Ecosphere
Environmental Services

District 12
2012 Vegetation Inventory

Cove, Sanostee and Red Valley Communities

Arizona and New Mexico

Prepared for:

Bureau of Indian Affairs
Shiprock Agency – Natural Resources

January 2013

Durango, CO
Cortez, CO
Pagosa Springs, CO
Farmington, NM

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ACRONYMS

AUM	animal unit months
BIA	Bureau of Indian Affairs
Ecosphere	Ecosphere Environmental Services
ESD	ecological site description
ft^2	square foot
g	grams
GPS	global positioning system
MLRA	Major Land Resource Area
NNDOA	Navajo Nation Department of Agriculture
NNDWR	Navajo Nation Division of Water Resources
NRCS	Natural Resource Conservation Service
p.z.	precipitation zone
PNC	potential natural community
RMU	range management unit
Shiprock	Northern Navajo Agency
SOW	statement of work
SUYL	sheep unit year long
USDA	United States Department of Agriculture

ABSTRACT

Ecosphere Environmental Services was contracted by the Bureau of Indian Affairs to collect and compile vegetation data on portions of Land Management District 12, of the Northern Navajo Agency. Data were collected from transect locations in three communities; Cove, Sanostee and Red Valley. Data collection occurred during July of 2012. Measurements were taken for biomass production, ground cover, and species composition. The data were analyzed to determine annual production, species frequency, and initial stocking rates for each management area. The results include the carrying capacity of the range resource, as well as the similarity to the historic climax plant community.

Data were analyzed by soil map units and ecological sites within each community. Carrying capacities and recommended stocking rates were calculated by community using available forage. The data were aggregated by ecological site and then applied according to the acreage within each community. Reductions were applied for slope and distance to water.

Overall, the similarity of the ecological sites in the project area to their historical potential is low and available forage production is below potential, however the carrying capacity of the range resource prior to reduction for slope and distance to water is close to currently permitted numbers. Managing for water availability would greatly improve the adjusted carrying capacity.

1. INTRODUCTION

Ecosphere Environmental Services (Ecosphere) was contracted by the Bureau of Indian Affairs (BIA) to conduct under-story rangeland vegetation inventories on a portion of Grazing District 12 of the Northern Navajo Agency (Shiprock). Species-specific vegetation data measurements included annual production, cover, and frequency. This data was also used to calculate carrying capacity based on available forage production. Information derived from these calculations can be used to guide management decisions, including stocking rates. This report supplies the results of the vegetation inventory as well as the background, methodology, and discussion necessary for management planning.

1.1 Purpose and Need

Baseline range condition data is critical to establishing quality range management practices. The purpose of the inventory is to provide baseline information regarding the existing range resource so resource managers and permittees are further enabled to improve and/or maintain the condition of the range resource. The results of this inventory will also enable recommendations for adjusted stocking rates and more comprehensive range management plans that are crucial for future range productivity.

1.2 Regulatory Entities

The Navajo Nation Department of Agriculture (NNDOA) manages livestock grazing activities on the Navajo Nation, primarily through District Grazing Committees. Livestock grazing permits are administered by the BIA Natural Resources Program in accordance with the Navajo Grazing Regulations (25 CFR §167). All three parties—the BIA, NNDOA, and the Grazing Committees—coordinate their activities in an effort to utilize and manage the range resources.

1.2.1 BIA Agency Natural Resources Program

All livestock grazing permits are issued by the BIA Natural Resources. Master livestock grazing records are also maintained by the BIA Natural Resources. The BIA is responsible for complying with all federal statutes, orders, and regulations. According to the BIA, their obligation "is to protect and preserve the resources on the land, including the land itself, on behalf of the Indian landowners. Protection and preservation includes conservation, highest and best use, and protection against misuse of the property for illegal purposes. BIA will use the best scientific information available, and reasonable and prudent conservation practices, to manage trust and restricted Indian lands. Conservation practices must reflect local land management goals and objectives. Tribes, individual landowners, and BIA will manage Indian agricultural lands." A summary of the BIA range policy (BIA 2003) is outlined below.

BIA Range Policy

Comply with the American Indian Agricultural Resources Management Act of December 3, 1993, as amended.

Comply with applicable environmental and cultural resources laws.

Comply with applicable sections of the Indian Land Consolidation Act, as amended.

Unless prohibited by federal law, recognize and comply with tribal laws regulating activities on Indian Agricultural land including tribal laws relating to land use, environmental protection, and historic and/or cultural preservation.

Manage Indian agricultural lands either directly or through contracts, compacts, cooperative agreements, or grants under the Indian Self-Determination and Education Assistance Act, as amended.

Administer land use as set forth by 25 CFR 162—Leases and Permits and 25 CFR 167-Navajo Grazing Regulations.

Seek tribal participation in BIA agriculture and rangeland management decision making.

Integrate environmental considerations into the initial stage of planning for all activities with potential impact on the quality of the land, air, water, or biological resources.

1.2.2 District Grazing Committees

Districts, formally called Land Management Districts, were established in 1936 by the Soil Conservation Service (now called Natural Resource Conservation Service [NRCS]) and adopted by the BIA. The periodic sampling of rangelands allows district grazing committees to evaluate the carrying capacity and resulting stocking rates of rangelands (Goodman 1982).

The Navajo Nation is organized into 110 chapters. Chapters, also called communities, are locally organized entities similar to counties, and are the smallest political unit. District grazing committees consist of elected representatives from each community who are responsible for monitoring livestock grazing within their respective chapters. District grazing committees reviews and recommends the carrying capacities of their districts.

Individual grazing district committee members are directly accountable to their local chapters and administratively accountable to the Director of the NNDOA. The NNDOA is also responsible for annual livestock tallies to determine if permittees are in compliance with their permit. In addition, the NNDOA and the district grazing committees are responsible for enforcement of range management and resolving grazing disputes. The district grazing committee members are responsible for attending district grazing committee meetings, as well as chapter meetings, and for ensuring that permittees respect applicable laws, regulations, and policies.

1.3 Grazing Overview

Timing of grazing, movement, and dispersal of livestock, and animal numbers are all factors that must be considered when optimizing livestock production. Prior to considering these factors, managers should first recognize animals' ability to harvest efficiently the nutrients present in their surroundings. This requires an understanding of foraging behavior as influenced by an animal's environment. Established grazing patterns are dictated by topography, plant distribution, composition, and location of water, shelter, and minerals (Heitschmidt 1991). The total forage production of a given pasture or grazing area does not necessarily reflect the amount of forage available to livestock. It is important, therefore, to recognize specific factors that restrict forage availability such as inaccessibility, long distances to water, or steep slopes. Once identified, production from these areas can be subtracted from the total or adjustments can be made for inclusion of these areas. An example of this would be to develop additional water sources in areas rarely visited by livestock due to a scarcity of water.

After likely foraging patterns have been determined for a given area, production and forage value data can be used to help determine how many animals should be allowed to graze in the given area. Low stocking rates benefit individual animals, as more resources are available due to lowered competition with other animals. Conversely, high stocking rates can inhibit the individual animal, but the increase in total livestock production allows for greater, short-term gains for the producer. The final stocking-rate decision must take into consideration the ecosystem as a whole. Maintaining long-term viable rangelands provides for the continued health of livestock and long-term financial gains for producers or permittees. Viable rangelands also provide for the continued health of the local air, water, and other ecological resources.

Grazing during the initial growing season and late season grazing at the time of seed development can be very detrimental to plant vigor and root development. This will remain a problem for rangeland managers as long as livestock grazing permits are issued for year-round grazing. However, Holecheck (1999) argues that stocking rate has a much greater impact on range condition than the season of use.

Stocking rates are correlated with the prevention of overgrazing. When livestock, wildlife, and feral horses graze and browse on a site, they each select their own preferred species. If the site is stocked too heavily and for too long a time, the desired forage species will become overgrazed. These preferred species are weakened and their mortality rate increases, resulting in a reduction of their percent composition on the site. If deterioration continues, the less valuable forage species are replaced by invaders and noxious weeds.

In general, managers should be aware that the final products of this inventory are subject to a variety of factors. The application of stocking rates to determine carrying capacity should be used with care and in context to seasonal, topographic, and behavioral factors.

2. RESOURCE DESCRIPTIONS

Knowledge of the resource issues that affect rangeland health and productivity is essential to any management plan. Stocking rates, season of use, annual precipitation, soil types, location of water sources, and topography strongly influence the variety and quality of forage on rangelands. The results of this vegetative inventory quantify the current conditions of the rangelands on District 12 communities. This information can be used to document future changes on the rangelands and assist with management decisions.

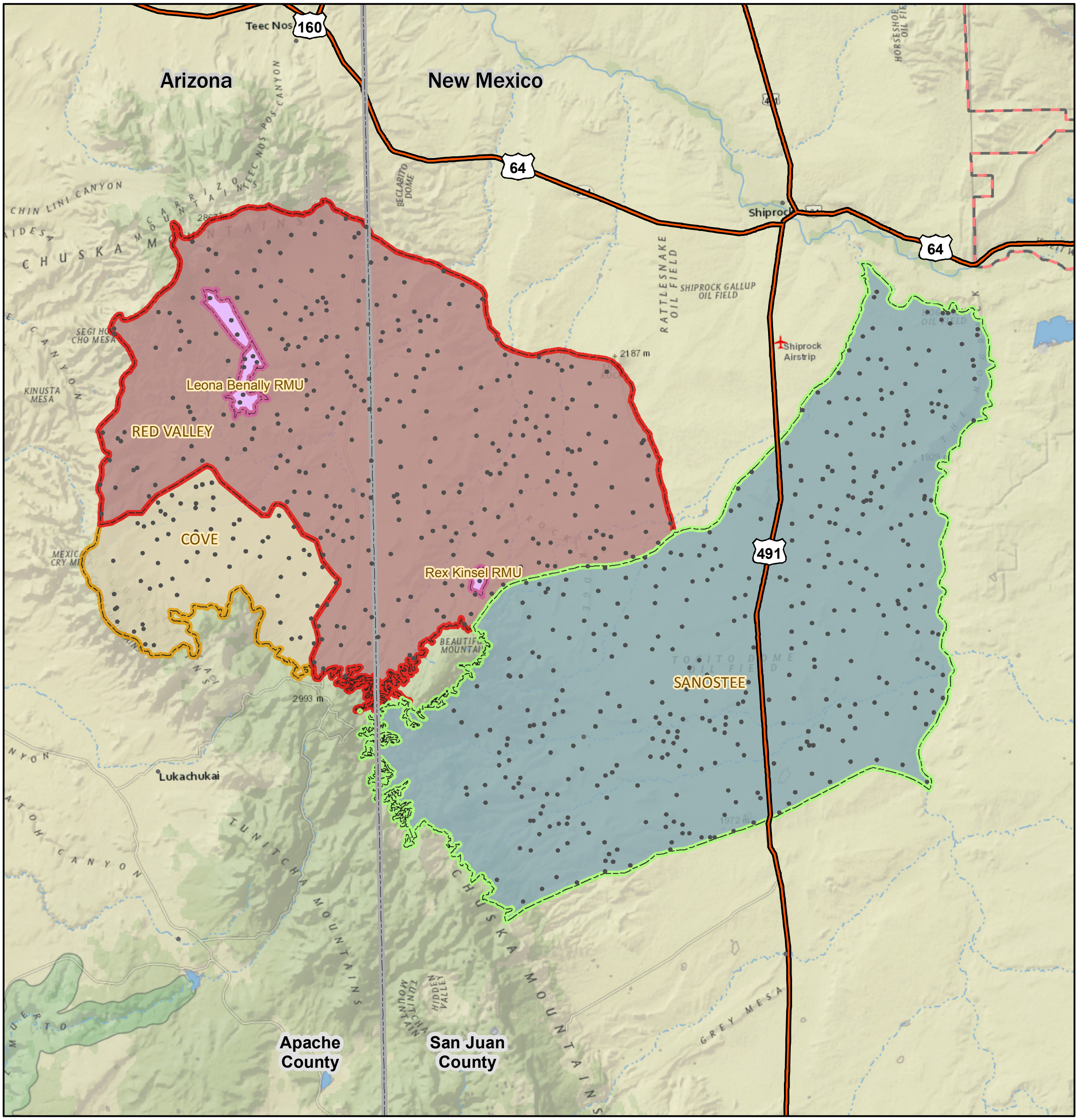
2.1 Geographic Setting

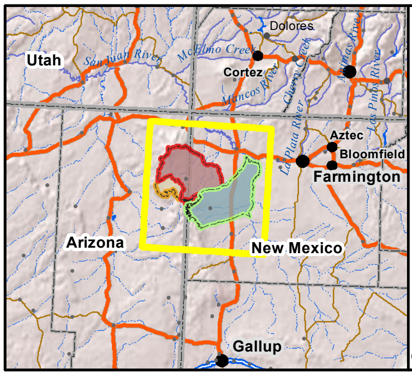
The project area is located within the Colorado Plateau Major Land Resource Area (MLRA). The surveyed study area is topographically and ecologically diverse, ranging from the forests in the Chuska Mountains at more than 9,000 feet in elevation down to the badlands near Chaco Wash, with rolling hills, scattered woodlands, sand dunes, bottomlands and rock outcroppings in between.

The Cove Community is located in Apache County, Arizona and forms the western part of the project area. Red Valley and Sanostee Communities lie to the east of Cove; Red Valley is bisected by the Arizona/New Mexico border. Sanostee Community is nearly entirely in San Juan County, New Mexico; a small western extent lies in Apache County, Arizona, but this area was not sampled. Elevations in the project area range from 5,000 to over 9,000 feet. The Chuska Mountains are approximately five to ten miles wide and extend 60 miles in a southeast to northwest direction. The elevation along the summit is above 9,000 feet. Further north lie the Carrizo Mountains with Pastora Peak reaching approximately 9,400 feet. Cove community extends into the Chuska mountains with Douglas-fir and ponderosa pine forests, piñon-juniper canyons, and red rock outcrops. Red Valley likewise contains these features but also extends to high points in the Carrizo Mountains and to lower elevation badlands at the base of the iconic Shiprock outcrop. Sanostee Community includes rolling hills, scarps, shrublands and grasslands. A map of the study area is provided on the following page.

Acreages for each compartment were extracted from shapefiles provided by the Shiprock Agency. Using these shapefiles and the soil survey boundaries, the three communities in District 12 covered 510,788 acres and are distributed as follows:

- Cove—41,357.19 acres
- Sanostee—250,991.33 acres
- Red Valley—218,439.49 acres
    - There are also 2 Range Management Units (RMUs) within Red Valley which are 3,377.76 and 477.09 acres.





- District 12 Transects COMMUNITY
- Navajo Nation
- State
- County
- US Highway
- Cove
- Red Valley
- Sanostee
- RMUs

0 2.5 5 10
Miles

1:400,000

Coordinate System: NAD 1983 UTM Zone 12N

BIA Shiprock Agency

2012 District 12 Range Assessment

Project Overview Map

Navajo Nation, AZ & NM

Date: 4/17/2013

Name: D12_Overview.mxd

2.2 Precipitation

An accurate precipitation monitoring system is essential to range management programs. Biomass production calculations are directly affected by precipitation measurements when reconstructing the plant community to a normal production year. If precipitation is overestimated in the reconstruction factor, the total annual production estimate decreases. If precipitation is underestimated in the reconstruction factor, the total annual production estimate increases. Precipitation gauges are located throughout the Navajo Nation and the corresponding data is managed by the Navajo Nation Division of Water Resources (NNDWR). The NNDWR provided 18 years of precipitation data from gauging stations in or close to District 12. These precipitation stations are Beautiful Mountain, Buffalo Pass, Hidden Valley SC, Junction, Newcomb, Shiprock O&M, Teec Nos Pos O&M, Toadlena and Toadlena Fish Hatchery. The precipitation data are provided as Appendix A.

