management may result in a minor increase of the dispersal of elk into areas that have experienced recent conifer encroachment; however, livestock utilization may increase in those areas as well. The same efforts would not significantly increase the dispersal of elk into more forested areas of the preserve, because the potential quantity and quality of the forage in the forested environments is not adequate to support large numbers of ungulates. Forage preference for elk would likely remain in the more productive grasslands where high quality forage is more abundant.

Modeled Capacity Estimates

Forage production is based not only on how much precipitation is received during a year, but also what time of year that precipitation is received. An animal unit defines forage consumption on the basis of one standard mature 1,000 pound cow, either dry or with calf up to 6-months old. An AUM is the amount (800 pounds) of air-dry forage calculated to meet one animal unit's requirement for 1 month (Ruyle and Ogedn 1993). For this model 900 pounds was used to remain consistent with previous modeling conducted by the Preserve. An elk requires less forage; therefore, stocking for elk will be based on an animal equivalent of 0.6 AUM (USDA Natural Resources Conservation Service 2003). Refer to Map 4 for forage production in a typical year. Table 17 shows forage production and capacity in AUMs calculated for what would be considered a typical year, a year with low production such as a dry year, and a year with high production.



Map 4. Categories of forage production within 6th order watersheds

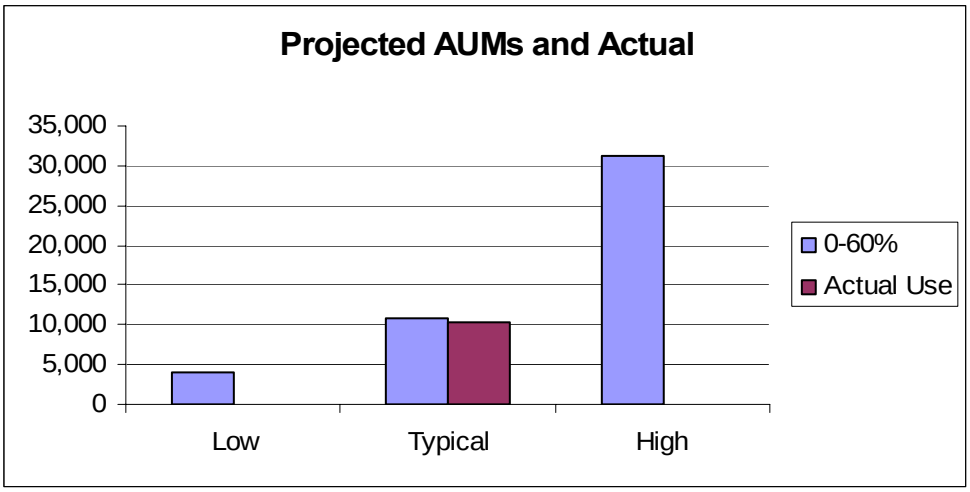
Table 17. Forage production and the estimated AUMs this amount of forage can carry on a sustainable basis

Eco-Site	San Antonio	EastFork Jemez	Confluence	Onion Creek	Sulfur Creek	Blank	Totals	AUMs
Typical								
<35% 0-60% slope	584,855.952	285,713.868	442.936	41,220.266	244,037.552	7,872.360	1,164,142.934	1,293.492
<35% 0-30% slope	337,263.402	266,741.663	442.186	41,143.563	213,632.158	6,976.347	866,199.319	962.444
>35% 0-60% slope	4,421.332	36,259.236	329.665		63,336.501		104,346.734	115.941
>35% 0-30% slope	4,053.540	34,373.380	279.769		58,144.997		96,851.686	107.613
MM 0-60% slope	701,447.994	2,263,649.618			94,237.429		3,059,335.041	3,399.261
MM 0-30% slope	693,786.702	2,253,588.166			92,465.528		3,039,840.396	3,377.600
MV 0-60% slope	2,264,072.057	1,807,607.631			513,702.390		4,585,382.079	5,094.869
MV 0-30% slope	2,246,737.917	1,801,220.988			510,906.471		4,558,865.376	5,065.406
Rip 0-60% slope	295,894.024	528,270.798		1,509.331	115,334.576		941,008.728	1,045.565
Rip 0-30% slope	290,406.169	526,818.401		1,509.331	111,180.417		929,914.318	1,033.238
Total Forage	**3,850,691.359**	**4,921,501.150**	**772.601**	**42,729.597**	**1,030,648.449**	**7,872.360**	**9,854,215.516**	
AUMs 0 - 60% slope	**4,278.546**	**5,468.335**	**0.858**	**47.477**	**1,145.165**	**8.747**		**10,949.128**
Forage 0-30% slope	**3,572,247.731**	**4,882,742.598**	**721.955**	**42,652.894**	**986,329.570**	**6,976.347**	**9,491,671.095**	
AUMs 0-30% slope	**3,969.164**	**5,425.270**	**0.802**	**47.392**	**1,095.922**	**7.751**		**10,546.301**
Low								
<35% 0-60% slope	271,678.323	133,178.771	394.645	18,296.108	113,340.380	3,561.628	540,449.856	600.500
<35% 0-30% slope	249,262.461	124,323.552	393.987	18,262.061	99,144.156	3,157.010	494,543.227	549.492
>35% 0-60% slope	0.000	0.000	0.000		0.000		0.000	0.000
>35% 0-30% slope	0.000	0.000	0.000		0.000		0.000	0.000
MM 0-60% slope	248,775.021	776,734.092			35,244.195		1,060,753.308	1,178.615
MM 0-30% slope	245,974.654	773,268.279			34,576.855		1,053,819.788	1,170.911
MV 0-60% slope	842,762.362	688,568.742			199,446.347		1,730,777.452	1,923.086
MV 0-30% slope	835,716.081	686,130.183			198,359.418		1,720,205.683	1,911.340

Eco-Site	San Antonio	EastFork Jemez	Confluence	Onion Creek	Sulfur Creek	Blank	Totals	AUMs
Rip 0-60% slope	89,166.374	159,192.845		615.460	39,497.656		288,472.333	320.525
Rip 0-30% slope	87,495.830	158,754.533		615.460	38,047.380		284,913.202	316.570
Total Forage	1,452,382.081	1,757,674.449	394.645	18,911.568	387,528.578	3,561.628	3,620,452.949	
AUMs 0 - 60% slope	1,613.758	1,952.972	0.438	21.013	430.587	3.957		4,022.725
Forage 0-30% slope	1,418,449.026	1,742,476.548	393.987	18,877.520	370,127.809	3,157.010	3,553,481.900	
AUMs 0-30% slope	1,576.054	1,936.085	0.438	20.975	411.253	3.508		3,948.313
High								
<35% 0-60% slope	1,538,546.049	571,066.966	998.221	100,567.516	582,320.583	24,104.764	2,817,604.099	3,130.671
<35% 0-30% slope	1,416,579.239	533,143.417	996.532	100,380.324	518,227.669	21,421.255	2,590,748.436	2,878.609
>35% 0-60% slope	5,197.496	51,403.246	558.613		95,166.199		152,325.553	169.251
>35% 0-30% slope	4,765.893	48,776.046	474.420		87,540.247		141,556.606	157.285
MM 0-60% slope	2,011,572.726	6,941,511.902			298,353.487		9,251,438.115	10,279.376
MM 0-30% slope	1,989,143.843	6,910,757.962			292,764.566		9,192,666.371	10,214.074
MV 0-60% slope	6,018,936.417	5,434,494.012			1,593,639.584		13,047,070.014	14,496.744
MV 0-30% slope	5,968,959.340	5,415,324.137			1,585,009.472		12,969,292.949	14,410.325
Rip 0-60% slope	873,040.434	1,582,389.180		5,110.403	296,536.855		2,757,076.871	3,063.419
Rip 0-30% slope	857,048.664	1,578,055.756		5,110.403	286,087.495		2,726,302.319	3,029.225
Total Forage	10,447,293.122	14,580,865.306	1,556.834	105,677.919	2,866,016.707	24,104.764	28,025,514.652	
AUMs 0 - 60% slope	11,608.103	16,200.961	1.730	117.420	3,184.463	26.783		31,139.461
Forage 0-30% slope	10,236,496.979	14,486,057.318	1,470.952	105,490.727	2,769,629.449	21,421.255	27,620,566.681	
AUMs 0-30% slope	11,373.886	16,095.619	1.634	117.212	3,077.366	23.801		30,689.519

Actual stocking rates for both elk and livestock during 2003 was 2,270 AUMs of livestock and an estimated 7,200 to 9,000 AUMs of elk (see Table 16). This is thought to be a typical moisture year with approximately 14 inches of precipitation during the growing season. This indicates that actual stocking (9,470 – 11,270 AUMs) was almost the same as the modeled capacity of the Preserve (10,949 AUMs). Assuming elk and cattle were congregating on slopes 0 to 30 percent (which is a safe assumption), the Preserve was very close to meeting the modeled capacity for these slopes (10,546 AUMs). Utilization data indicate that the capacity was generally not exceeded except in the riparian areas. More active herding or establishment of water/salt/mineral sources in the upland grasslands could alleviate this overgrazing and shift use to other ecological sites. Based on the monitoring data, which are supported by modeling, the Preserve is close to the maximum number of livestock with the existing number of elk. Total modeled capacity and actual use (using a median elk use) during a year with approximately 15 inches of precipitation during the growing season is show in Figure 3.