2.3 Soils

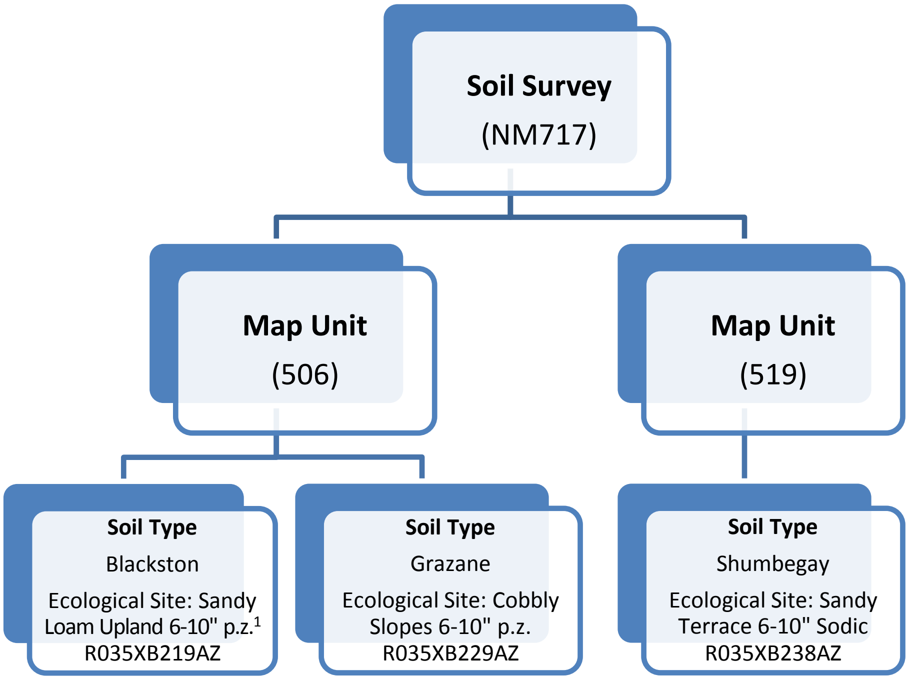
Knowledge of the soil properties in a particular area can help in predicting forage production. Soil properties such as texture, depth, moisture content, and capacity can dictate the type and amount of vegetation that will grow in that soil. The application of soil survey information is what enables rangeland managers to provide estimates of forage production in a given area.

“The type and size of map unit delineations, scale of data collection, sampling protocols, and date of the last inventory completed are all factors to consider when using existing soil surveys and rangeland inventories… [S]oil types, plant composition and production yield are representative for an area but may have significant dissimilar inclusions and/or change over time (USDA BIA 2003).”

The inventory project area is located within the boundaries of a soil surveys produced by the United States Department of Agriculture, Soil Conservation Service. The soil surveys is called: Shiprock Area, Parts of Apache County, Arizona and San Juan County, New Mexico (NM717).

These soil surveys are Order III mapped, which means they include soil and plant components at association or complex levels (called map units). Within each soil map unit, finer levels (called soil types) are described, but not mapped. Each soil map unit contains one, two, or three soil types within it. Each soil type is correlated with a specific ecological site. But ecological sites cannot be mapped directly from Order III soil map information because they are not correlated with the soil map units; these are correlated with the finer levels of unmapped soil types.

Some of the associated ecological site descriptions that correspond to soils in these soil surveys are in draft form and have not yet been finalized, or have changed. Soil surveys and ecological site descriptions are valuable for rangeland managers, as long as their limitations are understood. The following graph illustrates the hierarchy of *unmapped* soil types and their corresponding ecological sites within a *mapped* soil unit within a given soil survey. The examples in the chart are extracted from the soil survey used for this project.



[1] p.z.—precipitation zone.

It is worth noting that biological soil crusts occur occasionally throughout the study area. Biological soil crusts are a complex mosaic of organisms that weave through the top few millimeters of soil, gluing loose particles together to stabilize and protect soil surfaces from erosive forces. Additionally, roughened soil surfaces created by biological crusts act to impede overland water flow, resulting in increased water infiltration into the soil (Belnap et al. 2001). Biological soil crusts can provide a vital component for healthy, functioning soils.

3. ECOLOGICAL SITES

Ecological sites are differentiated from each other based on significant differences in species and species groups of the characteristic plant community, and their proportional composition and production. Additional determining factors include soils, hydrology, and other differences in the overstory and understory plants due to variations in topography, climate, and environmental factors or the response of vegetation to management. Each ecological site description (ESD) describes the historic climax plant community (HCPC) that was present during European settlement of North America. Many rangelands have undergone significant transitions to a state in which they are never again expected to display the characteristics of the HCPC. In their best condition, these rangelands would instead reach their potential natural community (PNC). PNCs may include non-native plant species and other factors, which differentiate them from an HCPC on the same site.

Ecological sites are directly associated with soil types. The determination of ecological site for each transect was complicated due to inconsistencies of scale in the soil surveys. As described in Section 2.3 Soils, the Soil Survey was mapped at the soil complex scale (Order III), meaning that there are up to three soil types inside of a mapped soil complex. The smaller soil types are not mapped. Since each soil type has a single ecological site assigned to it, the map unit has up to three unmapped ecological site possibilities.

Rangeland managers should be aware that maps of ecological sites are available on the Natural Resource Conservation Service (NRCS) Web Soil Survey website. The mapping, however, is by dominant ecological site. Unfortunately, this may grossly misrepresent soil units. For example, in soil map units where the dominant soil type/ecological site is 60 percent of the soil map unit, then the other 40 percent of the soil unit would be mapped incorrectly. An analogy might use a basket of fruit in which there are six apples and four oranges. Using the dominant system, the entire basket of fruit would be labeled as apples. While the dominant ecological site map may be appropriate at a landscape level, it is not correct to use for rangeland management.

The assignment of a soil type and ecological site for each transect was based on interpretation of the current vegetative community compared to the expected HCPC, as well as soil texture test results and the map unit descriptions from the soil survey. In cases where the ESD was not developed, an educated guess was applied based on the ESD name, the soil map unit description, and the vegetation community in the area. However, in some cases transects were not assigned an ecological site due to the lack of comparable ecological site data from ecological site descriptions or because the soil description was distinctly different (i.e. clay was found at the transect site but the only ecological site choices were for sandy soils). These inconsistencies are often the result of coarse-scale soil mapping, or from inclusions within a soil unit that contrast with the major components; these inconsistencies are not unexpected. Data from transects in these areas were calculated but they were not included in the analysis by ecological site except as labeled “Unassigned”.

In general, these ESDs represent the most up-to-date information available at the time of this study. It should be noted that they are also continually updated as new information is brought forth from field studies. The ESDs in this report should not be relied upon for future studies; instead the most recent information should be collected from the NRCS. Approved and published ESDs are available on the internet at http://esis.sc.egov.usda.gov/.

The ecological sites from the District 12 study area transect sites are listed in Table 3-1; followed by representative examples of each site in one or two photographs, with transect locations identified. Some sites had only one transect located within the ecological site.

Table 3-1. Ecological Site

Ecological Site*
F035XG134NM Gravelly - Woodland
F035XH005NM Pseudotsuga menziesii-Pinus ponderosa/Symphoricarpos albus
F036XA001NM south of Gallup 13-16
F039XA002NM PIPO-PSME/QUGA-CEMO/POFE
F039XA007NM Montane slopes 12-18"
R036XB006NM Gravelly Loamy
R035XB016NM Clay Loam Terrace (sodic) 7-10"
R035XB018NM Loamy Bottom 6-10"
R035XB020NM Loamy 6-10" terrace
R035XB021NM Loamy Upland 7-10"
R035XB022NM Loamy Upland sodic
R035XB024NM Saline Bottom 6-10"
R035XB028NM Sandy Bottom 6-10"
R035XB030NM Sandy Loam Upland 6-10"
R035XB034NM Sandy Terrace 6-10" sodic
R035XB035NM Sandy Upland 6-10"
R035XB204AZ Sandstone Upland 6-10" p.z. Very Shallow
R035XB210AZ Loamy Upland 6-10" p.z.
R035XB216AZ Sandy Wash 6-10" p.z.
R035XB217AZ Sandy Upland 6-10" p.z.
R035XB219AZ Sandy Loam Upland 6-10" p.z.
R035XB222AZ Sandy Terrace 6-10" p.z.
R035XB227AZ Sandy Loam Upland 6-10" p.z. Sodic
R035XB228AZ Loamy Upland 6-10" p.z. Sodic
R035XB238AZ Sandy Terrace 6-10" p.z. Sodic

Ecological Site*
R035XB268AZ Shale Hills 6-10" Sodic
R035XB271AZ Loamy Upland 6-10" p.z. Saline-Sodic
R035XB274AZ Sandy Loam Upland 6-10" p.z. Saline
R035XB275AZ Loamy Fan 6-10" p.z.
R035XB276AZ Siltstone Upland 6-10" p.z. Saline
R035XB277AZ Siltstone Upland 6-10" p.z. Limy
R035XB278AZ Loamy Upland 6-10" p.z. Saline, Gypsic
R035XB279AZ Clay Loam Upland 6-10" p.z. Sodic, Gypsic
R035XC302AZ Sedimentary Cliffs 10-14" p.z.
R035XC307AZ Clay Loam Upland 10-14" p.z.
R035XC313AZ Loamy Upland 10-14" p.z.
R035XC314AZ Sandstone Upland 10-14" p.z.
R035XC315AZ Sandy Upland 10-14" p.z.
R035XC316AZ Clay Loam Swale 10-14" p.z. Limy, Shallow
R035XC317 Sandy Loam Upland 10-14" p.z.
R035XC318AZ Silty Shallow 10-14" p.z.
R035XC324AZ Clayey Slopes 10-14" p.z. Bouldery
R035XC325AZ Stony Slopes 10-14" p.z.
R035XC326AZ Sandy Loam Upland 10-14" p.z. Saline
R035XC327AZ Clayey Upland 10-14" p.z. Sodic
R035XC328AZ Cobbly Slopes 10-14" p.z.
R035XC329AZ Loamy Upland 10-14" p.z. Gravelly
R035XC330AZ Sandy Terrace 10-14" p.z. Stony
R035XC335AZ Clay Loam Hills 10-14" p.z. Limy
R035XH813AZ Silty Upland 17-25" p.z.
R035XH814AZ Sandstone Upland 17-25" p.z. Cobbly
Badlands
Rock Outcrop

*These are new correlations; at the time of this vegetation inventory, the new correlations were not included in the soil survey but were address in a separate document from the New Mexico NRCS. This document is included as Appendix B.

1 p.z. refers to precipitation zone.

F035XG134NM- Gravelly – Woodland (Transects RV-311 and CO-007)

F035XH005NM – Pseudotsuga menziesii-Pinus ponderosa/Symphoricarpus albus (Transect RV-183)

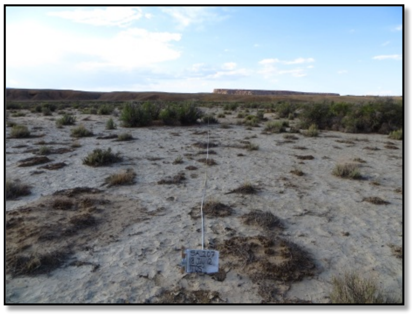
F036XA001NM - South of Gallup (Transects RV-129 and RV-102)

F039XA002NM – Pinus ponderosa-Pseudotsuga menziesii/ Quercus gambelii-Cercocarpus Montanus/ Poa fendleriana(Transect CO-056)

F039XA007NM - Montane Slopes (Transects CO-004 and CO-062)

F036XB006NM - Gravelly Loamy

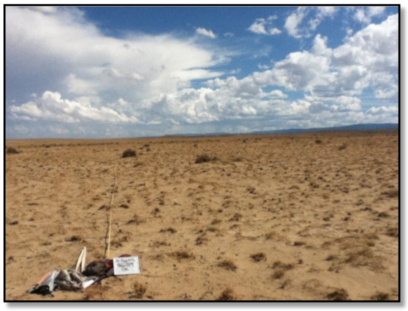
R035XB016NM - Clay Loam Terrace 7-10” p.z. Sodic (Transects RV-104 and SA-207)



R035XB018NM - Loamy Bottom 6-10” p.z. (Transect SA-177 and SA-033)

R035XB020NM - Loamy Terrace 6-10" p.z. (Transects RV-279 and SA-272)

R035XB021NM - Loamy Upland 7-10" p.z. (Transects SA-019 and RV-319)



R035XB022NM - Loamy Upland Sodic (Transects SA-315 and SA-307)

R035XB024NM - Saline Bottom 6-10" p.z. (Transects SA-015 and SA-310)

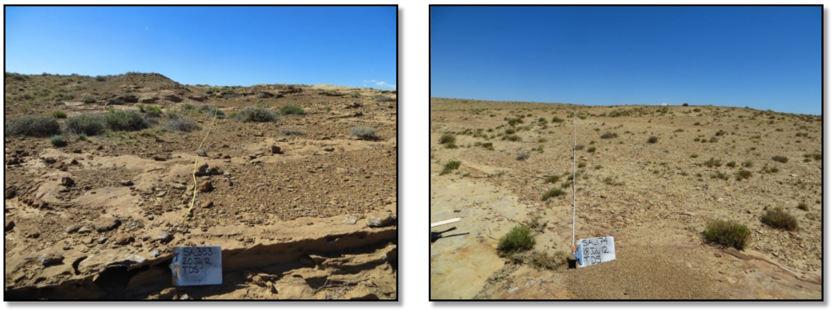
R035XB028NM - Sandy Bottom 6-10" p.z. (Transects SA-276 and RV-121)

R035XB030NM - Sandy Loam Upland 6-10" p.z. (Transects RV-191 and SA-350)

R035XB034NM - Sandy Terrace Sodic (Transects RV-134 and SA-056)

R035XB035NM - Sandy Upland 6-10" p.z. (Transects SA-064 and SA-136)

R035XB204AZ - Sandstone Upland 6-10” p.z. Very Shallow (Transects SA-353 and SA-174)

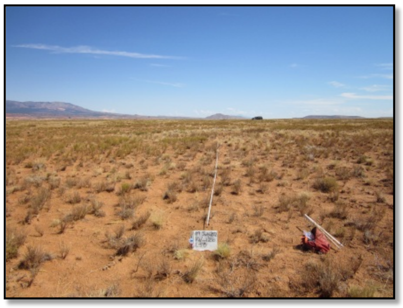


R035XB210AZ - Loamy Upland 6-10" p.z. (Transects RV-168 and RV-244)