Figure 3. Total modeled capacity and actual use during a year with approximately 15 inches of precipitation during the growing season



Most of the Preserve is covered by forest vegetation with reduced forage production as compared to the valles. The greatest number of acres within a production category consisted of acres producing 125 to 225 pounds per acre (see map 4). In fact 28,678 acres contained this production value. These production values occur in dispersed pockets of forage within the forests on thin soils that do not share the productive capacities of the deeper soils associated with the valles. The productivity of these areas would be difficult to sustain if use by domestic livestock was assigned and animals were actively herded throughout the forest interior. Therefore, the 250 pound per acre threshold for determining suitability appears to be reasonable and realistic.

Literature Cited

Barnes, W.J. 2001-2005. Valles Caldera National Preserve rangeland and riparian monitoring metadata, data summary tables. Unpublished data tables, Valles Caldera Trust.

Burke, I.C.; W.K. Lauenroth; M.Vinton; P.B. Hook; R.H. Kelly; H.E. Epsttein; M.R. Aguiar; M.D. Robles; M.O. Aguilera; K.L. Murphy; and R.A. Gill. 1998. Plant-soil interactions in temperate grasslands. Biogeochemistry 42: 121-143.

Clary, W.P.; and Webster, Bert F. 1989. Managing grazing of riparian areas in the Intermountain Region. Gen. Tech. Rep. INT-263. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 11 p.

D'Antonio, C.M.; N.E. Jackson; C.C. Horvitz; and R. Hedberg. 2004. Invasive plants in wildand ecosystems: Merging the study of invasion processes and management needs. Frontier Ecological Environment 2(10): 513-521.

Elliot, W.J.; D.E. Hall; and S.R. Graves. 1999. Predicting sedimentation from forest roads. Journal of Forestry 97: 23-29.

Hans, J. 1996. Factors of soil formation: A system of quantitative pedology. Courier Dover Publications, Toronto, Ontario. 197 p.

Havstad, K. 2002. Report on rangeland assessment and potential grazing capacity for Valles Caldera National Preserve. Unpublished report, Jornada Experimental Range. 8 p.

Herrick, J.E.; J.R. Brown; A.J. Tugel; P.L. Shaver; and K.M. Havstad. 2002. Application of soil quality to monitoring and management: Paradigms from rangeland ecology. Agronomy Journal 94: 3-11.

Holecheck, J.L., H. Gomez, F. Molinar, and D. Galt. 1999. Grazing studies: what we've learned. Rangelands 21(2).

Jones, J.A. and G.E. Grant. 1996. Peak flow responses to clear-cutting and roads in small and large basins, western Cascades, Oregon. Water Resources Research 32(4): 959-974.

Knops, J.M.; H D. Tilman; N.M. Haddad; S. Haeem; C.E. Mitchell; J. Haarstad; M.E. Ritchie; K.M. Howe; P.B. Reich; E. Siemann; and J. Groth. 1999. Effects of plant species richness on invasion dynamics, disease outbreaks, insect abundance, and diversity. Ecology Letters 2: 286-293.

Kohlmann, S.G. 2005. A synopsis of elk population data and some management suggestions for the Valles Caldera National Preserve. New Mexico Department of Game and Fish, unpublished paper. 4 p.

Lutgen, E.R. and M.C. Rillig. 2004. Influence of spotted knapweed (*Centaurea maculosa*) on management treatments on arbuscular mycorrhizae and soil aggregation. Weed Science 52: 172-177.

McWilliams, S. 2000a. Watershed condition summer of 2000. Baca Location 1 Purchase, Valle Caldera National Preserve. Internal report, Valles Caldera National Preserve. 60 p.

McWilliams, S. 2000b. Terrestrial ecosystem survey interim work for Valle Caldera National Preserve (no metadata available).

McWilliams, S. 2006. Watershed Condition Summer of 2006. NM Cadre of the Creeks and Community Strategy, Valles Caldera National Preserve. Unpublished report, Valles Caldera Trust. 23 p.

Mulchavans, D.G. 2006. Responses of plant communities to grazing in the southwestern United States. Gen. Tech. Rep. RMRS-GTR-169. Fort Collins, CO: USDA Forest Service, Rocky Mountain Research Station. 126 p.

Muldalvin, E.; P. Neville; C. Jackson; and T. Neville. 2005. A vegetation map of Valles Caldera National Preserve, New Mexico. Final report and supporting data. New Mexico Natural Heritage Program. 27 p.

Muldavin E. and P. Tonne. 2006. A vegetation survey and preliminary ecological assessment of Valles Caldera National Preserve, New Mexico. Unpublished report, Valles Caldera Trust. 73 p.

Napper, C.O. 2001. Cumulative watershed effects – Battle Creek. Analysis of beneficial uses and water quality criteria to evaluate CWE susceptibility. USDA Forest Service, Lassen NF, Susanville, CA. 22 p.

Natural Resource Conservation Service. Date unknown. Soil survey of Sandoval County area, New Mexico. Draft copy of the partial manuscript of the soil survey of Los Alamos County and the majority of Sandoval County, NM. 872 p.

National Riparian Service Team. 2002. Valles Caldera riparian report, Valles Caldera National Preserve, October 2-4, 2001. Unpublished report for the Santa Fe National Forest. 26 p.

New Mexico Environment Department. 2002. Total maximum load (TMDL) report for the Jemez river watershed. Surface Water Quality Bureau, TMDL Development Section.

New Mexico Department of Game and Fish. Date unknown. Elk management in New Mexico, an introduction. Unpublished report compiled by Stephan Kohlmann. 45 p.

Norton, J.B.; T.A. Monaco; J.M. Norton; D.A. Johnson; and T.A. Jones. 2003. Soil morphology and organic matter dynamics under cheatgrass and sagebrush-steppe plant communities. [2004]. Journal of Arid Environments 57: 415-466.

Pellant, M.; P. Shaver; D.A. Pyke; and J.E. Herrick. 2005. Interpreting indicators of rangeland health, version 4. Technical reference 1734-6. USDI, BLM, National Science and Technology Center, Denver, CO. BLM/WO/ST-00/001+1734/REV05. 122 p.

Powers, R.; D.A. Scott; F.G. Sandchez; R.A. Voldseth; D. Page-Dumroese; J.D. Elioff; and D.M. Stone. 1999. The North American long-term soil productivity experiment: Findings from the first decade of research. Forest Ecology and Management 220: 31-50.

Prichard, D.; J. Anderson; C. Correll; J. Fogg; K.Gebhardt; R. Krapf; S. Leonard; B. Mitchell; and J. Staats 1998. Riparian area management; A user guide to assessing proper functioning condition and the supporting science for lotic areas. Tech. Ref. 1737-15. Denver, CO; U.S. Department of the Interior, Bureau of Land Management, National Applied Resource Sciences Center.

Pyke, D.A.; J.E. Herrick; P. Shaver; and M. Pellant. 2002. Rangeland health attributes and indicators for qualitative assessment. Journal of Range Management 55: 584-597.

Ruyle, G. and P. Ogden. 1993. What is an A.U.M.? *In:* Gum, R.; G. Ruyle; and R Rice; eds. Arizona ranchers' management guide. AZ Cooperative Extension Service.

Stacey, P.B.; A.L. Jones; J.C. Catlin; D.A. Duff; L.E. Stevens; and C. Gourley. 2006. User's guide for the rapid assessment of the functional condition of stream-riparian ecosystems in the American southwest. University of New Mexico. 56 p.