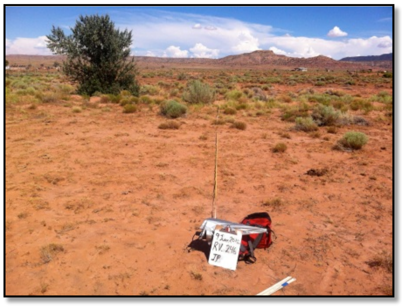
R035XB216AZ – Sandy Wash 6-10” p.z. (Transects RV-195 and RV-135)

R035XB217AZ - Sandy Upland 6-10" p.z. (Transects RV-217 and RV-283)

R035XB219AZ - Sandy Loam Upland 6-10" p.z. (Transects RV-025 and RV-126)



R035XB222AZ - Sandy Terrace 6-10" p.z. (Transect RV-246)



R035XB227AZ – Sandy Loam Upland 6-10" p.z. Sodic (Transect RV-212)

R035XB228AZ – Loamy Upland 6-10" p.z. Sodic (Transect RV-292)

R035XB238AZ - Sandy Terrace 6-10" p.z. Sodic (Transect RV-026 and RV-038)

R035XB268AZ – Shale Hills 6-10” Sodic (Transect SA-368)

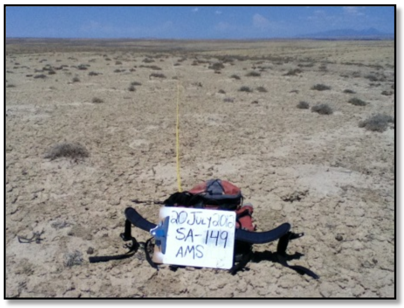
R035XB271AZ - Loamy Upland 6-10” p.z. Saline Sodic (Transects SA-341 and SA-176)

R035XB274AZ - Sandy Loam Upland 6-10” p.z. Saline (Transects SA-333 and SA-183)

R035XB275NM - Loamy Fan 6-10” p.z. (Transects RV-108 and SA-270)

R035XB276AZ - Siltstone Upland 6-10” p.z. Saline (Transects RV-123 and RV-230)

R035XB277AZ - Siltstone Upland 6-10” p.z. Limy(Transects SA-035 and SA-149)



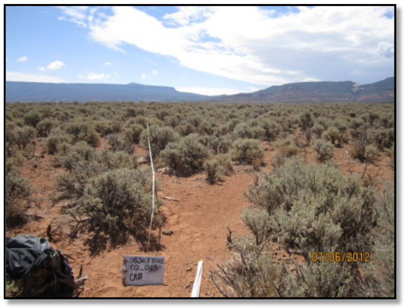
R035XB278AZ - Loamy Upland 6-10” p.z. Saline, Gypsic (Transects SA-020 and SA-213)

R035XB279AZ – Clay Loam Upland 6-10" p.z. Sodic, Gypsic (Transects SA-344 and SA-178)

R035XC302AZ – Sedimentary Cliffs 10-14" p.z. (Transects RV-270 and RV-305)

R035XC307AZ - Clay Loam Upland 10-14" p.z. (Transect SA-241)

R035XC313AZ - Loamy Upland 10-14" p.z. (Transects RV-146 and CO-013)



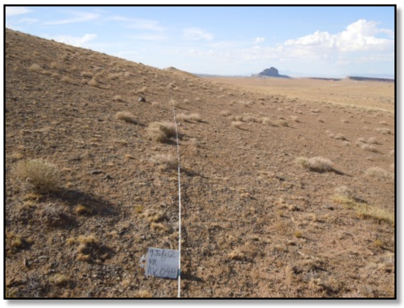
R035XC314AZ - Sandstone Upland 10-14" p.z. (Transects RV-084 and RV-306)

R035XC315AZ - Sandy Upland 10-14" p.z. (Transects RV-089 and RV-192)

R035XC316AZ - Clay Loam Swale 10-14" p.z. Limy, Shallow (Transects RV-214 and RV-096)

R035XC317AZ - Sandy Loam Upland 10-14" p.z. (Transects RV-264 and RV-226)

R035XC318AZ - Silty Shallow 10-14" p.z. (Transects SA-281 and RV-048)



R035XC324AZ - Clayey Slopes 10-14" p.z. Bouldery (Transects RV-106 and RV-194)

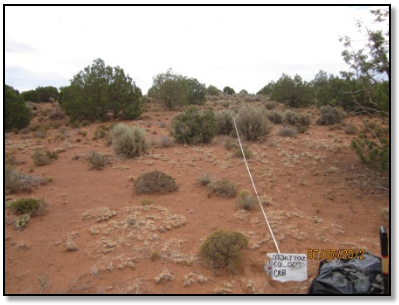
R035XC325AZ - Stony Slopes 10-14" p.z. (Transects RV-078 and RV-235)

R035XC326AZ - Sandy Loam Upland Saline 10-14" p.z. (Transects RV-141 and RV-178)

R035XC327AZ - Clayey Upland 10-14" p.z. Sodic (Transects RV-014 and RV-058)

R035XC328AZ - Cobbly Slopes 10-14" p.z. (Transects RV-265 and SA-234)

R035XC329AZ - Loamy Upland 10-14" p.z. Gravelly (Transects CO-009 and RV-042)



R035XC330AZ - Sandy Terrace 10-14" p.z. Stony (Transect CO-038)

R035XC335AZ - Clay Loam Upland 10-14" p.z. Limy (Transects SA-266 and SA-083)

R035XH813AZ – Silty Upland 17-25" p.z. (Transect RV-148)

R035XH814AZ – Sandstone Upland 17-25" p.z. Cobbly (Transect RV-009)

Badlands - (Transects SA-40 and SA-240)

Rock Outcrop – (Transects New-6 and RV-239)

4. METHODOLOGY

The methods used to collect project data included protocols provided by the BIA modified to standards used in federally published Technical References.

The Statement of Work (SOW), provided by the BIA, described the study design and cited specific methodologies for data collection (Coulloudon 1999, Habich 2001, and USDA NRCS 2003).

The field methodology was based on the SOW and the technical references listed above, with modifications approved by the BIA.

4.1 Field Methodology

4.1.1 Transect Establishment

Data collection in the field occurred between July 3 and July 21, 2012. The BIA provided Ecosphere with predetermined transect locations. The Universal Transverse Mercator UTM coordinates of these transect locations were downloaded into hand held Global Positioning System (GPS) units. The GPS unit was used in combination with topographic maps to navigate by vehicle and foot to the transect locations. Transects were established within ten meters of the GPS coordinates and usually within one meter.

Transects consisted of a 200-foot straight line measured with an open reel tape placed flat and straight along the ground and stretched taut as much as possible. Using field maps and topography as a guide, each transect was placed within a single soil unit and vegetation community. The transect azimuth was randomly determined by selecting a prominent distant landmark, such as a mountain or lone tree. The transect azimuth was read with a compass and recorded. The 200-foot tape was then extended along the transect azimuth. Vegetation attributes were read from ten plots at 20 foot intervals along the open reel tape. The plots were measured with a square 9.6 foot (ft^2) quadrant frame. The 9.6 ft^2 plot is generally used in areas where vegetation density and production are relatively light (USDA NRCS 2003). Care was taken to avoid bias by establishing each plot using a consistent method, in this case always laying the frame to the right side of the tape. The point intercept for ground cover was measured first, on the left side of the tape. Aspect, slope, surface soil texture, and notes were recorded in addition to the vegetative attributes.

4.1.2 Production Data Collection

Weight is the most meaningful expression of the productivity of a plant community or an individual species. It has a direct relationship to feed units for grazing animals that other measurements do not have. Production is determined by measuring the weight of annual aboveground growth of vegetation. Some aboveground growth is used by insects and rodents, or it disappears because of weathering before production measurements are made.

For the purposes of this study, production was measured as standing forage crop and reconstructed to peak standing crop. Standing forage crop is the total herbaceous and woody plant biomass present aboveground and available to herbivores, while peak standing crop is the greatest amount of plant biomass aboveground present during a given year (Coulloudon et al. 1999). Production includes the aboveground parts of all plants produced during a single growth year. Excluded are underground growth, production from previous years, and any increase in the stem diameter of shrubs.

Production and composition of the plant communities were determined by a combination of estimating and harvesting (double sampling). Ecosphere followed the double sampling methodology of the United States Department of Agriculture, Natural Resources Conservation Service (USDA NRCS) modified to standards outlined in the SOW, and modifications generated from the pre-work conference. This double sampling method is detailed in the following sections.

4.1.2.1 Establishing a Weight Unit

The weight unit method is an efficient means of estimating production. A weight unit is a part of a plant, an entire plant, or a group of plants of the same species used for assessing production. After weight units are established, field teams can be very accurate in production estimation. A weight unit is created by visually selecting part of a plant, an entire plant, or a group of plants that will most likely equal a particular weight. For example, a fist-sized clump of healthy, un-grazed *Achnatherum hymenoides* (Indian ricegrass) may be visually estimated to equal ten grams. This clump of grass is then harvested and weighed with a hand scale to determine actual weight. This process is repeated until ten grams of *Achnatherum hymenoides* (Indian ricegrass) may can be visually estimated with accuracy. The field team maintained proficiency by periodically harvesting and weighing to check estimates of production.

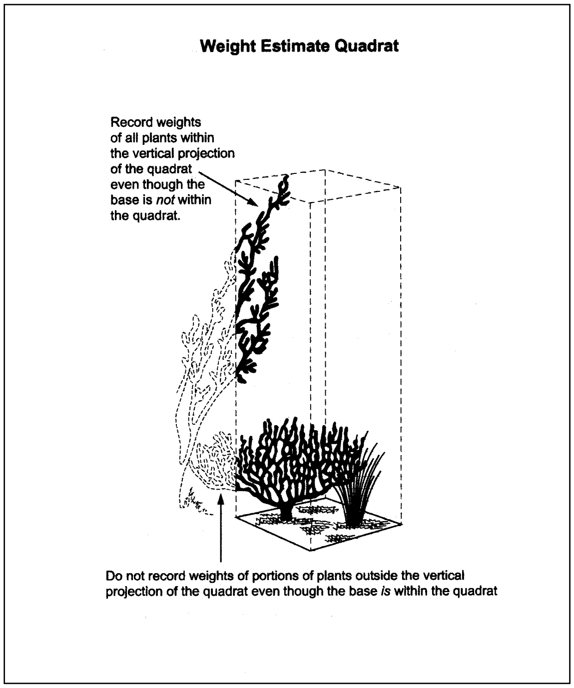
4.1.2.2 Double Sampling Methodology (Estimating and Harvesting)

Production (in grams) was estimated by counting the weight units of each species in each plot. All plants and parts of plants inside an imaginary box outlined by the actual 9.6 ft^2 frame up to a height of four feet were estimated. Excluded were any plants and parts of plants outside of the box (Figure 4.1). Two plots on each transect were chosen for harvesting. On the harvested plots, all species were estimated in situ and then harvested at ground level (1/4 in. stubble height). In many cases, vegetation was diverse and widespread so no two plots could effectively represent all species.

Ecosphere has determined, through several years of data collection and analysis, that intermittently occurring species are underrepresented in the harvested material to be used for both correction factors and air dry weights. In an effort to include more species in the harvested material, a weight unit of any species that contributed ten grams or more of estimated production on the transect, but did not occur in the two selected harvested plots, was estimated and harvested individually outside of the transect and recorded as plot 11.

Harvested biomass was weighed with a hand scale, and both estimated and harvested (green) weights were recorded. All harvested materials were collected and stored in paper bags labeled with tracking information including transect, date, species, and plot number. All of the harvested material was allowed to air dry for ten days or more before re-weighing to convert from green weight to air-dry weight (ADW). The purpose of the double sampling was to correct any variability between the estimation of production and the actual weighed production. This was accomplished by using an estimation correction factor, which is calculated in the post-field methodology.

Figure 4-1 Weight Estimate Box



Source: USDA NRCS 2003

4.1.2.3 Large Shrub Plots

Extended plots were established when the vegetation consisted of “large” shrubs. Neither the SOW or the National Range and Pasture Handbook adequately define the large shrub plot methodology. However, the purpose of the large shrub plots is to capture the production of larger shrubs that are too big to be adequately measured within the 9.6 ft^2 frame. Following consultation with NRCS (Peter Lefebvre, personal communication) the following methods were established for this project. Two extended plots (0.01 acre each) were measured at fixed points along the transect and only the large shrub species inside those plots were estimated. These shrubs were not measured in the ten 9.6 ft^2 plots because that would have doubled the measurement. Large shrub plots were usually established in areas of tall, thick *Artemisia tridentata* (big sagebrush) or on flats of *Sarcobatus vermiculatus* (greasewood), or in mountain shrub communities with *Purshia tridentata* (bitterbrush) and *Cercocarpus montanus* (mountain mahogany), for example.

4.1.2.4 Ocular Estimates of Utilization

Utilization, or use, is the proportion of annual growth that has been consumed by grazing animals. The purpose of estimating utilization is to include in the vegetation measurements the forage which has been consumed prior to the vegetation inventory. With the Ocular Estimation Method (Coulloudon et al. 1999a), utilization is determined by visual inspection of forage species. This method is reasonably accurate, commonly applied, and suited for use with both grasses and forbs. Field team personnel were thoroughly trained and practiced in making ocular estimates of utilization of plants. An attempt was made to locate un-grazed plants near the transect. These un-grazed plants were assumed to approximately represent the species before grazing occurred. Un-grazed plants were used as a comparison to estimate grazed plants. Some re-growth may have occurred before the inventory period. However, if grazing patterns are undetectable on the plant, it is impossible to determine what re-growth, if any, may have occurred. The percentage of un-grazed plant remaining was recorded for each species on each transect.

4.1.2.5 Sensitive Plants Protocol

Threatened, endangered, culturally important, or otherwise sensitive plants were never intentionally harvested for the purposes of this inventory. The weight of such plants was estimated but the plants were not clipped. Cacti and yucca species were not clipped, their annual production was estimated using standard protocols as described in the National Range and Pasture Handbook (2003). Production for yuccas was considered 15 percent of total green weight. Cholla cacti production was considered 15 percent of active tissue, prickly pear 10 percent, and barrel cacti 5 percent. A list of all plant species recorded during the inventory is included as Appendix C. Also in Appendix C is a list of scientific collections made during the data collection, under Ecosphere's valid Navajo Nation permit.

4.1.3 Frequency Data Collection

Frequency describes the abundance and distribution of species. Frequency measurements are an easy and efficient method for monitoring changes in a plant community over time. Frequency is the number of times a species is present in a given number of sampling units, usually expressed as a percentage.

On rangeland, regeneration of desirable plants maintains good range conditions. Grazing by too many animals (livestock and wildlife), or heavy utilization by a few animals results in overuse, loss of vigor, and ultimately disappearance of the preferred and desirable plants. Deterioration of the range vegetation begins when less valuable forage species replace the desirable species. If deterioration continues, the less valuable forage species are replaced by invaders and noxious weeds. The frequency and composition of preferred and desirable species compared to less valuable forage is an indication of the range condition.

4.1.4 Cover Data Collection

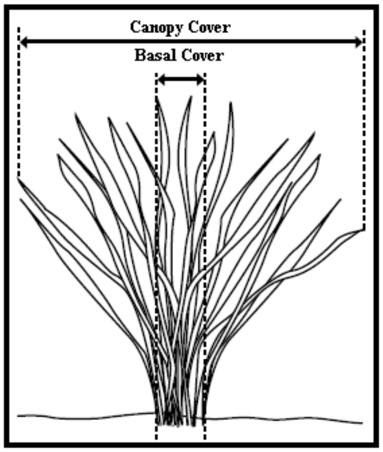
Ground cover measurements are used to quantify the amount of vegetation, organic litter, biological crusts, and exposed soil surface throughout an area. Cover is also important from a hydrologic perspective when examining basal and canopy (foliar) cover of perennial and annual species and litter cover. This study measured understory vegetation and no trees were included in the cover data.

Ground cover data can assist in determining the soil stability and proper hydrologic function of a site, as well as the biotic integrity of a site. Point-Intercept cover measurements are highly repeatable and lead to more precise measurements than cover estimates using quadrants. For trend comparisons in herbaceous plant communities, basal cover is generally considered to be the most stable because it does not vary as much from climatic and seasonal conditions (compared to canopy cover). Canopy cover can vary widely over the course of the growing season. The change in canopy cover over the course of the growing season can make it hard to compare results from different portions of large areas where sampling takes several weeks or a few months. In the future, ground cover monitoring for each ecological site within each grazing unit should replicate the sampling time period from this baseline inventory.

The line-point intercept method employed on this study is described in *Monitoring Manual for Grassland, Shrubland and Savanna Ecosystems* (Herrick et al. 2005). There are 50 point measurements spaced evenly (every 4 feet) along a 200-foot measuring tape anchored securely at each end. At each point along the transect, a sighting device (pin flag) was placed perpendicular to the ground along the measuring tape. Three layers of point intercept were recorded as the pin flag was dropped into place—Top Canopy, Lower Canopy, and Soil Surface. The first cover category is determined by the first plant interception of the pin flag. The species of plant that the pin flag hits is recorded as the “Top Canopy.” If no plants are intercepted, “None” is recorded. Up to three additional species intercepted by the pin flag below the top canopy are recorded as “Lower Canopy” layers. If herbaceous or woody litter is intercepted, this is recorded as a lower canopy layer. “Soil Surface” is recorded as either the base of a plant species (See Figure 4.1-2) or one of the following categories: Rock, Bedrock, Embedded Litter, Duff, Moss, Lichen Crust, or Soil. Bare ground occurs only when the Top Canopy is “None” and there are no Lower Canopy layers, and the Soil Surface is “Soil.”

Measuring cover by points is considered one of the least biased and most objective cover measures (Bonham 1989). Results of the ground cover data analysis are included in Section 5: Results.

Figure 4-2 Vegetative Cover



Source: Elzinga, Salzer, and Willoughby 1998)

4.1.5 Soil Surface Texture Test

At each transect in which there was a choice of soil types and ecological sites, the A Horizon (top 0-6 inches) of the soil surface was sampled. The surface was cleared of debris to bare mineral soil. A small sample was analyzed using the USDA Soil Texturing Field Flow Chart (Appendix D). The Flow Chart uses a step-by-step procedure for estimating sand, silt, and clay content. The test also uses the ribbon method to determine the fraction of fine-grained particles within the sample. Field teams assigned a texture class to the sample based on its tested content and ribbon characteristics.

4.2 Post-Field Methodology

After field data collection is complete, the data was prepared and analyzed. All field data was downloaded into a database. Harvested biomass was air dried for ten days and then each sample was weighed. Dry weights were then entered individually into the database, by each species on each transect. When the initial field dataset was complete, calculations were applied to reconstruct the collected production data to the amount of vegetation that would occur in a “normal” year. These adjustments included utilization, climate, growth curve, and air dry weight corrections.

When the reconstruction factor calculation was complete for every species on every transect, the results were grouped by ecological sites within each community and the data were analyzed. Analysis included similarity indices, available forage based on forage value and harvest efficiency factors, stocking rates, and carrying capacity.

4.2.1 Reconstructed Annual Production

The translation of a plot full of plants to a measure of pounds per acre was achieved through a series of calculations. The formula, derived from technical reference 1734-7 Ecological Site Inventory (Habich 2001) and the National Range and Pasture Handbook (USDA NRCS 2003), reconstructed the measured weight of biomass to a “normal” annual air-dry production weight that accounts for physical, physiological, and climatological factors. First, the green weight of a species that was estimated in the field was multiplied by an estimation correction factor and then by a reconstruction factor. The reconstruction factor is the percent air-dry weight (%ADW) of the species, divided by the result of the utilization, multiplied by percent of normal precipitation for the current water year, and multiplied by the growth curve for that time of year. This may be more easily understood with the formula below:

$$\mathit{CorrectedGreenWeight}\left\{\frac{\%\mathit{ADW}}{(\%\mathit{Utilization})(\%\mathit{NormalPrecipitation})(\%\mathit{GrowthCurve})}\right\}$$

The result is called the total reconstructed annual production. The details of each of the elements in this equation are explained in the following sections.

4.2.1.1 Corrected Green Weight (Estimation Correction Factor)

The harvested or clipped plots provide the data for correction factors of estimated species weights from the field. Measured (clipped) weights of species were divided by the estimated weights of the same species in the same plots to establish a correction factor. This correction factor was then applied to all estimations of that species for the entire transect. For example, if *Sporobolus airoides* (alkali sacoton)was estimated to weigh 10 grams (g), but the clipped weight was actually 9 g, then all estimates of *S. airoide*s for that transect would be multiplied by 0.90. If the total estimated weight for estimates of *S. airoides* on all plots in this transect was 80g, the resulting corrected weight would be 72 g, as illustrated below:

$$\text{Correction Factor} = \frac{\text{Sum of Measured Weights}}{\text{Sum of Estimated Weights}} = \frac{9g}{10g} = 0.90$$

Thus, in the example: (estimated green weight(g) x correction factor) = 80g x 0.90 = 72g. The corrected green weight is 72 grams.

4.2.1.2 Biomass ADW Conversion

The air dry weight percentage is part of the Reconstruction Factor and accounts for the amount of water contained in the plants. The purpose is to remove the weight of water from the weight of the actual forage of the plant. All biomass from harvested plots was collected in paper bags with tracking information recorded on the bags (date, transect identification, plot number, and species). Harvested, or green, weights were immediately weighed with a hand scale, which was adjusted for the weight of the bag, and recorded. The paper bags filled with biomass were air dried for a minimum of ten days. All bags were then weighed again and dry weights were recorded into the dataset. After drying, the weights were divided by the green weights to give a %ADW in grams to be used in the reconstruction factor. In the example above, the green weight of the harvested biomass was 9g. If the dry weight in the lab was measured at 8g, then the %ADW would be 0.888.

For species in a transect that were not harvested, an average %ADW was used that was generated from the same species in the same community. The community average, by growth form and duration, was also used on transects for species when the total green weight was less than five grams. This helped to avoid errors of proportion when dealing with very small numbers. The ADW values are included with the data for this report.

$$\%ADW = \frac{Dry\ Weight\ (lab)}{Green\ Weight(field)} = \frac{8g}{9g} = 0.8888$$

This value (0.8888) represents the numerator of the reconstruction factor. The three values in the denominator are explained below.

4.2.1.3 Utilization

The utilization estimate is applied to adjust for portions of plants that were not measured due to grazing of the plant prior to the survey. The default is 100 percent un-grazed. Grazed or utilized species were measured according to the average amount of plants that remained un-grazed in the vicinity of the transect. For example, if *S. airoides* was recorded at a utilization factor of 90 percent un-grazed, then the amount of *S. airoides* estimated would represent only 90 percent of the total amount of *S. airoides*:

Utilization = 0.9000

The total weight of the species in the transect is divided by 0.9 to bring the measured weight up to 100 percent.

4.2.1.4 Growth Curves

Growth curves are used to reconstruct the aboveground portion of a plant that has not yet reached its full growth potential for the season. The application of a growth curve accounts for the amount of forage that has not yet grown and thus was not measured during the vegetation inventory. A measurement taken in June will be much less than a measurement of the same plant taken in September, when the plant is nearing full growth. A growth curve calculates the average growth, by month, of plant species throughout the year within a specific region. For example, if *S. airoides* was measured in a transect during August, that measurement may represent only 88 percent of the full growth of that species.

Each growth curve entry was a pro-rated value according to the day of the month. For example, using the growth curve AZ3521, and a transect that was sampled August 21st, the first step would be to total the percentage of growth completed up to that date by adding up the monthly categories:

Feb (1%) +Mar(9%)+Apr(20%)+May(27%)+June(14%)+July(10%) for a subtotal of 81 percent of the growth curve completed.

Then, for the month of August, 21 days would need to be prorated and added to the total. The value is determined by dividing the percent of growth occurring in August (11 percent) by the 31 days that occur during the month of August. This calculation yields a rate of .35 percent per day. The number of days that have occurred up to that date (21 percent) is multiplied by the daily rate (.35 percent) for 7.45 percent. This is added to the 81 percent that had occurred up to the end of July for 88.45 percent of the growth curve completed.

Growth curves are typically presented in an ecological site description. However, many of the ESDs in Ecosphere's study area were incomplete or had incorrect growth curves. If the ESD was not available, no growth curve was written in the ESD, or the growth curve in the ESD was incorrect, then the ESD was replaced with the most suitable growth curve in the same common resource area if possible. Growth curves used for calculations are included with the data with this report.

The growth curve used for many sites listed in MLRA 35 (6-10" sites) is: AZ3521, 35.2, 6-10” p.z. all sites.

Growth Curve Description: Growth begins in the spring and continues through the summer, most growth occurs in the spring using stored winter moisture.

Percent production by month:

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	1	9	20	27	14	10	11	5	3	0	0

Growth Curve = 0.8845

The growth curve for the example equation is 0.8845 percent. The total weight of the species in the transect is divided by 0.8845 to bring the measured weight up to 100 percent of growth for the year.

4.2.1.5 Percent Normal Production

The Percent Normal Production is directly affected by growing conditions. Precipitation amount and timing, as well as temperature and their relationship, have an impact on species production. Production varies each year depending on the favorability of growing conditions. Biomass production measurements from year to year are not accurate without accounting for percent of normal production influences. For this inventory, the variation in precipitation was used as the value for percent of normal production. The factors of precipitation timing and temperature are extremely difficult factors to quantify and apply to biomass production because the impacts vary by individual species. Nine rain can stations were used in the calculations to determine the percent of normal production for the District 12 study area. These stations are Beautiful Mountain, Buffalo Pass, Hidden Valley SC, Junction, Newcomb, Shiprock O&M, Teec Nos Pos O&M, Toadlena, Toadlena Fish Hatchery. At the end of June of 2012, the water year average was about 81 percent compared to the previous 17 years of data.

For this example calculation, the water year was 102 percent of the average.

4.2.1.6 Reconstruction Equation

Using the example carried through the previous sections, we began with an estimated green weight (in the field) of 80 grams of *S. airoides*, multiplied by the estimation correction factor for a corrected green weight of 72 g. This corrected green weight of 72 g is then multiplied by the the reconstruction equation:

$$\mathit{Reconstruction\ Equation} = \frac{\underline{0.888}}{(0.900 \times 1.02 \times 0.8845)} = \underline{1.094}$$

The formula for the reconstruction equation, as explained above, is repeated here:

$$\mathit{CorrectedGreenWeight}\left\{\frac{\%ADW}{(\%Utilization)(\%NormalPrecipitation)(\%GrowthCurve)}\right\}$$

When actual values from the *S. airoides* example are inserted into the formula the equation becomes:

$$72g\left\{\frac{0.8888}{0.900 \times 1.02 \times 0.8845}\right\} = 72g \times 1.094 = 78.74g$$

The corrected green weight from the example above (72 g) multiplied by the reconstruction factor (1.094) results in a total reconstructed annual production of 78.74 grams. In summary, the original field estimate, with correction factor, of 72 grams of S. airoides was adjusted for water content, amount that may have been grazed, the percent of normal precipitation for the year, and the amount of growth that may have occurred after measurement, for an adjusted weight of 78.74 grams.

4.2.1.7 Conversion from Grams to Pounds Per Acre

The conversion from the working unit of grams (per transect) into the application of pounds per acre is factored into the formula. The plot size, 9.6 ft^2, was repeated ten times in each transect, thereby creating 96 ft^2 of sampling area, which calculates into a 1:1 conversion (Coulloudon et al. 1999); therefore, in this case the conversion factor equals one and so is not explicitly written into the equation. Hence, in the example, there were 78.74 pounds per acre of *S. airoides*. The value 78.74 represents the total reconstructed annual production of the species in pounds per acre.

4.2.2 Calculating Ground Cover

Fifty ground cover point intercepts were measured, so ground cover categories were divided by 50 and the result was multiplied by 100 to reach a percentage. Ground cover calculation categories were top canopy, basal cover, and bare ground. For example, if 30 hits were recorded for bare ground, the percent bare ground on that transect would be 60 percent. It is important to note that bare ground refers to situations where soil was the only substrate present. A lack of foliar or basal cover in conjunction with duff, litter, rock, or bedrock is not considered to be “bare ground.” This is because true bare soil has less soil stability than duff, litter, rock, or bedrock. Cover data was averaged by Community or Range Management Unit (RMU):

*((30 “bare ground” hits per transect)/50 sample points per transect)*100= 60% bare ground*

4.2.3 Calculating Frequency

Species frequency was measured when weights were estimated for all species in each production plot using the intensive method (Herrick et al. 2005). For example, if *S. airoides* occurred in six of the ten plots on a given transect, the frequency would be 60 percent. Frequency of species within each transect is included in the spreadsheet production data with this report (Appendix E). Frequency of the five most common species to appear on transects within each community is presented in Section 5: Results.

4.2.4 Calculating Similarity Index

Each ecological site has a unique HCPC described in the ESD. The similarity index is a process of comparing the plant community that currently exists on the ground to the HCPC. The similarity index is expressed as a percentage. One hundred percent would mean that the current plant community is at its climax stage and represents 100 percent of what would be expected to be found on the site, while a lower percentage would indicate that the current vegetation community is dissimilar in species weight and composition from the HCPC. A similarity index was calculated for all transects that were assigned to ecological sites with available ESDs.

The plant community that is currently present on a site may never reach HCPC, but instead may have changed such that its final successional state would result in what is called a PNC. The PNC, unlike the HCPC, is a result of natural disturbances and may include non-native species. For purposes of comparison, the HCPC is used because this baseline has already been established for all ecological sites.

Each ESD lists a range of expected production for above-average years and below-average years for each species (or group of species), as well as the total annual production for the site. The median of the above average and below average is always used as the comparison production amount because all of the variable factors (such as above average precipitation) have already been factored into the reconstruction process. This is the recommended and accepted method of calculating a similarity index. The sum total of these median values is used to compare the measured vegetation against the HCPC.

To calculate a similarity index, each plant species was compared to the ESD. The ESD has an assigned production value for each species (or group of species) expected to occur in the HCPC. Production that is expected to occur in the ecological site (up to the maximum percent listed) is termed allowable production. If an individual species (or group of species) is not listed in the ESD, no production is assigned or “allowed” from that species. For example:

1. A transect had 78.74 lbs/acre of *S. airoides*.
2. Based on the information in the ESD, the “allowable” production for *S. airoides* is 50 lbs/acre.
3. No more than 50 pounds may be “allowed” to be counted toward the similarity index for the transect.

4. If the ESD had listed the allowable percentage of *S. airoides* at 200 lbs/acre, then all 78.74 pounds (and no more) would have been "allowed" to be counted toward the similarity index for the transect.