Sublette, James E, James E Hatch, D. Micheal, and Mary Sublette. 1990. The Fishes of New Mexico. UNM Press.

Strenger, S. 2006. [Personal Communication]. USDA Forest Service soil scientist. Discussion on current mapping on the Preserve and observations of perched water tables.

Thorpe, A.S; Archer, V.; and T.H. DeLuca. 2006. The invasive forb, *Centaurea maculosa*, increases phosphorus availability in Montana grasslands. Applied Soil Ecology 2(1): 118-122.

Trombulak, S.C. and C.A. Frissell. 2000. Review of ecological effects of roads on terrestrial and aquatic communities. Conservation Biology 14(1): 18-30.

U.S. Government Account Office. 2005. Valles Caldera, Trust has made some progress, but needs to do more to meet statutory goals.GAO-06-98.

USDA and NRCS. 2006. Field indicators of hydric soils. A guide for identifying and delineating hydric soils. Version 6.0. G.W. Hurt and L.M. Vasilas; eds. USDA, NRCS, in cooperation with the National Technical Committee for Hydric Soils. 47 p.

USDA Forest Service. 1987. Santa Fe National Forest Plan (as amended). Santa Fe NF, Region 3, Santa Fe, NM. 235 p.

USDA Forest Service. 1993. Santa Fe National Forest terrestrial ecosystem survey. Santa Fe National Forest, Region 3, Santa Fe, NM. 539 p.

USDA Forest Service. 2000. Terrestrial ecosystem survey. Unpublished report. Santa Fe NF.

USDA Forest Service. 2002a. East Fork Jemez River stream inventory report. Unpublished report by James Simino, Santa Fe National Forest. 75 p.

USDA Forest Service. 2002b. WSA findings interium grazing environmental document Valles Caldera National Monument. Unpublished report by S. McWilliams, Santa Fe NF. 7 p.

USDA Forest Service. 2003. San Antonio stream inventory report. Unpublished report by Damon Goodman, Santa Fe NF. 122 p.

USDA Forest Service. 2004. Stream condition core GIS coverage to depict and label streams. Santa Fe NF, Santa Fe, NM.

USDA Forest Service. 2006. Unpublished field data summary for years 2004, 2005, USFS and NRCS terrestrial ecosystem survey for the Valle Caldera. R3, Ecosystem analysis and

Planning, Terrestrial Ecosystem Inventory Project. Data available upon request. Albuquerque, NM.

USDA Natural Resources Conservation Service. 2003 National Range and Pasture Handbook. Grazing Lands Technology Institute. Issued 1997, revised 2003.

Valles Caldera Trust. 2000. Benthic survey summary for Jaramillo Creek, Rio de los Indios, East Fork of Jemez River, and San Antonio Creek. Unpublished summary. 1 p.

Valles Caldera Trust. 2002. Environmental assessment for the interim grazing strategy. Unpublished EA. Jemez Springs, NM. 17 p.

Valles Caldera Trust. 2003. Valles Caldera National Preserve. Framework and strategic guidance for comprehensive management. 158 p.

Valles Caldera Trust. 2006. Range readiness analysis for VCT livestock program for summer, 2006. Unpublished report. 18 pp.

Vieira, N.K.M. and B.C. Kondratieff. 2004, unpublished. Survey of selected aquatic insect taxa of the Valles Caldera National Preserve, Sandoval County, New Mexico – stoneflies (*Plecoptera*), mayflies (*Ephemeroptera*), caddisflies (*Trichoptera*), dragonflies and damselflies (*Odonata*), beetles (*Coleoptera*) and true bugs (*Hemiptera*). 74 p.

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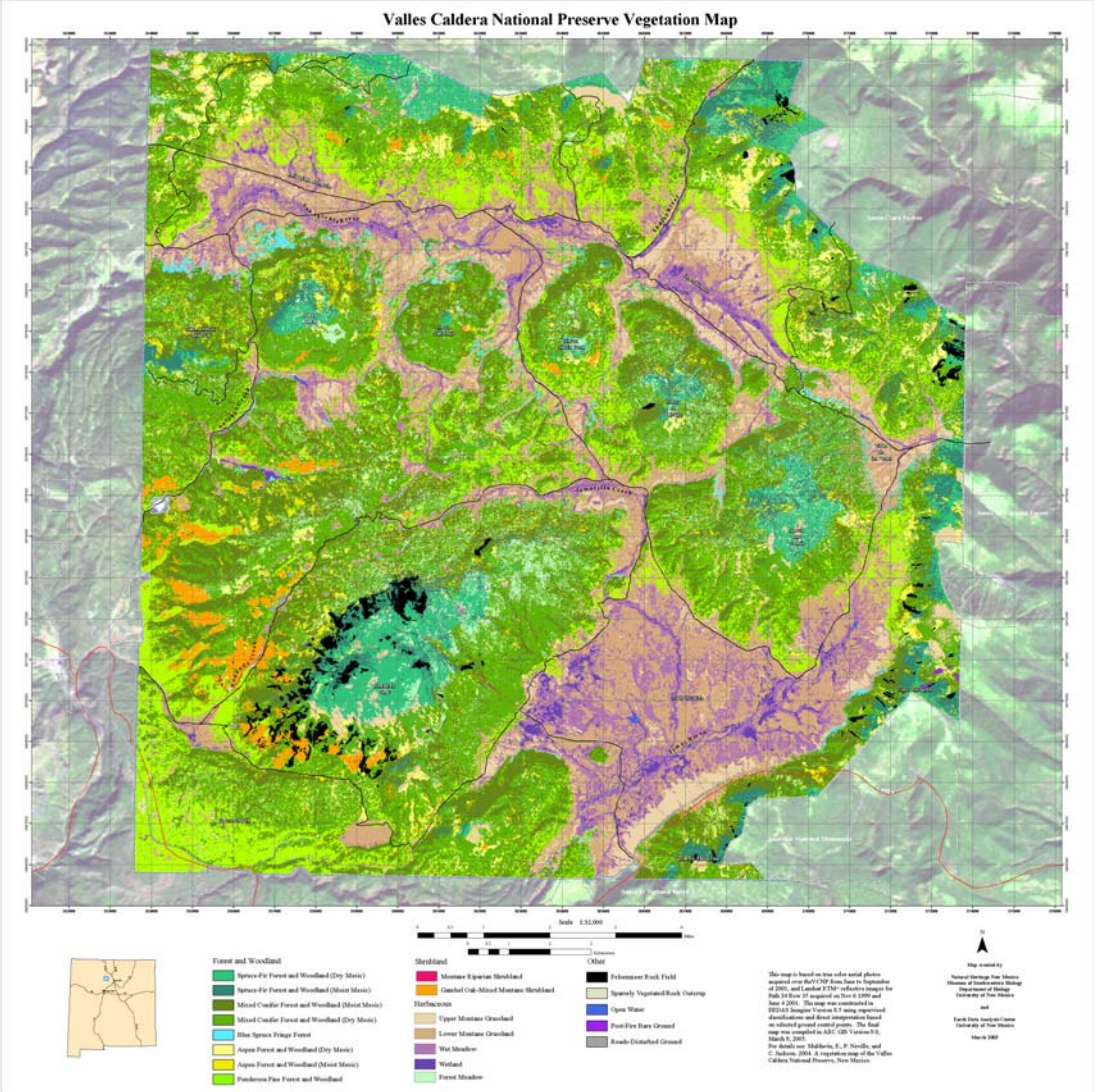
Appendix A

The information below is a condensed summary of current vegetation information gathered largely from Muldalvin and Tonne (2003) and Muldalvin et al. (2005) (Map 5), and others; and through communication with resource staff affiliated with the recent vegetation and inventory surveys.



Map 5. Vegetation types found throughout the Valles Caldera National Preserve

Climate

The regional climate is considered semi-arid continental. The climate is characterized by cold, wet winters in which most of the precipitation is received as snow. On average, summer rainfall peaks in August with a drying trend as fall approaches. The balance of the precipitation is received in the summer months, some of it in the form of high intensity thunderstorms. Average annual precipitation is about 22 inches but ranges from 16 to 30 inches and yearly fluctuations are common. The average frost-free period is about 80 days, but ranges from 60 days at the highest elevations to 110 days at the lowest elevations; however, the period lengths vary. The average last-killing frost in the spring occurs about June 10. The average first-killing frost in the fall occurs about September 20. Average annual air temperature is 22.6 degrees F in January and 64.5 degrees F in July, with extremes ranging from -40 degrees F to 95 degrees F (NRCS 2006).