Thus, every species on a transect was compared against the ESD. If the species was not expected to occur in the ecological site, it was given a zero percent allowable production value. If the species was expected to occur on the site, it was assigned the maximum value "allowable" assigned in the ESD. The total allowed pounds of each species was summed for each transect.

4.2.5 Calculating Available Forage

The forage value of a species is defined in terms of palatability and availability, as they apply to a particular type of livestock. Ecological site descriptions list only the values for common plant species. However, a comprehensive list of species from the Colorado Plateau area was developed by the Utah NRCS. This list was used to assign forage values to all species recorded in the data collection. The list is included with the digital data in Appendix E. Species are grouped into five categories and each category is weighted accordingly. The five groups recognized by the National Range and Pasture Handbook (USDA NRCS 2003) are as follows:

- **Preferred plants**—These plants are abundant and furnish useful forage for a reasonably long grazing period. They are preferred by grazing animals. Preferred plants are generally more sensitive to grazing misuse than other plants and they decline under continued heavy grazing.
- **Desirable plants**—These plants are useful forage plants, although not highly preferred by grazing animals. They either provide forage for a relatively short period, or they are not generally abundant in the stand. Some of these plants increase, at least in percentage, if the more highly preferred plants decline.
- **Emergency (or Undesirable) plants**—These plants are relatively unpalatable to grazing animals, or they are available for only a very short period. They generally occur in insignificant amounts, but may become abundant if more highly preferred species are removed.
- **Nonconsumed plants**—These plants are unpalatable to grazing animals or they are unavailable for use because of structural or chemical adaptations. They may become abundant if more highly preferred species are removed.
- **Toxic plants**—These plants are poisonous to grazing animals. They have various palatability ratings and may or may not be consumed. Toxic plants may become abundant if unpalatable and if the more highly preferred species are removed.

Species that can be injurious to livestock, regardless of their palatability, were also noted with the forage value.

In many cases, a species has more than one forage value according to the season of use. For example, *Poa fendleriana* is considered preferred in the spring, but desirable during the remainder of the year. The District 12 range management currently allows for year round grazing so a single forage value is needed. The least palatable value for sheep was chosen for each species in order to achieve a conservative estimate of the forage available and to avoid overgrazing during times of the year when palatability is lowest and forage resources are limited.

Each category of plants is assigned a harvest efficiency factor. The harvest efficiency factor accounts for production that is actually consumed by grazers and generally averages 25 percent on rangelands with continuous grazing (NRCS 2003). Not all annual production is available for livestock consumption due to trampling, loafing and other non-livestock factors such as loss to disease, insects or utilization by wildlife. Using NRCS guidelines, the harvest efficiency factors applied for this project were 35 percent for preferred plants, 25 percent for desirable, and 15 percent for undesirable/emergency plants. Non-consumed and toxic species were excluded from the calculations. The harvest efficiency factor is applied to the amount of production within a management area and its purpose is to ensure watershed protection and sustainability of the range resource by limiting allocation of the available forage.

The available forage was calculated from the amount of production provided by preferred, desirable, and undesirable/emergency plants with harvest efficiency applied. Initial stocking rates were calculated from the available forage.

4.2.6 Acreage Reductions

The amount of actual land available for grazing was quantified using geographic information systems (GIS) files from the BIA. Homesites, farmland, and roads were buffered and removed from the total acreage available for livestock grazing.

Slopes that are greater than 60 percent are generally inaccessible to livestock and were not be included in the grazing area. Moderately steep slopes had a reduced stocking rate (Table 4-1).

Livestock will rarely range more than 2 miles from a water source Holechek (1988). Areas further than 2 miles from a water source can be considered un-grazeable and that acreage should be removed from stocking rate calculations. Permitting in areas beyond 2 miles will lead to overgrazing and deterioration. However, if permittees are hauling water to their stock, this should be considered when determining stocking rates.

Based on livestock behavior, stocking rates were adjusted in the geodatabase for this study to account for distance to water and the steepness of slopes. Distance to water and slope percent were adjusted incrementally. BIA recommendations include 100 percent stocking rates between 0 and 1 mile from a water source, 50 percent stocking rate between 1 and 2 miles from the water source, and no grazing more than 2 miles from the water source (Table 4-1).

Water sources included windmill and artesian well data supplied by the BIA and wetland data created by Ecosphere for the Navajo Nation Wetland Mapping Project. Monitoring of the condition, addition, or loss of water sources should be updated in the geodatabase and resulting stocking rates.

Table 4-1. Distance to Water Reduction and Slope/Reductions

Distance to Water/ Reduction	Slope/Reduction
0-1 Mile/0%	0-10%/0%
1-2 Miles/50%	11-30%/30%
>2 Miles/100%	31-60%/60%
	>60%/100%

4.2.7 Initial Stocking Rates and Carrying Capacity

A maximum stocking rate is the number of animals grazing a specific area of land for a specific period of time. Carrying capacity for rangeland management purposes defines the number of grazing animals (maximum stocking rate) that a specified area is able to support without depleting the forage resources of that area. Carrying capacity incorporates both domestic and wild grazing animals, and the capacity may vary annually in response to forage production.

Maximum stocking rates were derived from the preferred and desirable and the undesirable or emergency production with an application of harvest efficiency factors. The pounds of preferred, desirable, and emergency forage were incorporated into animal unit months (AUMs) or 790 pounds of forage per month. This standard figure was approved by BIA rangeland managers instead of a more conservative figure. One animal unit is equivalent to four sheep, so the amount of forage needed per month for one sheep is 197.5 pounds (1/4th of 790). A total of 2,370 pounds is needed for a sheep unit year long (197.5 multiplied by 12 months).

Carrying capacities were calculated using the available forage. Carrying capacities were calculated by the acreage of each ecological site within a grazing unit. This was accomplished using the soil types to which each ecological site is correlated. The soil types with which ecological sites are correlated are not mapped; therefore, acreage estimates for ecological sites were based on soil map unit descriptions. Soil map unit descriptions allocate percentages of the entire soil map unit to each individual soil type; therefore, for each ecological site within that soil map unit complex. For example, if there are 200 acres of the Shumbegay soil map unit and 20 percent of this soil map unit consists of soil type “yy” while 80 percent consists of soil type “zz”, then soil type “yy” is calculated as 40 acres, while soil type “zz” is calculated as 160 acres.

Often, minor soils are included in the soil complex and the percentage of minor soils is added to the major soil units to account for 100 percent of the acreage of the soil map unit complex. Sometimes, the soil map units do not usually add up to 100 percent of the acreage in an area and no minor soils are described. On the advice of the NRCS (Scott Zschetzsche, personal communication), Ecosphere filled in the percentage gap with the major components in their same proportions.

5. RESULTS

The District 12 study area included the communities of Cove, Red Valley and Sanostee. Red Valley community contains two smaller management areas called RMUs and results were applied to these analysis units separately. The attributes collected at each transect were biomass production, ground cover, and species composition. The biomass data was used to calculate total annual production, species frequency, and initial stocking rates by ecological sites within each analysis area. Carrying capacity was calculated by GIS analysis of the acres of each ecological site within each analysis area. A total of 761 transect locations were provided by the BIA for data collection. Ecosphere collected production data on five additional transects to ensure against potential data loss or errors. The final data set includes 774 transects for forage production data and 761 transects for point intercept cover data. Three transects were excluded from the final analysis due to a lack of ecological site descriptions. Nine transects were read twice and data from both readings were included in the analysis.

The results of the data analysis (Table 5-1) indicate the carrying capacity of the range resource is currently exceeded. The total size of the study area is 510,788.00 acres. Currently, there are 18,490 sheep units year long permitted in the project area. The study results show an unadjusted carrying capacity of 19,611.80 sheep units (including RMUs). However, after slope and distance to water reductions were made, the carrying capacity was adjusted to 8,342.07 SUYL. This carrying capacity is the sum of the carrying capacities in each community, which in turn are the sum of carrying capacities of ecological sites. The carrying capacity is not consistent across a community therefore it is important to examine the stocking rates of each ecological site to determine which areas may be able to tolerate more livestock and which areas may be exceeding the carrying capacity. The addition of water sources would greatly improve forage availability.

The analysis covered about 90 percent of the acreage in the study area. The remaining fraction of the study area was not analyzed because there were no transects located in the soil units or no transects were located in ecological sites within specific soil units.

Results are indicative of declining forage availability in the District 12 rangelands of Cove, Red Valley, and Sanostee:

Table 5-1 Carrying Capacity Results

Carrying Capacity Category	Cove	Sanostee	Red Valley (including RMUs)
Unadjusted Initial Carrying Capacity	1,941.72	6,468.43	11,201.12
Initial Carrying Capacity Adjusted for Slope and Distance to Water	831.24	2,774.10	4,736.51
Currently permitted Sheep Units Year Long	2,436	8,899	7,155

5.1 Description of Results by Community

The carrying capacity, stocking rates, similarity indices, available forage, ground cover and species frequency and composition results are provided by community. This allows managers to see all the results of each community in order to interpret the various factors contributing to the range condition of each community. An initial description of each category of results precedes the results by community.

5.1.1 Carrying Capacity and Initial Stocking Rates

The initial stocking rate and carrying capacities were calculated by percentage of ecological site within each soil map unit within each community. The calculations for carrying capacity are run in a GIS model to calculate the percentage of each soil component of each soil map unit within each grazing unit. Soil map units that did not have any transects were not included in the GIS analysis. In general, the derived stocking rates reflect an accurate depiction of available forage. However, in some cases only one transect was located in an ecological site. If the single transect happened to have extra high or extra low production, the resulting high or low stocking rate was applied to all acres of the ecological site within the community. In these situations, it may be necessary to gather additional data prior to adjusting animal numbers.

5.1.2 Available Forage Production

Available forage is the portion of the total reconstructed production classified as preferred, desirable, and emergency forage. It is this quantity that is used to calculate stocking rates. Forage production is fairly low throughout much of the District 12 project area. The highest average production of available forage is in the Cove analysis unit (22 lbs/acre), followed by Red Valley (21 lbs/acre), and Sanostee (11lbs/acre). The two RMUs are both located in the Red Valley analysis unit. The Leona Benally RMU (77 lbs/acre) is in the northwest region and the Rex Kinsel RMU (0.3 lbs/acre) is in the southeast region.

In the available forage and stocking rate table associated with each analysis unit, these figures are compared with the production expected for the reference plant community for each ecological site and the average reconstructed production calculated from the collected biomass data. In addition, each table presents the acres associated with each ecological site, the number of transects that fell within each ecological site, and the number of acres needed to support one sheep unit for one year (Acres/SUYL). The sheep unit yearlong numbers are derived from an AUM of 790 pounds rather than the more conservative AUM of 912.5 pounds. One sheep unit year long is equivalent to 2370 pounds of forage.

5.1.3 Similarity Index

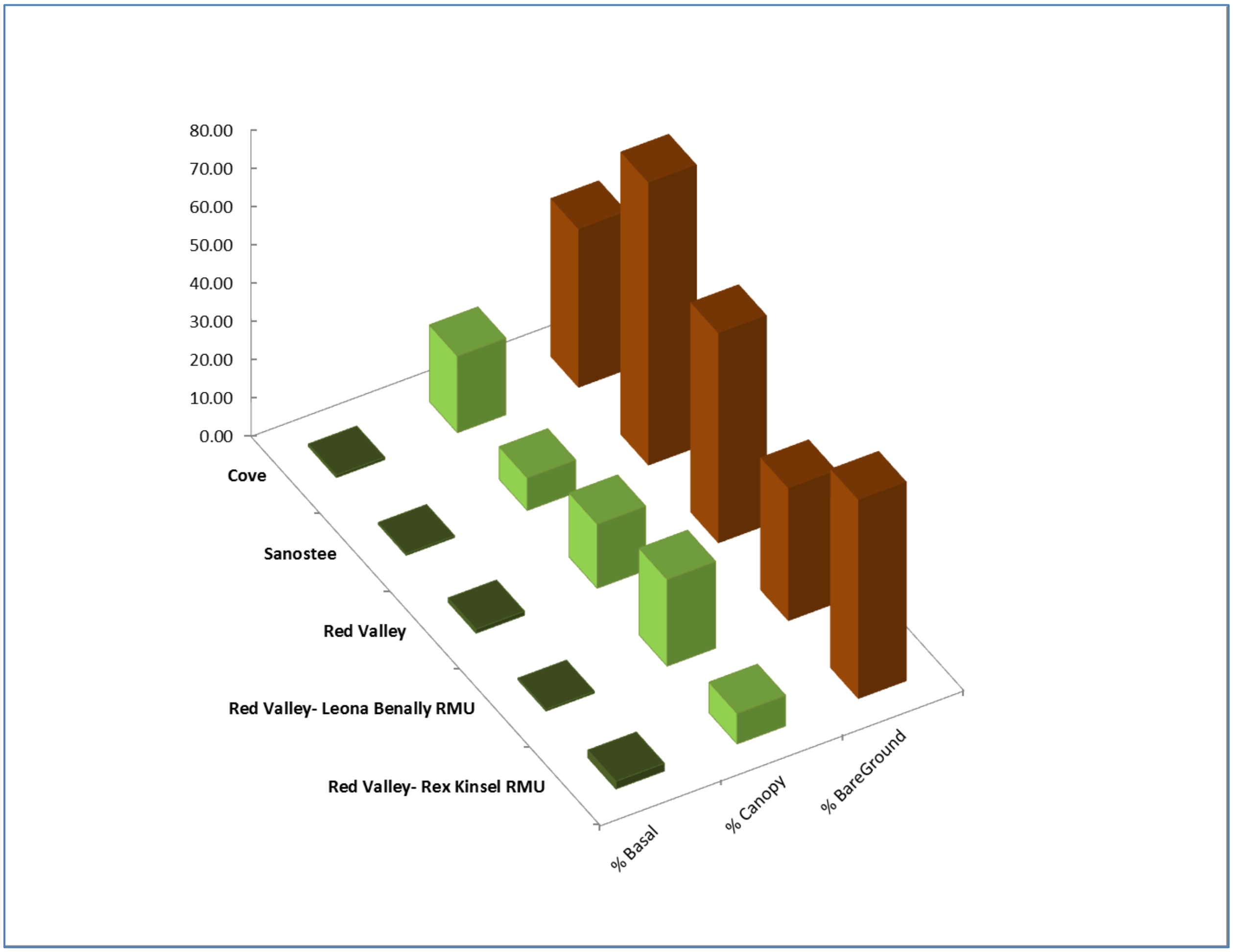
Similarity indices are only possible for those ecological sites with developed ecological site descriptions. In Cove, only 30 of the 70 transects have similarity indices; 241 of the 375 transects in Sanostee and 200 of the 317 transects in Red Valley have similarity indices. The one transect in the Rex Kinsel RMU does have a similarity index, as well as 2 of the 9 transects in the Leona Benally RMU. Similarity index values are medium to low throughout the project area, although five transects have a maximum value of more than 50 percent. Keeping in mind that many ecological sites are not expected to reach their climax state, a similarity index of 50 percent is not as low as it may at first appear.