Vegetation

Much of vegetation information was compiled from a recently completed vegetation inventory by Muldalvin and Tonne (2003) and Muldalvin et al. (2005). Additional information was taken from McWilliams (2000, 2002) landscape assessments, Havstad (2002) range assessment, and the USFS Stream Inventory Reports for San Antonio Creek and the East Fork Jemez.

The physiographic setting strongly influences the current vegetation assemblage. The Preserve encapsulates the caldera rim with volcanic domes from more recent resurgence from the collapsed caldera floor. The steep-sided domes give way to remnant old lakebed sediments along valley bottoms. Broad grasslands have taken hold along the colluvial footslopes and valley bottoms. Hillslopes primarily support mixed species coniferous forests. Upland grasslands occur near plateau summits on volcanic domes and the caldera rim. The unique combination of high elevation, contrasting mafic and sedimentary-based soils, in addition to vegetative influences from the southern Rocky Mountains, provides for a diverse assemblage of plant communities. Muldalvin and Tonne (2003) described 65 plant associations for the Preserve. The dominantly grassland lowlands also have unique wetland attributes. Major forest and grassland types include: high elevation sub-alpine forests, mixed conifer forests, open foothill pine woodlands, high montane grasslands, and valley floor wetlands. This assemblage of plant communities makes the Preserve one the most diverse sites in the Southern Rocky Mountains Ecoregion that extends from southern Wyoming to northern New Mexico (Muldavin and Tonne 2003).

The Preserve does show signs of the past resource extraction history, with the most notable influence from past timber harvest. Of the estimated 65,000 acres of forest land, roughly 40,000 acres were logged from the 1920s to 2000 (Muldalvin and Tonne 2003). The logging included selective and clearcut practices that primarily occurred in the 1960s and early 1970s (VCNP 2002).

Forests

The Preserve forests have diverse mixed conifer species along with quaking aspen intergrades. Approximately 59,356 acres (67 percent) of the Preserve are forested. Upper elevations over 10,000 feet are dominated by Engelmann spruce (*Picea engelmannii*) forests with corkbark fir (*Abies lasiocarpa* var. *arizonica*). Lower elevations have rich mixed conifer forests, though may vary in species influence based on aspect and elevation. Species within this mixed conifer zone include Douglas-fir (*Psuedotsuga meziesii*), white fire (*Abies concolor*), blue spruce (*Picea pungens*), southwestern whitepine (*Pinus strobiformis*), limber pine (*Pinus flexilis*) and ponderosa pine (*Pinus ponderosa*). Lower elevations of these mixed conifer stands are dominated by ponderosa pine. Northern aspects of this lower elevation mixed conifer forest have blue spruce

(*Picea pungens*) increasing, especially along grassland fringes. Though aspect may influence the forest species composition, many areas have both mesic and zeric species. Engelmann spruce may co-occur along with ponderosa pine. Old logged or burned areas typically have prominent quaking aspen (*Populus tremuloides*) growth or shrubland dominated by Gambel oak (*Quercus gambelii*) on warm aspects. There are also small occurrences of pinyon pine (*Pinus edulis*) woodlands within the ponderosa pine zone (Muldavin and Tonne 2003).

The spruce-fir forests on the Preserve are cold forest types near their southern limit for the Rocky Mountain Province. Spruce-fir forests are mapped for 7,780 acres (9 percent) of the Preserve. These forests are not tolerant of fire, though the fire interval may be from 30 to 250 years. Conifer regeneration is mostly corkbark fir since Engelmann spruce need either soil disturbance or lighter duff levels for establishment. Spruce-fir forests generally have less than 10 percent herbaceous cover. High elevation north or northeast slopes may have almost no herbaceous cover. Understories may have conifer regeneration or are dominated by whortleberry (*Vaccinium myrtillus*) (Muldalvin and Tonne 2003).

Among the spruce-fir forests, increased herbaceous cover may occur along sparse northern ridges, montane meadow fringes, or most predominantly on low-sloped mesic areas. The latter is described by the Engelmann spruce/forest fleabane plant association and has herbaceous cover around 30 percent. The Engelmann spruce/Parry's oatgrass plant association is not common, perhaps due to suppressed natural fire. The Engelmann spruce/Dryspike sedge plant association has low herbaceous cover with roughly 10 percent herbaceous cover (Muldalvin and Tonne 2003).

Quaking aspen may succeed the spruce-fir forests following disturbance. These forests are mapped as 5,103 acres (6 percent) of The Preserve. The understory may be dominated by a luxurious forb mat, kentucky bluegrass (*Poa pratensis*) in old logged areas, or with stronger native grass influences. Mesic aspen areas may have herbaceous cover up to 60 percent, while dry sites have greater graminoid cover (up to 80 percent). Dominant graminoid species are Kentucky bluegrass, Thurber's fescue, and Parry's oatgrass (Muldalvin and Tonne 2003).

The mixed conifer forests have much greater variety of conifer and understory species. These forests are dominated by white-fir on the cooler, more mesic areas; and Douglas-fir on the drier sites. The total mapped acreage for mixed conifer forest is 35,791 acres (40 percent) of the Preserve. Of this, 21,828 acres (25 percent) of the Preserve are a dry forest type. The mesic sites have fire-intolerant species mixes with white-fir and blue spruce common. Drier sites favor the less shade tolerant, though greater drought and fire tolerant Douglas-fir. However, absence of fire has increased the amount of white fir in these dryland sites. Southwestern white pine and limber pine only dominate along very dry rocky sites, scattered throughout in low numbers. Blue spruce co-occurs throughout, though dominates along the grassland fringes, but usually no more than 30 meters wide. Muldalvin and Tonne (2003) suggest the expansion of these into the grassland may be held back by the heavier textured grassland soils.

The typical understories for these mixed conifer sites are dominated by either conifer regeneration or shrubs. Herbaceous cover increases along rocky ridges, montane meadow, and grassland fringes. Primary forest understory species are fleabane, Fendler's meadow-rue, bigtooth maple, and dryspike sedge. Primary dry forest understory species are Oregon grape (*Mahonia repens*), dryspike sedge (*Carex siccata*), and common juniper (*Juniperus communis*). Using the vegetation mapping plot data (Muldalvin et al. 2005), the average herbaceous cover is roughly 20 percent. Plant associations that have high amounts of herbaceous cover of grass and forbs are secondary components Douglas fir/Fringed Brome and inclusions of Quaking Aspen/Thurber

Fescue with herbaceous cover averaging 50 percent. Amongst old harvest areas where Kentucky bluegrass is predominant, grass cover was observed at 80 percent (Muldlavin et al. 2005).

Ponderosa pine increases along drier sites and lower elevation. These forests are mapped for 9,240 acres (10 percent) of the Preserve. Much of these forests make up the "grazeable woodlands" ecotype (VCNP 2002). These stands are the most resistant to frequent low intensity fire. Typically, these ponderosa stands are open savannahs with understory grasses of Parry's oatgrass and Arizona fescue. Additional graminoid cohorts include Thurber fescue, prairie junegrass, and Kentucky bluegrass. Shrubs increase with elevation and slope. In these areas, grassland forbs persist, though grasses decrease in cover. Upland stands may have common juniper along toe slopes of Redondo Peak and elsewhere have trumpet gooseberry (*Ribes leptanthum*) and Woods' rose (*Rosa woodsii*).

Encroachment of ponderosa pine into grassland margins is common in some areas of the preserve. The encroachment may be a combination of lack of fire and selective grazing of grasses on these poorer soils. In addition, Muldalvin and Tonne (2003) describe separate associations with gambel oak and Arizona fescue not linked to the valle grasslands. In these areas, ponderosa recruitment is forming dense doghair clumps with low representation of gambel oak and Arizona fescue. This plant association may also be due to lack of fire.

Gambel oak woodlands and shublands account for 1,443 acres (2 percent) of the Preserve. These shrublands usually are associated with past disturbance from fire or logging of mixed conifer forests, especially in the southwest quadrant of the Preserve. Other shrubs can include New Mexico locust (*Robinia neomexicana*) and common chokecherry (*Prunus virginiana*). These shrublands typically have sparse herbaceous layers, though dry, warm aspects of upper slopes and ridges may have mountain muhly (*Muhlebergia montana*) and blue grama (*Bouteloua gracilis*). Along Alamo canyon, greater forbs and grass are associated with gambel oak where Kentucky bluegrass co-occurs. Grass cover in these areas can approach 80 percent (Muldalvin and Tonne 2003).

Grasslands

The estimated 17,563 acres (20 percent) of the Preserve is montane grasslands in the valle bottoms. Within these valles, an additional 6,852 acres, 7 percent of the Preserve, is wetland and wet meadow. Together these grasslands represent some of the largest and highest quality occurrences of ecological function and biodiversity within the ecoregion. The grasslands of the Preserve fall into two broad categories: (1) Montane Valley Grasslands dominated by upland grasses and forbs; and (2) Montane Wet Meadows and Wetlands of valley bottoms dominated by facultative and obligate wetland grass and grass-like (graminoid) species (Muldavin and Tonne 2003). Forest meadows cover 2,293 acres (3%) of the preserve; these meadows are commonly associated with disturbance from clearcut logging where Kentucky bluegrass predominates.

Montane Valley Grasslands

Montane Valley Grasslands make up the majority of the grasslands on the Preserve, dominating the expansive lower elevation valles, but also occurring at higher elevations along the caldera rim and in small interior mountain valleys. Despite their seemingly high abundance on the Preserve, montane grasslands are relatively uncommon in New Mexico. On the Preserve five major Montane Valley Grassland alliances were identified based on relative dominance: the Parry's Oatgrass, Thurber Fescue, Arizona Fescue, Pine Dropseed, and Kentucky Bluegrass Alliances.

Overall, these are highly diverse communities, with over 125 species of grasses and forbs recorded (Muldavin and Tonne 2003).

The high elevation grasslands and upper piedmont slopes along the forest and woodland edges of lower elevation valleys are commonly dominated by Parry's Oatgrass associations. The two co-dominants of the Parry's Oatgrass/Thurber Fescue association can approach 70 to 90 percent canopy cover. Although Arizona fescue or other grasses may be present, they are clearly subordinate. An association of Parry's Oatgrass/Arizona Fescue does occur on ridge and mountain valley sites, but under seemingly drier conditions. The combined cover of Arizona fescue and Parry's oatgrass in this association can exceed 80 percent, and the combination of grass and forb cover can approach 100 percent. Both associations are highly diverse assemblages, with over 50 species of grasses and forbs recorded so far (Muldavin and Tonne 2003).

The Thurber Fescue/ Letterman's Needlegrass association was identified in small drainages of the eastern piedmont of the Valle Grande where Parry's oatgrass is absent, though present in the adjacent sites. Further down the slopes both Parry's oatgrass and Thurber fescue diminish and Arizona fescue becomes more dominant. Three Arizona fescue plant associations tend to separate out by aspect and geomorphology. The Arizona Fescue/Mountain Muhly association is found on northerly facing slopes, while the Arizona Fescue/Blue Grama association tends to be on southerly slopes. The Arizona Fescue/Pine Dropseed association occurs along the lower piedmont slopes and on the mid-valley benches and terraces where it often grades into pine dropseed-dominated types (Pine Dropseed/June Grass, Pine Dropseed/Mountain Muhly, and Pine Dropseed/Spike Muhly associations). Kentucky bluegrass also appears particularly abundant in pine dropseed types, and Kentucky bluegrass phases were identified for several of the previously described plant associations. In these areas bluegrass can reach 10 to 50 percent cover and is often associated with woolly cinquefoil on benches and valley bottom terraces where almost all native grass species are absent or uncommon. The benches or terraces, remnants of ancient alluvial fans, stream terraces, and lake bed sediments, lie just above the valley floor and represent both the lowest topographic position of the upland grasslands and where Montane Valley Grasslands meet Montane Graminoid Wet Meadows and Wetlands that occur on the current floodplain of the valley floor (Muldavin and Tonne 2003).

Montane Wet Meadows and Wetlands

Montane Wet Meadows and Wetlands occur throughout the lowland valleys commonly adjacent to perennial streams of the valley bottoms, but also along seeps, springs and creeks in the uplands. Most of these communities are on sites subject to periodic flooding, or where the soils saturate at some point during the year in most years. These diverse communities have 142 species recorded and are dominated by facultative and obligate wetland graminoid species made up primarily of sedges (*Carex* spp.) and rushes (*Juncus* spp.). Woody perennial species such as willows, alders, and water birch are absent or very rare (Muldavin and Tonne 2003).

Northwest territory sedge, water sedge, woolly sedge, and smallwing sedge (*Carex microptera*) are similar species that form an operational functional group of tall coarse sedges growing near or adjacent to the stream channels and springs of the Preserve. They are difficult to differentiate morphologically (except when flowering) and their habitat seems similar: frequently flooded sites with saturated or near saturated soils. They typically form dense, sometimes wide bands of 10 meter or more along perennial channels. They are important to stream function because they serve to stabilize the banks and shade the channel (Muldavin and Tonne 2003).

Spikerush-dominated communities typically occur in close association with sedge communities, but along low bars and beaches within the active channels and at the interiors of spring wetlands. In contrast, Baltic rush and tufted hairgrass associations are typically found away from the channel on slightly higher ground than either the sedges or spikerushes (although sometimes these can also be found directly adjacent to the active channel). Flooding may still occur in these locations, but not necessarily every year, and ground water and snowmelt may be more important in saturating soils with standing water at or near the surface for long periods (Muldavin and Tonne 2003).

Northern mannagrass communities are associated with shallow pond and lake edges, and in the case of the Preserve, stock tanks. Northern mannagrass is a native, perennial, hydrophytic grass of cold temperate climates. It grows where soils remain saturated during the growing season, but can dry out later in the year (Muldavin and Tonne 2003).

Kentucky bluegrass phases were identified for the associations listed above and are typically associated with other exotic and/or weedy species in areas where native plant communities have experienced shifts in their composition due to some form of disturbance (Muldavin and Tonne 2003).

Soil Resources

Soils are typically an expression of the soil forming factors described by Hans Jenny (1996) including parent material, topography, climate, biota, and vegetation. Soils on the Preserve have a strong tie to the geology and geomorphology. Soils segregate strongly according to alluvial terraces and bottomlands, and volcanic rim and dome hillslopes from rhylotic intrusions in the caldera floor. Generally, the bottomlands support grassland soils while colluvial and residual hillslopes have forest soils. Grassland soils are productive with deep development and enhanced organics in the mineral surface soil. In contrast, forest soils have shallow depth, are less developed and large rock fragments persist in the surface soil. Forest soils are less productive and are shallow with less development.

Grassland soils are primarily mollisols developed in the mafic alluvium of the adjacent alluvial fans and piedmonts, or in recent water-deposited sediments of the valley bottoms. These valley bottom soils are deeper and have rich organic material accumulations in the top layers along with fine textures and little rock accumulation.

Mountain Soils

Soils on hillslopes developed either in place or within colluvial/alluvial slopewash material. These soils are mainly classified as inceptisols given their limited development, although in some locations clay accumulation has occurred to the extent to form alfisols. Typically, these hillslope soils have very little organic material within the mineral surface layer and are very well drained given the very rocky substratum of rhyolite and andesite along with some dacites and latites, tuffs and pumices (Muldalvin and Tonne 2003). Organic matter is largely found on the soil surface as duff or needle litter, compared to below the soil surface in finer factions as with grassland soils (McWilliams 2002). Coarse rock persists in surface soils and facilitates rapid infiltration (2002). The organic mat on forest soils plays a strong role in moderating temperature and moisture since surface mineral layers lack the soil aggregation and organic matter attributes that enhance soil productivity in grassland soils (Powers et al. 2005).

These hillslope soils favor growth of coniferous or shrubland species given the relatively rapid drainage and overall less productive capacity. Lower slope areas, swales, or broad ridges may support greater herbaceous undergrowth given the more advanced soil development and antecedent higher water holding capacity. In addition, some spring areas or old grassland patches on caldera rims may have support higher herbaceous growth than the slope setting would imply.

Production on mountain soils is largely relegated to woody vegetation. Herbaceous vegetation is listed as anywhere from 25 to 250 tons/acre using map units from the Santa Fe NF Terrestrial Ecosystem Survey (USDA 1993) for forested areas. Montane meadows on the northern caldera rim are listed as having upwards of 4,000 pounds/acre production (USDA 1993), although realized production from VCNP monitoring has shown markedly less potential on more productive soils within the lower elevation valle grasslands. Lower slope soils on the upper alluvial terraces where woodlands persist, also termed grazeable woodlands (see VCNP 2002), may have higher potential production than other forested soils due to the lower slope and alluvial material. VCNP monitoring suggests production can range from 100 to 2,300 pounds/acre on these soils.