These values are meant to be used as a management tool and do not factor into stocking rate and carrying capacity. For example, a given ecological site may be producing over 2,000 pounds of *Pleuraphis jamesii* (galleta grass) and *Sporobolus Airoides* (alkali sacaton). These two grasses are considered to be “available forage” and all of this weight would be factored into the stocking rate and carrying capacity calculations. As a result, both the stocking rate and the carrying capacity would be relatively high. However, the reference plant community in the ecological site description may only be comprised of a small percentage of the two aforementioned grass species. This would likely result in a low similarity index. In this case, it becomes a management decision as to whether or not it is more beneficial to manage for the current, high producing plant community or to try and establish a plant assemblage more similar to the reference community. The benefit of the reference community is that it is typically comprised of the suite of species best adapted to the area and reflects healthy, functioning rangeland. In most cases, production and similarity indices are both low, so although it may not be desirable to try and achieve a similarity index of 100 percent, managing for increased similarity indices would likely improve range conditions and result in more forage availability for livestock at the same time.

5.1.4 Ground Cover

Ground cover values provide a baseline for determining trend in future studies. An average of all ground cover data for the project area in District 12 is included for comparison (Figure 5-1). The most represented ground cover category across the project area is bare ground. The lowest amount of bare ground was reported from the Cove analysis unit (41 percent), followed by Red Valley (55 percent), and then Sanostee (74 percent). The amount of bare ground in the two RMUs located within the Red Valley unit was about average for the Rex Kinsel RMU (52 percent) and below average in the Leona Benally RMU (35 percent). The lower percentages of bare ground in the Cove unit and the Leona Benally RMU are like due to their locations. Both are at higher elevations, receive more precipitation than the surrounding project area and are associated with deeper soils. All of these factors contribute to more plant cover and litter production.

Figure 5-1 Point Intercept Cover Results



Note: The Figure includes the following acronyms—Range Management Unit (RMU) and percent (%).

5.1.5 Frequency and Composition

The five most common species recorded on transects in each community are presented with forage value information (an explanation of forage values is found in Section 4.2.5: Calculating Available Forage.) The Individual species frequency data (by the ten plots within each transect) are included in the electronic data with this report. The results tables presented for each community report frequency data by transect. Composition is reported by the total amount of reconstructed production of each species in the community. Several species are repeatedly found in the top five across the project area, these include *Pleuraphis jamesii* (galleta grass), *Artemisia tridentata* (big sagebrush)*, Gutierrezia sarothrae* (broom snakeweed)*, Salsola tragus* (prickly Russian thistle), *and Sporobolus airoides* (alkali sacaton).

5.2 Cove

There are 70 transects in the Cove analysis unit. Table 5-2 displays the total acreage in the unit. The column heading titled "Analyzed Acres" refers to the number of acres associated with ecological sites containing transects. The "Remaining Acres" column gives the number of acres associated with ecological sites that did not contain any transects. Carrying capacity and the carrying capacity following slope and distance to water adjustments are also presented in this table.

Table 5-3 shows the ecological sites with the highest and lowest stocking rates. Table 5-4 breaks out the unit by ecological site. Displayed for each ecological site, is the number of transects within the site, the production in the reference state, average reconstructed production, average available production, stocking rate, acres associated with each ecological site, and the carrying capacity.

Ten ecological sites had no transects located within them and so could not be analyzed, resulting in 1.07 percent of the acreage in Cove not contributing to the carrying capacity. An additional 7.78 percent was excluded due to a lack of transects combined with no NRCS correlated ecological sites, including more than 1,800 acres of badlands and almost 1,000 acres of rock outcrop.

The adjusted carrying capacity for this unit is 831 SUYL. The amount of acres necessary to support one sheep unit per year ranges from 45 to 242. The most productive ecological site is Loamy Upland 10-14" (R035XC329AZ). However this site only makes up about three percent of the project area and consequently, the carrying capacity is low. The lowest stocking rate was reported from the PIPO-PSME/QUGA-CEMO/POFE (F039XA002NM) site which comprises about nine percent of the analysis unit. The majority of transects fell within the Gravelly-Woodland (F035XG134NM) and Loamy Upland 10-14" (R035XC313AZ) ecological sites. Both of these sites are prevalent throughout the project area. The stocking rate for the Loamy Upland 10-14" (R035XC313AZ) site is one of the highest in the unit, but the Gravelly-Woodland (F035XG134NM) site has one of the lowest.

Table 5-2 Cove Carrying Capacity

Total Acres	Analyzed Acres (# of Ecological Sites)	Remaining Acres (# of Ecological Sites)	Excluded Acres	Carrying Capacity SUYL	Adjusted Carrying Capacity SUYL
41,357.19	37,696.85 (11)	442.82 (10)	3,217.52	1,941.72	**831.24**

Table 5-3 Cove Maximum and Minimum Stocking Rates

Analysis Area	Stocking Rate Minimum (Acres/SUYL)	Ecological Site with Minimum Stocking Rate	Stocking Rate Maximum (Acres/SUYL)	Ecological Site with Maximum Stocking Rate
Cove	242	F039XA002NM PIPO-PSME/QUGA-CEMO/POFE (5 Transects)	45.1	R035XC329AZ Loamy Upland 10-14" p.z. Gravelly (1 Transect)

Table 5-4 Available Forage and Stocking Rate by Ecological Site

Ecological Site	# of Transects	Total Production in Reference State (Lbs/Acre)	Average Reconstructed Production (Lbs/Acre)	Available Forage (Lbs/Acre)	Acres/ SUYL	Total Acres	Carrying Capacity (SUYL)	Adjusted Carrying Capacity (SUYL)
F035XG134NM Gravelly - Woodland	2	N/A	104.26	12.44	190.45	19776.8	726.9	311.5
F036XA001NM south of Gallup 13-16”	1	N/A	108.03	15.33	154.60	609.13	3.9	0.0
F039XA002NM PIPO-PSME/QUGA-	5	N/A	114.47	9.80	241.96	2542.12	73.5	31.5
F039XA007NM Montane slopes 12-18"	6	N/A	134.74	12.60	188.03	3417.79	127.2	54.5
R035XC302AZ Sedimentary Cliffs 10-14”	1	417.5	133.26	15.94	148.69	964.48	45.4	19.5
R035XC313AZ Loamy Upland 10-14"	2	700	300.09	34.87	67.96	6927.77	713.5	305.8
R035XC317 Sandy Loam Upland 10-14"	1	640	506.50	49.92	47.48	104.27	6.6	4.4
R035XC326AZ Sandy Loam Upland 10-14"	6	420	140.06	16.33	145.09	1736.06	83.8	35.9
R035XC328AZ Cobbly Slopes 10-14"	1	500	105.73	10.23	231.61	265.33	8.0	3.4
R035XC329AZ Loamy Upland 10-14"	1	516	365.44	52.51	45.14	972.89	150.9	64.7
R035XC330AZ Sandy Terrace 10-14"	1	515	143.52	11.73	201.96	380.19	1.9	0.0

The highest similarity index values are virtually all from the Loamy Upland 10-14” (R035XC313AZ) ecological site. The historic climax community is composed primarily of mid to short grasses like Pascopyrum smithii (western wheatgrass), Bouteloua gracilis (blue grama), and Achnatherum hymenoides (Indian ricegrass) as well as a moderate cover of shrubs such as Artemisia tridentata (big sagebrush) and Atriplex canescens (fourwing saltbush). Species most likely to invade or increase include Artemisia tridentata (big sagebrush), Gutierrezia sarothrae (broom snakeweed), Ericameria nauseosa, (rubber rabbitbrush), Juniperus species (juniper), and annuals. Currently this site is composed mostly of Artemisia tridentata (big sagebrush), Gutierrezia sarothrae, and Pleuraphis jamesii (galleta grass). Several transects also encountered the invasive annual grass, Bromus tectorum (cheatgrass). Grazing/drought disturbances have caused this site to deteriorate, but it hasn't yet reached the degraded state typified by a uniform cover of Gutierrezia sarothrae (broom snakeweed) and annual plants. A number of transects within this site also have some of the lowest similarity index values. The variability in similarity numbers is not surprising given the number of transects and large acreage associated with this site. Transects on the lower end of the similarity scale are characterized by low producing plant communities containing mostly Gutierrezia sarothrae (broom snakeweed) and annual species. The most prevalent ecological site in the analysis unit is Gravelly-Woodland (F035XG134NM). Unfortunately, a description has not yet been developed for this site, so the similarity values are not known.

Table 5-5 Cove Similarity Index

Maximum Similarity Index	Minimum Similarity Index	Median Similarity Index
44.27%	0.00%	15.59%

The Cove analysis unit has the lowest percent of bare ground and an average amount of canopy cover. Transects located at lower elevations tended to be in more degraded plant communities, and thus recorded a higher percentage of bare ground. Transects located on the wooded slopes at the higher elevations had much less bare ground, due partially to more intact plant communities and partially to higher amounts of litter accumulation from the tree canopy.

Table 5-6 Cove Ground Cover

Canopy (%)	Bare Ground (%)	Basal (%)
20.03	41.40	0.63

The percent frequency of occurrence is an important number as it provides an idea of the distribution of a species across a given area. Table 5-7 displays the top five most frequently occurring species in the Cove analysis unit. Two composite shrubs, *Gutierrezia sarothrae* (broom snakeweed) and *Artemisia tridentata* (big sagebrush) occur in 70 percent of all transects. The invasive grass, *Bromus tectorum* (cheatgrass) is a common invasive species and two perennial forage grasses; *Elymus elymoides* (bottlebrush squirreltail) and *Pleuraphis jamesii* (galleta grass) are also widespread.

It is also useful to know how much biomass or weight is being produced by a given plant species. Based upon reconstructed weights, Table 5-8 displays the top five contributors of biomass to the total production in the Cove analysis until. All of the top five most frequent species are also the top contributors to biomass with the exception of *Elymus elymoides* (bottlebrush squirreltail). The most significant producer of biomass is *Artemisia tridentata* (big sagebrush). This species, along with *Gutierrezia sarothrae* (broom snakeweed), is a common species associated with the ecological sites present in this unit. However, grazing pressures are causing them to increase beyond desirable proportions.

Table 5-7 Cove Species Frequency

Species	Frequency by Transect	Percentage of Total Transects	Growth Habit	Duration	Nativity I=Introduced, N=Native	Sheep Forage Value (Most Limiting Season of Use)
Gutierrezia sarothrae	51	72.86%	Shrub	Perennial	N	Toxic
Artemisia tridentata	50	71.43%	Shrub	Perennial	N	Emergency
Bromus tectorum	47	67.14%	Graminoid	Annual	I	Injurious
Elymus elymoides	33	47.14%	Graminoid	Perennial	N	Emergency
Pleuraphis jamesii	21	30.00%	Graminoid	Perennial	N	Emergency

Table 5-8 Cove Species Composition

Species	Sum Total Reconstructed Weight (pounds/acre)	Percentage of Total Weight in Community	Growth Habit	Duration	Nativity I=Introduced, N=Native	Sheep Forage Value (Most Limiting Season of Use)
Artemisia tridentata	5,058.60	40.79%	Shrub	Perennial	N	Emergency
Gutierrezia sarothrae	1,210.63	9.76%	Shrub	Perennial	N	Toxic
Pleuraphis jamesii	911.76	7.35%	Graminoid	Perennial	N	Emergency
Agropyron cristatum	739.25	5.96%	Graminoid	Perennial	I	Emergency
Bromus tectorum	496.68	4.01%	Graminoid	Annual	I	Injurious

5.3 Sanostee

There are 377 transects located in the Sanostee analysis unit. Table 5-9 displays the total acreage in the unit. The column heading titled “Analyzed Acres” refers to the number of acres associated with ecological sites containing transects. The “Remaining Acres” column gives the number of acres associated with ecological sites that did not contain any transects. Carrying capacity and the carrying capacity following slope and distance to water adjustments are also presented in this table.

Table 5-10 shows the ecological sites with the highest and lowest stocking rates. Table 5-11 breaks out the unit by ecological site. Displayed for each ecological site, is the number of transects within the site, the production in the reference state, average reconstructed production, average available production, stocking rate, acres associated with each ecological site, and the carrying capacity.

Fifteen ecological sites had no transects located within them and so could not be analyzed, resulting in 0.65 percent of the acreage in Sanostee not contributing to the carrying capacity. An additional 2.67 percent was excluded from the analysis due to a lack of transects in areas with no NRCS correlated ecological sites

The adjusted carrying capacity for the Sanostee analysis unit is 2,774.33 sheep units per year. The highest stocking rate occurs in the Loamy 6-10” terrace (R035XB020NM) ecological site. This site also has the highest carrying capacity and occupies close to 17,000 acres. The lowest stocking rate (non stockable) was recorded for the Shale Hills 6-10” Sodic (R035XB268AZ) ecological site. The total acreage for this site is about 900 and received only one transect. It is difficult to maintain adequate forage production at this site. Slopes are usually steep, soils are shallow, and precipitation events are infrequent. A large share of the transects are located in the Sandy Loam Upland 6-10" (R035XB274AZ), Loamy Fan 6-10" (R035XB275AZ), Siltstone Upland 6-10" (R035XB276AZ), Sandy Loam Upland 6-10” (R035XB030NM), Sandstone Upland 6-10" (R035XB204AZ), and Clay Loam Terrace 7-10"R035XB016NM ecological sites. In all ecological sites, the average reconstructed production is well below the production associated with the reference state. Average available forage is also low in all sites and ranges from 0-31 pounds per acre.