The Muldalvin et al. (2005) vegetation mapping also indicated roughly 2.5 percent of the Preserve as forest meadow. These areas were largely clearcut timber harvested. Soils are mapped as mountane type soils though currently support small regeneration of conifers with abundant Kentucky bluegrass. Production on these soils is not available though Mulchunas (2006) lists some estimated potential from conversions of mixed conifer forests to early seral herbaceous species. Mulchanas reports anywhere from 30 to 250 pounds/acre may be gained from clearing mixed conifer forest though utilization may vary widely.

Grassland/Wetland Soils

The soils on the valles have developed in place on primarily alluvial transported materials. They occupy the lower third of hill slope and valley landforms and are organic rich with deep to very deep soil development. Soil development and productivity may decrease away from drainages and wetland swale areas.

Along the main valle stream reaches, McWilliams (2000) in his preliminary landscape analysis found valley soils to include an association of hydric soils next to valley streams and an alluvial soil with rich, deep organic matter. Hydric criteria are important since these soils are saturated or near saturated for longer periods during the growing season (USDA and NRCS 2006). Hydric soils typically have the water table at least 12 inches from the soil surface (2006). These soils support healthy, very productive riparian-wetland communities of facultative and obligate wetland communities of grass and grass-like plants (Valles Caldera Trust 2002). Recovering banks with hydric soils have a very high potential for revegetation due to the high organic matter content and available water, though compaction can decrease recovery by limiting the capillary transport of moisture outward from the streamside soils. Production is listed as upwards of 6,500 pounds/acre (TES 1993) and VCNP monitoring has nearly demonstrated this potential with maximum rates as high as 5,500 pounds/acre.

Adjacent to these wetland soils are mollic grassland soils developed on alluvial valley fill, or in some areas, lacustrian deposits. The NRCS (2006) characterizes these as mountain meadow and mountain valley soils with dark loam to sandy-loam surface horizons with litter (mulch) *potential* accumulations of 1 to 2 inches thick. Findings in 2002 suggested current conditions were below this potential for grasslands (NRST 2002). Soil subhorizons have organics and heavier textures with clay accumulations, especially on lacustrian deposits such as in the San Antonio Valle. These

soils also have high productive capacity. Monitoring production over a 3-year period in these areas had much more variable results depending on the location. Average production was roughly 1,000 pounds/acre though the potential was found as high as 3,500 pounds/acre.

The high variability of production on these valley soils indicates that more site-specific variables may drive the production; e.g., soils and vegetation may have finer differences such as plant species mixes, drainage, depth of development and organic matter. These differences may lead to widely different productive capacity than the similar landscape position in the valle would suggest. Substratum may vary widely depending on the distance from the central valle streams. Also, the depth to water may not track directly with valley position. Steve Strenger, the USDA Forest Service Soil Scientist heading the new TES, mentioned one location on an alluvial terrace adjacent to Redondo Peak developed a periodic water table, close to the surface during a wet year (2006, *personal communication*). Given the extremely well drained conditions of the volcanic domes, possibly some of the adjacent terraces may develop these water tables and therefore have increased productive capacity. Though vegetation may be indicative of drier conditions, the productive capacity could be amplified on wet years with the development of these periodic water tables. Another example of the variable water availability is the development of strong ground water pressure heads in some of the valles on alluvial terraces.

The terrace and alluvial valley soils may have limitations for revegetation where streams cut into drier valley soils. Observations in the Upper Jaramillo Valle found that cutbanks were readily revegetating on hydric or rich alluvial soils; however, revegetation was limited where upland valley or less-developed hillslope soils were stream cut. The lower amount of organics, coarser soil texture, and overall less available moisture likely limit revegetation. These areas are typical of the sedimentation sites highlighted in McWilliams (2000) report, National Riparian Service Team Report (2002), and USFS Fisheries reports (2002).

Current Soil Conditions

Soils on the preserve are in a productive capacity and should continue to recover as watersheds are better managed. Soil impacts persist where old logging roads modify soil hydrologic status by concentrating surface and subsurface water flows on hillslopes and where stream banks remain fragile from continued use by ungulates and upland vegetation species establishment. Overall, rangeland soils showed slight to moderate departure from reference for stable and well functioning conditions and were considered recovering from past heavier grazing by livestock (Havstad 2002). Soil production capacity may be lower than anticipated as more site-specific production figures are developed and recovery from historical grazing continues. Soil impacts from noxious weed invasion remain small, though Kentucky bluegrass establishment in much of the preserve may skew species composition away from native grassland species.

Current soil erosion is rare within the grasslands though more common along the steep slopes where old roads bisect the hillslopes. Soil erosion may be associated with native surface roads, along non-graveled road alignments, borrow pits, and geothermal drill pads. Soil losses may be exacerbated where ground cover is removed along steep slopes (Elliott et al 1998). Though heavily roaded, the hillslope forest soils may have less erosion due to high amounts of protective rock groundcover. Grassland soils generally may have less soil erosion when in place. However, grassland soils developed on the short steep slopes of the bottomland lake sediments have higher risk for erosion due to finer textures where soil particles are easily displaced. Also, stream channel banks may be prone to erosion where upland vegetation species have replaced deep rooted riparian species (McWilliams 2000a).

The productive capacity of the preserve soils may be on the lower range of NRCS estimates for the coarse ecotype mapping and TES mapping of the adjacent Santa Fe NF (USFS 1993). Findings by the National Riparian Service Team (2002) suggested some areas may have reduced soil productivity from lack of mulch. Currently, grassland and wetland soils are not producing forage up to the expected natural capability using figures from the Mountain Meadow and Mountain Valley Ecosites. However, these values may not fully account for the unique vegetation, soil and climatic conditions of the preserve since these figures are averaged for the rocky mountain province. The new TES is a finer resolution soil survey that may more aptly identify soil resources and their productive capacity. Vegetation production continues to be monitored for the grasslands and savannah woodlands.

For grassland and open forested soils, the vegetative species composition may impact soil productivity. This productivity may or may not translate to palatable production for use by ungulates. Exotic grassland species such as Kentucky bluegrass may affect the bio-geochemical cycling. The exact impact of bluegrass on these grassland systems is not known, though species shifts from an influx of exotic forbs (Thorpe et al. 2006; Lutgen and Rillig 2004) and annual grasses and shrubs (Norton et al. 2003; DeAntonio et al. 2004) are documented. Burke et al. (1998) suggests that with establishment of plant species that have different physiological characteristics such as vegetative cover, nutrient composition, and root:shoot ratios, soil mediated differences could result that shift favor from native species. The dominance of Kentucky bluegrass in areas on the Preserve suggests an added risk for invasive weeds where palatable production could be reduced. Further, reductions in grassland biodiversity may enhance risk for potential weed invasions (Knops et al. 1999).

Stream Condition

East Fork of the Jemez River

Proper Functioning Condition. The East Fork Jemez River was properly functioning for pool quality where it exists. The average residual pool depth was 2.7 feet, exceeding the properly functioning indicator of 1 foot. Overall, the average pool was of an adequate size, but the number of pools was far below acceptable levels. An average pool: riffle ratio of 1:1 is acceptable, but having more pools than riffles is ideal. The East Fork Jemez River had only 10.7 percent pool habitat, an indicator that the stream is not properly functioning. The indicator of a properly functioning stream is >30 percent pool habitat. The amount of pools began to decline once the survey exited “The Box”. The undercut banks of the East Fork had begun to slough off into the stream in Valle Grande, and the stream had become wider and shallower.

This bank erosion was removing the undercut bank habitat and adding fine sediments to the stream and creating a situation where the stream was dominated by riffle habitat and the pool habitat in Valle Grande was extremely low (1 pool per mile of stream). Almost eight times as much riffle habitat existed as compared to pool habitat. This lack of pools provided limited over-wintering habitat and decreased thermal protection for aquatic organisms. This has been attributed to stream widening, decrease in sinuosity, and sediment input filling in pools mostly attributed to the lack of large woody debris. The amount of large woody debris per mile for the entire river was 8.31 pieces per mile. This amount of wood indicates that the river is not properly functioning for large woody debris. A properly functioning stream must have >30 pieces of large woody debris per mile. The geomorphology of the East Fork Jemez River greatly affects the levels of large woody debris. In a typical stream, high gradient reaches (transport reaches) in forested areas add large woody debris to the stream, transporting it downstream. Once the gradient decreases,

the wood begins to settle into riparian areas or gets caught in bedrock features (response reaches). The East Fork Jemez geomorphology is such that the transport reaches are located in the middle and lower reaches, with no response reaches downstream. Hence, the East Fork Jemez has a low amount of wood that is being recruited into the floodplain where it is needed. Large woody debris is only being recruited locally (USDA Forest Service 2002).

A second factor in the low amounts of large woody debris in the East Fork Jemez River can be attributed to fire suppression. Since large woody debris recruitment is confined to local recruitment, only large disturbance events could increase the amount of large woody debris recruitment. In the forest type found in the Jemez Mountains, fires are one of the most common disturbance events. Fire suppression has hindered the extent of natural fires, which has reduced the amount of large woody debris recruitment. Some other disturbance events that might assist in large woody debris recruitment are insect outbreaks, which have been reduced due to insecticide use; windstorms, which are not common in this region; and landslides, which have limited impact on this watershed due to its geology (USDA Forest Service 2002).

The high gradient of the lower reaches have increased the numbers of pools, but have decreased the length of pools. Sediment input from bank and upland erosion occurring in the Preserve has greatly diminished pool volume. The amount of fine sediment input from the erosion has begun to fill in much of the pool habitat (USDA Forest Service 2002).

The lower reaches have numerous short riffles, while the upper reaches have a smaller number of riffles, but the average length increases dramatically. There were several riffles in reaches 7 and 8 that were close to 1 mile long. In Valle Grande, there was a lack of quality habitat; the riffles continued for the majority of the length across the valley. Valle Grande is essentially a 9-mile long riffle with a few pools. An undersized bridge created the most prominent pool (albeit unnatural) feature in Valle Grande. If this bridge was repaired, it is very likely that this pool would fill in with fine sediment (USDA Forest Service 2002).

Habitat-wise, the average sediment levels in riffles throughout the entire river are far exceeding allowable levels, giving it a not properly functioning rating. The amount of fines (sand, silt, and clay) found in the riffles of the East Fork Jemez River is 27 percent, while the necessary level for a properly functioning stream is <20 percent fines. The riffles throughout the entire river are dominated by a fine substrate while riffles are typically dominated by a gravel/cobble substrate. The river was very turbid, and at times it was difficult to see the stream bottom. The turbidity began to diminish once the survey entered the waters above Jaramillo Creek (USDA Forest Service 2002).

A primary source of sediment is the existing road conditions which are thought to be slowing or reversing an improving riparian health trend. Inadequate surface drainage, ditches, stream crossings, stream channel impacts, and increased drainage density were all attributed to the Preserve's transportation system (NRST 2002).

The East Fork Jemez River had 8.7 percent unstable banks throughout the entire river. The stream bank condition of the East Fork Jemez River was properly functioning, as the percentage was below the indicator of <10 percent. However, this measurement does not truly depict the upper reaches of the East Fork Jemez River. As mentioned previously, the Valles Caldera had high amounts of unstable banks, for example, 21 percent in reach 7. Some of the middle reaches, like "The Box" and above Jemez Falls, flowed through areas with numerous bedrock features; thus had low amounts of unstable banks, decreasing the overall percentage (USDA Forest Service 2002).

Where it passes through the culvert under the A-Road, the East Fork of the Jemez River represents a meandering 3rd order river. The riparian zone consists entirely of meadow vegetation; woody vegetation is absent. Water clarity is low due to suspended silt, and streambed substrate consists largely of gravel and silt. Aquatic vegetation is prominent in deeper runs and pools, while gravel dominates riffle areas. Summer water temperatures are warm and have exceeded the recommended maximum of 23°C (or 20°C for 4 hour duration). The pH of the stream is neutral to basic and can exceed 8.8. Ammonia and aluminum levels also can exceed water quality standards. East Fork of the Jemez River contains sections that were rated as functioning at risk or impaired, thus explaining the relatively low diversity of aquatic organisms that were found (a total of 23 species) (Vieira and Kondratieff 2004).

Natural detachment forces comparing particle size resistance for the bottom and channel sides as per T-WALK would indicate that under normal bottom conditions at the reference reaches there should not be significant down cutting within East Fork. The sides of the channels on all streams have particle class sizes smaller than necessary to resist the force of water at normal high flows. This would require the maintenance of effective riparian vegetation to provide additional resistive strength to the banks. This is especially true when additional sediments above natural bed-load are supplied to the system causing increased forces on the banks (USDA Forest Service 2002b).

T-WALK's Tarzwell substrate ratio was used to characterize the reference reach and was assessed as robust and near potential, mainly because of the quantity of non-emergent aquatic plant growth at 93 percent of the 100 sampling sites along 700 feet of stream reach. The Thalwag depth profile for the reference reach indicates the stream is functioning as a continuous pool. There were no evidence of dissolved oxygen problems, metals, poisons, salts, or shifts in equilibrium states at the reference reach. Temperature increases from the headwater spring through reach 4 were nearly stable through the reach, but increased in reach 6 to 23 degrees C. This was attributed to shading and decreased width/depth ratio found along this reach.

Stream Vegetation. Slightly little less than half of the river was meadow habitat, approximately 9 miles. The area of stream in the low gradient, high sinuosity meadow systems should have had much higher amounts of side channel habitat (wetlands). Side channel habitat was determined to be very low at 3 percent. Due to past grazing practices, these side channels have been converted to dry sites due to channel degradation and loss of meadows. In the non-meadow reaches, another factor of lack of side channel habitat is lack of large woody debris (USDA Forest Service 2002).

Jaramillo Creek

Benthic invertebrate surveys were performed during 2000 by Chic Spann, Region 3, Forest Service hydrologist; Steve McWilliams, Forest Service, Santa Fe NF, Watershed Program Manager; and Dr. Gerald Z. Jacobi (Valles Caldera Trust 2000). The benthic survey used Jaramillo Creek as the reference site for other streams and was classified as non-impaired. Jaramillo Creek had the largest number of taxa (31) and the most diversity of organisms within the Valles Caldera (benthic organism diversity index was 3.53) (Valles Caldera Trust 2002).

Natural detachment forces comparing particle size resistance for the bottom and channel sides as per T-WALK would indicate that under normal bottom conditions at the reference reaches there should not be significant down cutting in Jaramillo. The sides of the channels on all streams have particle class sizes smaller than necessary to resist the force of water at normal high flows. This would require the maintenance of effective riparian vegetation to provide additional resistive strength to the banks. This is especially true when additional sediments above natural bed-load are supplied to the system causing increased forces on the banks (USDA Forest Service 2002b).

T-WALK's Tarzwell substrate ratio was used to characterize the reference reach and was assessed as impaired. A factor in the determination is the amount of fine sediments. The Thalwag depth profile shows a general riffle dominated segment very similar to the reference reach on Rito de los Indios to the north (shallow pools 12 percent). Reduced extent of non-emergent vegetation was noted as compared to the East Fork.

San Antonio Creek

At upper sites, San Antonio Creek is a meandering 2nd order stream that runs through meadow habitat off of the F-Road. These upper reaches are fed largely by a broken artesian well, which has artificially created a clear, cold-water, 1st order tributary. Cobbles and gravels dominate the bed substrate of the man-made tributary, and aquatic macrophytes and mosses are present. Where the San Antonio Creek flows through a culvert under the B-Road, it is a meandering 3rd order stream. Water clarity is somewhat impaired by suspended silt, and streambed substrate consists largely of gravel and silt. Aquatic vegetation is prominent in deeper runs and pools, while gravel dominates riffle areas. The riparian zone consists entirely of meadow vegetation; woody vegetation is absent. San Antonio Creek west of the Broad crossing where a hot spring flows into the creek had boulders and cobbles added to the substrate. Here, off of the F-Road, San Antonio Creek is a still a meandering 3rd order stream, but water temperature is slightly warmer due to the input of 38°C water from the spring. Summer water temperatures are warm and have exceeded the recommended 23°C maximum (or 20°C for 4 hour duration). The pH of the stream is neutral to basic and often exceeds 8.8. Ammonia and aluminum levels can occasionally exceed water quality standards (Vieira and Kondratieff 2004).