Table 5-9 Sanostee Carrying Capacity

Total Acres	Analyzed Acres (# of Ecological Sites)	Remaining Acres (# of Ecological Sites)	Excluded Acres	Carrying Capacity SUYL	Adjusted Carrying Capacity SUYL
250,991.33	229,271.90 (28)	6,705.15 (15 Ecological Sites)	1,638.03	6,468.43	**2,774.10**

Table 5-10 Sanostee Maximum and Minimum Stocking Rates

Analysis Area	Stocking Rate Minimum (Acres/SUYL)	Ecological Site with Minimum Stocking Rate	Stocking Rate Maximum (Acres/SUYL)	Ecological Site with Maximum Stocking Rate
Sanostee	Not Stockable	R035XB268AZ Shale Hills 6-10" Sodic (1 Transect)	76.40	R035XB020NM Loamy 6-10" terrace (12 Transects)

Table 5-11 Sanostee Results by Ecological Site

Ecological Site	# of Transects	Total Production in Reference State (Lbs/Acre)	Average Reconstructed Production (Lbs/Acre)	Available Forage (Lbs/acre)	Acres/ SUYL	Total Acres	Carrying Capacity (SUYL)	Adjusted Carrying Capacity (SUYL)
Badlands	2	N/A	91.24	21.74	109.03	4836.76	310.6	133.1
F035XG134NM Gravelly - Woodland	17	N/A	109.54	11.03	214.93	22418.8	730.2	312.9
R035XB016NM Clay Loam Terrace 7-10"	25	410	147.45	13.61	174.15	11448.2	460.2	197.2
R035XB018NM Loamy Bottom 6-10"	2	1300	59.02	0.28	8475.21	1036.30	0.2	0.1
R035XB020NM Loamy 6-10" terrace	12	500	160.64	31.02	76.40	7863.55	720.5	308.8
R035XB021NM Loamy Upland 7-10"	22	450	113.78	12.98	182.56	11119.4	426.4	182.7
R035XB022NM Loamy Upland Sodic	13	334	51.03	5.88	402.89	16400.9	285.0	122.1
R035XB024NM Saline Bottom 6-10"	8	1600	157.17	16.09	147.29	2265.81	46.2	23.1
R035XB028NM Sandy Bottom 6-10"	5	850	47.31	2.05	1156.19	1950.41	11.8	5.1
R035XB030NM Sandy Loam Upland 6-	29	400	89.74	10.80	219.44	17942.6	490.6	220.8
R035XB034NM Sandy Terrace 6-10"	10	451	138.92	15.37	154.23	5693.33	258.4	110.7
R035XB035NM Sandy Upland 6-10"	5	400	61.92	6.87	344.79	4287.69	37.3	10.6
R035XB204AZ Sandstone Upland 6-10"	28	150	88.28	9.55	248.19	11013.3	310.6	133.1
R035XB268AZ Shale Hills 6-10" Sodic	1	209	11.09	0.00	Not Stockable	583.65	0.0	0.0
R035XB271AZ Loamy Upland 6-10"	19	150	46.73	5.99	395.47	11735.6	207.7	89.0
R035XB274AZ Sandy Loam Upland 6-10"	65	450	64.03	6.09	389.40	30933.7	556.1	238.3

R035XB275AZ Loamy Fan 6-10"	27	451	94.15	13.02	182.03	14236.4	547.5	234.6
R035XB276AZ Siltstone Upland 6-10"	25	176	37.76	4.40	539.18	23799.8	309.0	132.4
R035XB277AZ Siltstone Upland 6-10"	10	221	39.17	4.70	504.79	7966.29	110.5	47.3
R035XB278AZ Loamy Upland 6-10"	12	450	42.80	4.79	495.20	8637.15	34.9	8.7
R035XB279AZ Clay Loam Upland 6-10"	3	392	23.67	1.34	1772.17	780.44	0.4	0.0
R035XC302AZ Sedimentary Cliffs 10-14"	2	417.5	18.92	2.01	1178.64	4777.65	28.4	12.2
R035XC307AZ Clay Loam Upland 10-14"	1	603.5	153.98	15.26	155.35	406.80	18.3	7.9
R035XC313AZ Loamy Upland 10-14"	8	700	213.16	26.98	87.83	2596.96	207.0	88.7
R035XC317AZ Sandy Loam Upland 10-	3	640	167.58	18.09	131.02	2724.59	145.6	62.4
R035XC318AZ Silty Shallow 10-14"	1	294	169.24	24.00	98.75	1162.63	82.4	35.3
R035XC328AZ Cobbly Slopes 10-14"	4	500	153.85	6.66	355.66	2955.04	58.2	24.9
R035XC335AZ Clay Loam Hills 10-14"	10	450	83.42	8.11	292.09	3118.04	74.7	32.0
Rock Outcrop	5	N/A	26.28	0.37	6324.59	7955.83	0.5	0.2
Unassigned	4	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Similarity index values ranged from 0-84 percent. Three transects in the Loamy Upland 6-10” Saline-Sodic (R035XB271AZ) ecological site had values over 65 percent. This is a low producing site that is characterized by low growing shrubs, sparse grass cover, and a variety of annual and perennial forbs. The high salt content of the soils dictate that halophytes (salt-loving) like Atriplex corrugata (mat saltbush) will always dominate the site. Species that are likely to invade or increase following disturbance are *Salsola tragus* (prickly Russian thistle), *Atriplex corrugata* (mat saltbush), *Eriogonum cernuum* (nodding buckwheat), and members of the *Brassicaceae* family (mustard family). In general, transects are dominated by *Atriplex corrugata* (mat saltbush) and *Sporobolus* species (dropseed). A few transects contained the invasive species, *Salsola tragus* (prickly Russian thistle) and *Halogeton glomeratus* (saltlover). Sheep are very susceptible to toxins contained within *Halogeton glomeratus* (saltlover) and usually die within about ten hours after consuming the plant (Stubbendieck et al. 1992).

The ecological site with the most transects is Sandy Loam Upland 6-10" (R035XB274AZ). This historical climax community is made up primarily of perennial grasses like *Achnatherum hymenoides* (Indian ricegrass), *Aristida purpurea* (purple threeawn), *Elymus elymoides* (bottlebrush squirreltail), *Pleuraphis jamesii* (galleta grass), *Sporobolus airoides* (alkali sacaton), and *Sporobolus cryptandrus* (sand dropseed). A much smaller part of the community is composed of various *Atriplex* shrubs (saltbush) and forbs such as *Chaetopappa ericoides* (rose heath) and *Sphaeralcea* species (globe mallow). Similarity values range from 0-42. Overall, disturbances at this site have led to increases in *Atriplex* species, *Sporobolus airoides* (alkali sacaton), and *Salsola tragus* (prickly Russian thistle). Species that have decreased include *Achnatherum hymenoides* (Indian ricegrass) and *Elymus elymoides* (bottlebrush squirreltail).

Table 5-12 Sanostee Similarity Index

Maximum Similarity Index	Minimum Similarity Index	Median Similarity Index
84.22%	0.00%	6.68%

The Sanostee analysis unit has the highest percentage of bare ground. This unit extends out east into some of the driest, harshest, and saltiest regions of the project area. Much of the unit is characterized by shrub and grassland communities composed mostly of *Atriplex* species (saltbush), *Sarcobatus vermiculatus* (black greasewood), *Sporobolus* species (dropseed), and *Pleuraphis jamesii* (galleta grass). Given the nature of the climate and soils, it is not unusual to have a fair amount of bare ground in this area. However, grazing pressure, especially continuous grazing, can quickly lead to invasions of exotic species and increases in annual plants and shrub species. Consequently, the amount of bare ground will also increase. This appears to be the situation throughout the lower regions of this analysis unit. The percentage of canopy cover is also quite low.

Table 5-13 Sanostee Ground Cover

Canopy (%)	Bare Ground (%)	Basal (%)
8.52	73.87	0.44

The large size and diverse landscape encompassed by the Sanostee analysis unit gives rise to diverse set of plant species. This is reflected in Table 5-15 which shows the top five most frequently occurring species. The most widespread species are *Pleuraphis jamesii* (galleta grass) and *Sporobolus airoides* (alkali sacaton), but both of these grasses were only found in about half of the 377 transects. These two species are also the top producers of biomass. Three species of salt tolerant *Atriplex* species (saltbush) are the next highest producers of biomass. Production is not exceptionally high for the invasive forb, *Salsola tragus* (prickly Russian thistle) and the desirable forage grass, *Achnatherum hymenoides* (Indian ricegrass), but both are fairly prevalent in the analysis unit.

Table 5-14 Sanostee Species Frequency

Species	Frequency by Transect	Percentage of Total Transects	Growth Habit	Duration	Nativity I=Introduced, N=Native	Sheep Forage Value (Most Limiting Season of Use)
Pleuraphis jamesii	197	52.25%	Graminoid	Perennial	N	Emergency
Sporobolus airoides	189	50.13%	Graminoid	Perennial	N	Emergency
Salsola tragus	118	31.30%	Forb	Annual	I	Injurious
Achnatherum hymenoides	112	29.71%	Graminoid	Perennial	N	Desirable
Gutierrezia sarothrae	103	27.32%	Shrub	Perennial	N	Toxic

Table 5-15 Sanostee Species Composition

Species	Sum Total Reconstructed Weight (pounds/acre)	Percentage of Total Weight in Community	Growth Habit	Duration	Nativity I=Introduced, N=Native	Sheep Forage Value (Most Limiting Season of Use)
Pleuraphis jamesii	5,178.30	15.72%	Graminoid	Perennial	N	Emergency
Sporobolus airoides	5,152.42	15.64%	Graminoid	Perennial	N	Emergency
Atriplex obovata	4,167.74	12.65%	Subshrub/Shrub	Perennial	N	Emergency
Atriplex confertifolia	2,976.23	9.03%	Shrub	Perennial	N	Injurious
Atriplex canescens	2,856.12	8.67%	Shrub	Perennial	N	Desirable

5.4 Red Valley

There are 317 transects located in the Red Valley analysis unit not including the ten transects that fell within the two RMUs. Table 5-16 displays the total acreage in the unit. The column heading titled “Analyzed Acres” refers to the number of acres associated with ecological sites containing transects. The “Remaining Acres” column gives the number of acres associated with ecological sites that did not contain any transects. Carrying capacity and the carrying capacity following slope and distance to water adjustments are also presented in this table. Table 5-17 shows the ecological sites with the highest and lowest stocking rates. Table 5-18 breaks out the unit by ecological site. Displayed for each ecological site, is the number of transects within the site, the production in the reference state, average reconstructed production, average available production, stocking rate, acres associated with each ecological site, and the carrying capacity.

Thirteen ecological sites had no transects located within them and so could not be analyzed, resulting in 1.04 percent of the acreage in Red Valley not included in the carrying capacity calculation. An additional 2.05 percent was excluded due to a lack of transects combined with no NRCS correlated ecological sites, including more than 3,000 acres of badlands.

The adjusted carrying capacity for the Red Valley unit is 4,520.32 sheep units per year. Of the 41 ecological sites analyzed, the carrying capacity was highest for Gravelly-Woodland (F035XG134NM). The highest stocking rate comes from the Gravelly Loamy (R036XB006NM) site and the lowest from the Loamy Upland Sodic (R035XB022NM) and Loamy Bottom 6-10" (R035XB018NM) sites. However, only one transect fell within each of these ecological sites, so further information may be necessary to assign a more accurate stocking rate. The most prevalent ecological site is Gravelly-Woodland (F035XG134NM). Over a quarter of all transects are located within this site. The stocking rate and available forage is average for the Red Valley unit. The site with the most available forage (68 lbs/acre) is Silty Upland 17-25" (R035XH813AZ). Unfortunately, this site only comprises a very small fraction of the analysis unit. However, the least productive ecological sites also only make up very small areas of the unit. The one exception is the Siltstone Upland 6-10" Saline (R035XB276AZ) site. This site covers over 11,000 acres, but only averages 3.6 pounds of forage per acre.

Table 5-16 Red Valley Carrying Capacity

Total Acres	Analyzed Acres (# of Ecological Sites)	Remaining Acres (# of Ecological Sites)	Excluded Acres	Carrying Capacity SUYL	Adjusted Carrying Capacity SUYL
214,584.63	207,948.13 (40)	2,239.87 (13)	4,396.63	10,729.30	**4,520.32**

Table 5-17 Red Valley Initial Stocking Rates

Analysis Area	Stocking Rate Minimum (Acres/SUYL)	Ecological Site with Minimum Stocking Rate	Stocking Rate Maximum (Acres/SUYL)	Ecological Site with Maximum Stocking Rate
Red Valley	Not Stockable	R035XB022NM Loamy Upland Sodic and R035XB 018 Loamy Bottom 6-10" (1 Transect each)	27.05	R036XB006NM Gravelly Loamy (1 Transect)

Table 5-18 Red Valley Results by Ecological Site

Ecological Site	# of Transects	Total Production in Reference State (Lbs/Acre)	Average Reconstructed Production (Lbs/Acre)	Available Forage (Lbs/acre)	Acres/ SUYL	Total Acres	Carrying Capacity (SUYL)	Adjusted Carrying Capacity (SUYL)
F035XG134NM Gravelly - Woodland	86	N/A	213.25	24.56	96.49	51580.97	3742.0	1603.7
F035XH005NM Pseudotsuga menziesii-Pinus ponderosa/Symphoricarpos albus	1	N/A	413.56	54.46	43.52	2779.23	63.9	0.0
F036XA001NM south of Gallup 13-16”	2	N/A	164.51	27.99	84.66	593.64	7.0	0.0
F039XA007NM Montane slopes 12-18"	4	N/A	107.20	18.03	131.42	1139.91	8.7	0.0
R035XB016NM Clay Loam Terrace Sodic 7-10"	10	410	83.70	7.32	323.69	2645.86	57.2	24.5
R035XB018NM Loamy Bottom 6-10"	1	1300	13.27	0.00	0.00	1616.81	0.0	0.0
R035XB020NM Loamy 6-10" terrace	10	500	190.51	19.35	122.45	3960.41	194.1	87.3
R035XB021NM Loamy Upland 7-10"	17	450	196.79	22.49	105.36	6886.17	457.5	196.1
R035XB022NM Loamy Upland Sodic	1	334	0.00	0.00	0.00	920.29	0.0	0.0
R035XB028NM Sandy Bottom 6-10"	1	850	41.09	8.93	265.34	187.79	4.2	2.0
R035XB030NM Sandy Loam Upland 6-10"	8	400	262.76	35.66	66.46	4107.70	432.6	185.4
R035XB034NM Sandy Terrace 6-10" Sodic	2	451	274.26	11.78	201.21	876.35	26.1	12.4
R035XB204AZ Sandstone Upland 6-10” Very Shallow	2	150	157.94	27.57	85.95	2489.50	202.7	86.9
R035XB210AZ Loamy Upland 6-10"	25	538	169.39	16.12	146.99	13982.54	665.9	285.4
R035XB216AZ Sandy Wash 6-10"	2	900	53.03	8.57	276.46	1072.89	15.5	3.9
R035XB217AZ Sandy Upland 6-10"	2	443	234.87	28.60	82.87	674.54	48.8	22.0
R035XB219AZ Sandy Loam Upland 6-10"	13	663	199.87	27.11	87.41	5534.90	379.9	171.0
R035XB222AZ Sandy Terrace 6-10"	1	409	95.83	8.21	288.50	360.74	8.8	3.8
R035XB227AZ Sandy Loam Upland 6-10"	1	362	102.92	0.77	3083.75	288.65	0.1	0.0
R035XB228AZ Loamy Upland 6-10" Sodic	1	186	844.28	0.56	4203.51	178.67	0.0	0.0
R035XB238AZ Sandy Terrace 6-10" Sodic	5	500	226.96	21.66	109.40	1937.36	106.3	47.8
R035XB274AZ Sandy Loam Upland 6-10"	14	450	67.12	6.32	374.76	7118.35	133.0	57.0
R035XB275AZ Loamy Fan 6-10"	10	451	118.58	0.71	3341.07	4763.64	10.0	4.3
R035XB276AZ Siltstone Upland 6-10" Saline	12	176	49.26	3.57	664.22	11506.43	121.3	52.0

R035XC302AZ Sedimentary Cliffs 10-14"	7	417.5	188.30	18.60	127.39	3117.95	171.3	73.4
R035XC313AZ Loamy Upland 10-14"	17	700	345.07	38.78	61.12	12369.85	1416.8	607.2
R035XC314AZ Sandstone Upland 10-14"	3	430	207.61	25.46	93.09	2058.77	154.8	66.3
R035XC315AZ Sandy Upland 10-14"	6	600	240.53	35.46	66.84	3875.76	405.9	173.9
R035XC316AZ Clay Loam Swale 10-14"	12	N/A	115.72	13.59	174.37	8720.45	350.1	150.0
R035XC317AZ Sandy Loam Upland 10-14"	9	640	190.07	15.42	153.72	6933.34	315.7	135.3
R035XC318AZ Silty Shallow 10-14"	2	294	59.05	4.70	503.99	314.35	2.5	0.6
R035XC324AZ Clayey Slopes 10-14"	2	395	113.27	1.46	1624.41	2815.54	12.1	5.2
R035XC325AZ Stony Slopes 10-14"	3	375	242.85	22.02	107.63	2204.93	143.4	61.5
R035XC326AZ Sandy Loam Upland 10-14"	6	420	278.99	11.89	199.39	4602.28	161.6	69.2
R035XC327AZ Clayey Upland 10-14" Sodic	3	176	172.31	14.57	162.65	4640.86	199.7	85.6
R035XC328AZ Cobbly Slopes 10-14"	6	497.5	236.62	20.87	113.56	1547.38	95.4	40.9
R035XC329AZ Loamy Upland 10-14"	5	516	216.89	30.70	77.20	4029.68	365.4	156.6
R035XH813AZ Silty Upland 17-25"	1	940	633.37	67.87	34.92	886.13	25.4	0.0
R035XH814AZ Sandstone Upland 17-25"	1	780	403.03	57.03	41.56	1265.90	30.5	0.0
R036XB006NM Gravelly Loamy	1	842	584.86	87.63	27.05	2550.70	188.6	47.2
Rock Outcrop	12	N/A	60.45	4.80	493.87	18810.95	4.6	2.0

The higher and lower similarity index scores are associated with a wide variety of ecological sites. However, the median and average values both indicate that most plant communities are dissimilar from the historic climax community. At this time, there is no historic community description available for the dominant Gravelly-Woodland (F035XG134NM) ecological site. The site is currently comprised of *Artemisia tridentata* (big sagebrush), *Gutierrezia sarothrae* (broom snakeweed), *Yucca* species (yucca), *Poa fendleriana* (muttongrass), *Hesperostipa comata* (needle and thread), and *Bromus tectorum* (cheatgrass). This is typical of sites within this unit that still have valuable forage plants present in the community, but that has seen increases in shrub species and has started to become invaded by exotic species due to disturbance factors (grazing/drought).