The San Antonio reference reach is depending on the fiberous root system of riparian species to hold the channel. The sides of the channels on all streams have particle class sizes smaller than necessary to resist the force of water at normal high flows. This would require the maintenance of effective riparian vegetation to provide additional resistive strength to the banks. This is especially true when additional sediments above natural bed-load are supplied to the system causing increased forces on the banks (USDA Forest Service 2002b).

Riffle substrate content is important to the reproductive success of fish. The space between gravel in riffle habitat is crucial for spawning and fish development. Fine sediment fills in the space between gravel substrates and eliminates spawning habitat. The relative quantity of fine sediment in San Antonio Creek is not properly functioning by matrix standards. Riffle sediment content was 29.9 percent (USDA Forest Service 2003).

T-WALK's Tarzwell substrate ratio was used to characterize the reference reach and was assessed as precarious due to the amount of fine sediments and lack of non-emergent vegetation. A major reason for the rating was the amount of silt and fine sand sediments in the streambed and lack of vegetation. The Thalwag depth profile for the reference reach indicates the stream has a mix of pools (9 percent) and riffles. Sediments covered organic material and resulted in the anaerobic decomposition releasing a combination of gases such as methane, carbon dioxide, and hydrogen sulfide. The area might develop a histosol bog over part of the landscape, but sedimentation and down cutting of the channel may limit development. Temperature in August was above 20°C. Pools cover 9 percent of the reference reach. Stream bank vegetation is a grass/forb type.

Pool habitat is important over wintering, resting, and feeding habitat for fish. Pool habitat is evaluated by both quality (or residual depth) and area of pool habitat (by length). Pool quality in San Antonio Creek could not be analyzed due to surveyor error (surveyors assumed the definition of a pool to be that a pool had to have a residual depth greater than 1.0 foot). While this did

include lowering the number of overall pool volume calculated in the survey, pools with residual depth less than 1 foot are by nature filling in and would result in small volumes which would be negligible for the overall pool volume matrix. The relative pool habitat volume is not properly functioning. Pool habitat is 6.9 percent, well below the >30 percent standard (USDA Forest Service 2003).

Each stream class has an expected natural bankfull width:depth ratio which is related to how the stream should react to its valley formation (Rosgen and Silvey 1998). The properly functioning indicator is determined by the reaches classification, so each reach is evaluated separately for the bankfull, width:depth ratio. San Antonio Creek contains both properly functioning and not properly functioning reaches for width:depth ratio (USDA Forest Service 2003).

Using benthic invertebrate surveys, San Antonio Creek was rated as slightly impaired (Valles Calder Trust 2000). The dominant organisms found were primarily ones that could tolerate altered aquatic habitat (Valles Caldera Trust 2002). Few taxa (22) were found with 32 species during the survey and this was attributed to the poor quality of the homogenous fine substrate (Vieira and Kondratieff 2004).

Large woody debris has been related to habitat complexity and the health of fish populations in stream habitats (Fausch and Northcote 1992). Large woody debris density is not properly functioning in San Antonio Creek. The number of pieces of large woody debris per mile in non-meadow reaches is 0.2, far below the >30 pieces per mile standard (see Table 7). The total number of large woody debris in San Antonio Creek is 105 pieces (medium and large). Increasing large woody debris density should be a focus in the management of San Antonio Creek. Increasing large woody debris would also improve other degraded factors in the stream habitat including pool development and sediment deposition in riffles (USDA Forest Service 2003).

Rio de los Indios Creek

Benthic invertebrate surveys were performed during 2000. The benthic survey indicated that the stream reach was non-impaired with 82 percent of the reference attributes (Valles Caldera Trust 2000). Among the running water habitats, small creeks with well developed riparian vegetation like Rio de los Indios were the most diverse with the most number of benthic species (48 total species) (Vieira and Kondratieff 2004).

T-WALK’s Tarzwell substrate ratio was used to characterize the reference reach above the confluence with San Antonio Creek and was assessed as impaired. Major reason for the rating was the amount of sands and silts in the gravels. The reach is characterized by a pool riffle system with 20 percent shallow pools.

Appendix B

Production Database

Contains major datasets compiled and used for predicting production. Tables are:

Barnes_ALLSPECIES_Crosstab: Shows Barnes monitoring plots with all species detected in columns. Values are percent cover calculated as the number of measures per species/total number of measures per transects.

Barnes_PctCover_RipExclr: Compiles all Barnes riparian exclosure data.

Barnes_PctCover_All: Compiles all Barnes monitoring information.

Barnes_Species_Codes: Contains species information for acronyms.

Jornado_Production: Compiles all given Havstad production data at monitoring points.

NRCS_Ecosite_Production: Shows production values for ecosites mapped for the preserve.

R2_Veg_Attributes: Shows vegetation and groundcover attributes for delineated R2_Veg stands.

TEAMS_NMNHP_VegClasses_Production: Shows calculated and assigned production values for the New Mexico Natural Heritage Program vegetation mapping, stratified for upland (GW = Grazable woodland habitats) and lowland (MM_MV=Mountain Meadow and Mountain Valley Habitats). These values were used to spatially construct a forage production spatial layer. Statistics from this layer were used to prepare suitability and capacity estimates for the preserve.

TEAMS_Subbasin_Summary: Reports summary data for road density, road mileage, road % area, road acres, PFC stream condition, stream benthic ratings and number of stream crossing. Also, the abiotic and biotic ratings are summarized by percent for each low, moderate, or high condition class from vegetation plot data. Upland, riparian and overall watershed ratings are reported. Sub-basins were generated using ESRI ArcHydro tools.

TEAMS_Veg_Point_Data: Summarized all given vegetation plot data for the preserve. Datasets include Will Barnes monitoring points, Esteban Muldalvin vegetation plots used to detail plant associations and map vegetation for the NMNHP Vegetation Map, and USFS/NRCS vegetation and soil plots used for the current (2006) soil survey. Plot codes are year, surveyor initials, and plot iteration within the year. Plots were spatially assigned the pasture the points occur, in addition to map units from the TES mapping, NMNHP mapping, NRCS Ecosite mapping and pastures. Percent cover is reported for vegetation indicator species, soil and litter. Ranks for biotic, abiotic and overall condition are given where 1 is low, 2 is medium and 3 is high. Production from the TES and Havstad data is reported.

TES_Old_Map_Soil_Classification: Lists soils for the Terrestrial Ecosystem Survey mapping. This mapping is the extended linework done in 2000 from the adjacent Santa Fe NF TES mapping. Map units use Santa Fe NF attributes. At the time of this report, the new survey was not available.

TES_Old_Map_Veg_Potential_BareSoil: Lists potential bare soil percent, erosion hazard, and primary vegetation types for primary components of the TES map units (component 0.1). Values were obtained from the Santa Fe NF TES survey.

Terrestrial Ecosystem Survey Data Base

II. TES_New_PlotData.mdb: Contains plot data obtained from the current USFS Terrestrial Ecosystem Survey. Data was provided by Steve Strenger. Hard copy data was entered into this database for summary. NOTE: Steve warned not all data was cleaned at the time of data compilation and thus some listed species may be either mislabeled or misidentified.

Site2: Details site information including UTM coordinates (NAD 27), Soil Taxon, primary vegetation types, and climax classification.

Species_codes: Details vegetation species nomenclature associated with listed plot acronyms.

Ground surface cover: Details percents of groundcover classes such as bare soil.

tblSpeciesFloristic: Adds additional species information from New Mexico Natural Heritage Program species list.

Veg2: Lists species acronym, percent cover, and lifeform by plot ID.

Terrestrial Ecosystem Survey from Old Santa Fe NF

III. TES_Old_SantaFeNF_Mapping.mdb: Caches summary map unit information from the Santa Fe NF TES inventory. The map units correspond to linework drawn in 2000 by Steve McWilliams on the Santa Fe NF.

TES_Old_Map_Soil_Classification: Shows soil types that occur within map unit components for the preserve.

TES_Old_Map_Veg_Potential_Baresoil: Lists bare soil % and primary vegetation types for the preserve.

trCxPlt1_Forb: Data report for potential forb species and cover associated with map units components.

trCxPlt1_Graminoid: Data report for potential graminoid species and cover associated with map unit components.

trCxPlt1_Shrub: Data report for potential shrub species and cover associated with map unit components.

trCxPlt1_Tree: Data report for potential tree species and cover associated with map unit components.

trLndScp: Data report for potential landform characteristics associated with map unit components.

trSurPrp: Data report for geology, parent material and potential groundcover types and relative percents for map unit components.