The Siltstone Upland 6-10" Saline (R035XB276AZ) site is a cause for concern given that it makes up a fairly large portion of the analysis unit, but has extremely low production. The traditional production associated with this site is also low, but the current numbers are well below average. The site is considered to be one of the driest in the region and the erosion potential is high due to strong winds in the spring, violent thunderstorms in the summer and fall, and occurrence of fairly steep slopes. The saline and sodium content of the soils largely dictates the composition of the plant community. Grasses typically include *Achnatherum hymenoides* (Indian ricegrass), *Elymus elymoides* (bottlebrush squirreltail), *Pleuraphis jamesii* (galleta grass), *Sporobolus airoides* (alkali sacaton), and *Sporobolus nealleyi* (gyp dropseed). Shrubs include a large variety of *Atriplex* species (saltbush), *Krascheninnikovia* *lanata* (winterfat), *Picrothamnus desertorum* (bud sagebrush), and *Tiquilia latior* (matted crinklemat). Common forbs are *Sphaeralcea* species (globemallow) and *Cleome lutea* (yellow beeplant). Continued disturbance from grazing will increase *Pleuraphis jamesii* (galleta grass), *Sporobolus airoides* (alkali sacaton), and *Atriplex falcata* (sickle saltbush). Invaders include *Salsola tragus* (prickly Russian thistle) and a variety of other annual species. As the site further deteriorates, invasive species will increase and the original plant community will largely disappear with the exception of the highly adapted shrub, *Atriplex falcata* (sickle saltbush). The current species composition matches well with the historic climax community, but the abundance of each species is reduced which explains why production records at each transect were so low. Exotic species like *Salsola tragus* (prickly Russian thistle), *Bromus tectorum* (cheatgrass), and *Halogeton glomeratus* (saltlover) have also begun to invade portions of this ecological site.

The Loamy Upland 10-14" (R035XC313AZ) has relatively high values for available forage, stocking rate, and carrying capacity. It also occupies over 12,000 acres in the analysis unit. This site receives 10-14” of rain annually and soils tend to consist of deep loams. The historic climax community is composed primarily of grasses like *Pascopyrum smithii* (western wheatgrass), *Bouteloua gracilis* (blue grama), and *Achnatherum hymenoides* (Indian ricegrass) as well as a moderate cover of shrubs such as Artemisia *tridentata* (big sagebrush) and *Atriplex canescens* (fourwing saltbush). Species most likely to invade or increase include *Artemisia tridentata* (big sagebrush), *Gutierrezia sarothrae* (broom snakeweed), *Ericameria nauseosa*, (rubber rabbitbrush), *Juniperus* species (juniper), and annual species like *Bromus tectorum* (cheatgrass). The plant community encountered during the survey would indicate that grazing pressures have caused *Artemisia tridentata* (big sagebrush) and *Gutierrezia sarothrae* (broom snakeweed) to increase and although it is not yet abundant, *Bromus tectorum* (cheatgrass) has started to invade much of this ecological site.

Table 5-19 Red Valley Similarity Index

Maximum Similarity Index	Minimum Similarity Index	Median Similarity Index
51.66%	0.00%	11.48%

The percentages of canopy cover and bare ground in the Red Valley analysis unit are average for the project area. Bare ground is much more prevalent in the drier, lower elevation sites located in the eastern half of the unit and canopy cover is better in the higher, wetter western half. Restoration efforts targeting sites in the western half of the unit will be easier due to elevated precipitation and the fact that the plant communities are in better condition. It is important to try and reduce the amount of bare ground in the east, but this task will be difficult given the harsher climate and saline soils.

Table 5-20 Red Valley Ground Cover

Canopy (%)	Bare Ground (%)	Basal (%)
16.77	54.88	1.05

The most frequently encountered and highest producing species in Red Valley are *Gutierrezia sarothrae* (broom snakeweed), *Artemisia tridentata* (big sagebrush), and *Pleuraphis jamesii* (galleta grass). *Achnatherum hymenoides* (Indian ricegrass) is desirable forage grass that is not producing a substantial amount biomass, but is fairly widespread in the analysis unit. This grass is a component of virtually every historic climax community associated with Red Valley. The two exotic species that are either wide spread, *Bromus tectorum* (cheatgrass), or producing a lot of biomass, *Salsola tragus* (prickly Russian thistle), are indicative of degraded rangeland. However, their occurrence is not yet at the point that they have completely supplemented the native plant communities.

Table 5-21 Red Valley Species Frequency

Species	**Frequency by Transect**	**Percentage of Total Transects**	**Growth Habit**	**Duration**	**Nativity I=Introduced, N=Native**	**Sheep Forage Value (Most Limiting Season of Use)**
Gutierrezia sarothrae	208	65.62%	Shrub	Perennial	N	Toxic
Pleuraphis jamesii	187	58.99%	Graminoid	Perennial	N	Emergency
Salsola tragus	125	39.43%	Forb	Annual	I	Injurious
Achnatherum hymenoides	120	37.85%	Graminoid	Perennial	N	Desirable
Bromus tectorum	116	36.59%	Graminoid	Annual	I	Injurious

Table 5-22 Red Valley Species Composition

Species	Sum Total Reconstructed Weight (pounds/acre)	Percentage of Total Weight in Community	Growth Habit	Duration	Nativity I=Introduced, N=Native	Sheep Forage Value (Most Limiting Season of Use)
Artemisia tridentata	9,662.43	16.99%	Shrub	Perennial	N	Emergency
Pleuraphis jamesii	9,633.53	16.94%	Graminoid	Perennial	N	Emergency
Gutierrezia sarothrae	4,839.17	8.51%	Shrub	Perennial	N	Toxic
Atriplex canescens	2,666.72	4.69%	Shrub	Perennial	N	Desirable
Salsola tragus	2,557.07	4.50%	Forb	Annual	I	Injurious

5.5 RMUs

There are two RMUs in the project area and both occur within the Red Valley analysis unit. The Leona Benally RMU contains 9 transects and the Rex Kinsel RMU contains only one. Table 5-23 displays the total acreage in the unit. The column heading titled “Analyzed Acres” refers to the number of acres associated with ecological sites containing transects. The “Remaining Acres” column gives the number of acres associated with ecological sites that did not contain any transects. Carrying capacity and the carrying capacity following slope and distance to water adjustments are also presented in this table.

Table 5-24 shows the ecological sites with the highest and lowest stocking rates. Table 5-25 breaks out the unit by ecological site. Displayed for each ecological site, is the number of transects within the site, the production in the reference state, average reconstructed production, average available production, stocking rate, acres associated with each ecological site, and the carrying capacity.

Because only one transect was placed in the Rex Kinsel RMU, only one ecological site was sampled, and there are 10 additional ecological sites, plus rock outcrop, in the RMU with acres from 0.83 up to 99.17. More than 75% of the acres in the Rex Kinsel RMU could not be analyzed by ecological site. Therefore, the final carrying capacity is much lower than expected.

Three ecological sites were sampled in the Leona Benally RMU. Five ecological sites, covering a total of 70.64 acres, were not sampled. Also, 5.5 acres of badlands and 188.27 acres of rock outcrop were excluded from the analysis.

The carrying capacity for the Rex Kinsel RMU is extremely low, but as forage data was only available from one transect, this figure cannot be considered to be especially accurate. Given the RMU's small size, it is likely that more information would not significantly alter the results. Gaining additional data from unsampled ecological sites would help present a better overall picture of this RMU. The carrying capacity for the Leona Benally RMU is much higher and the amount of acres necessary to support a sheep unit for one year ranges from 27-44. The majority of transects occur in the two most productive sites in all of the Red Valley area. These are Loamy Upland 10-14" (R035XC313AZ) and Gravelly-Woodland (F035XG134NM). Available forage is fairly high for all ecological sites analyzed in this RMU.

Table 5-23 RMU Carrying Capacity

RMU	Total Acres	Analyzed Acres (# of Ecological Sites)	Remaining Acres	Carrying Capacity SUYL	Adjusted Carrying Capacity SUYL
Rex Kinsel	477.09	110.46 (1)	336.47 (10 Ecological Sites)	0.06	**0.01**
Leona Benally	3,377.76	3,113.35 (3)	70.64 (5)	471.77	**216.17**

Table 5-24 RMU Maximum and Minimum Stocking Rates

Analysis Area	Stocking Rate Minimum (Acres/SUYL)	Ecological Site with Minimum Stocking Rate	Stocking Rate Maximum (Acres/SUYL)	Ecological Site with Maximum Stocking Rate
Leona Benally RMU	44.14	F035XG134NM Gravelly – Woodland (5 Transects)	26.66	R035XC313AZ Loamy Upland 10-14" p.z. (3 Transects)
Rex Kinsel RMU	7,790.54	R035XC318AZ Silty Shallow 10-14" p.z. (1Transect)	7,790.54	R035XC318AZ Silty Shallow 10-14" p.z. (1Transect)

Table 5-25 RMU Results by Ecological Site

Ecological Site	# of Transects	Total Production in Reference State (Lbs/Acre)	Average Reconstructed Production (Lbs/Acre)	Available Forage (lbs/acre)	Acres/ SUYL	Total Acres	Carrying Capacity (SUYL)	Adjusted Carrying Capacity (SUYL)
R035XC318AZ Silty Shallow 10-14" (Rex Kinsel RMU)	1	294	49.72	0.30	7790.54	110.46	0.01	0.0
F035XG134NM Gravelly – Woodland (Leona Benally RMU)	5	N/A	361.85	53.69	44.14	2680.87	425.1	182.2
R035XC313AZ Loamy Upland 10-14" (Leona Benally RMU)	3	700	686.72	88.90	26.66	405.66	45.6	33.5
R036XB006NM Gravelly Loamy (Leona Benally RMU)	1	842	584.86	87.63	27.05	26.82	1.0	0.5

The only analyzed ecological site in the Rex Kinsel RMU is Silty Shallow 10-14" (R035XC318AZ). The historic climax community is made up primarily of grass species including *Achnatherum hymenoides* (Indian ricegrass), *Bouteloua gracilis* (blue grama), and *Pleuraphis jamesii* (galleta grass). Forbs and shrubs are not common, but when present usually consist of *Artemisia bigelovii* (Bigelow sagebrush), *Atriplex confertifolia* (shadscale), *Ephedra torreyana* (Torrey Mormon tea), *Eriogonum leptophyllum* (slender buckwheat), *Krascheninnikovia lanata* (winterfat), and *Tiquilia latior* (matted crinklemat). Continuous disturbance will cause *Atriplex confertifolia* (shadscale) and *Ephedra torreyana* (Torrey Mormon tea) to increase and allow annual exotics to invade. Currently the site is in a degraded condition. *Atriplex confertifolia* (shadscale) is contributing the most biomass and the majority of the remaining community is made up of a mix of native and exotic annual species.

The median similarity index value for the Leona Benally RMU is 10 percent and the highest score is 43 percent. All but one transect are within the Loamy Upland 10-14" (R035XC313AZ) and Gravelly-Woodland (F035XG134NM) ecological sites. A site description is not yet available for the Gravelly-Woodland (F035XG134NM) site. A discussion of the Loamy Upland 10-14" (R035XC313AZ) site can be found in the similarity Index section for the Red Valley analysis unit. The current communities for both sites contain a mix of *Artemisia tridentata* (big sagebrush), *Gutierrezia sarothrae* (broom snakeweed), *Elymus elymoides* (bottlebrush squirreltail), *Pleuraphis jamesii* (galleta grass), *Achnatherum hymenoides* (Indian ricegrass), *Hesperostipa comata* (needle and thread), and *Sphaeralcea ambigua* (desert globemallow). Also present are the invasive species *Bromus tectorum* (cheatgrass) and *Salsola tragus* (prickly Russian thistle).

The final analyzed ecological site in the Leona Benally RMU is Gravelly Loamy (R036XB006NM). This site historically supports a wide variety of grasses including *Pascopyrum smithii* (western wheatgrass), *Achnatherum hymenoides* (Indian ricegrass), *Hesperostipa comata* (needle and thread), *Bouteloua gracilis* (blue grama), *Sporobolus airoides* (alkali sacaton), and *Poa fendleriana* (muttongrass). Shrub and forb species include *Castilleja coccinea* (Indian paintbrush), *Eriogonum* species (buckwheat), *Artemisia tridentata* (big sagebrush), *Atriplex canescens* (fourwing saltbush), and *tetradymia canescens* (spineless horsebrush). The current community is dominated almost exclusively by *Artemisia tridentata* (big sagebrush) which indicates a substantial increase most likely due to grazing pressures.

Table 5-26 RMU Similarity Index

Analysis Area	Maximum Similarity Index	Minimum Similarity Index	Median Similarity Index
Leona Benally RMU	43.32%	0.43%	10.05%
Rex Kinsel RMU	9.36%	9.36%	9.36%

The high plant production found in the Leona Benally RMU corresponds to the relatively high canopy cover and fairly low percentage of bare ground. Similarly, the higher amounts of bare ground and reduced canopy cover reflect the low production found in the Rex Kinsel RMU.

Table 5-27 RMU Ground Cover

Analysis Unit	Canopy (%)	Bare Ground (%)	Basal (%)
Red Valley- Leona Benally RMU	22.67	34.67	0.44
Red Valley- Rex Kinsel RMU	8	52	2

The most abundant and productive species in the Leona Benally RMU is Artemisia tridentata (big sagebrush). Several forage grasses are also numerous and *Pleuraphis jamesii* (galleta grass) and *Hesperostipa comata* (needle and thread) are both among the top contributors to biomass. The invasive, annual grass, *Bromus tectorum* (cheatgrass) is a commonly encountered plant and the invasive, annual forb, *Salsola tragus* (prickly Russian thistle), is a top producer of biomass.

Table 5-28 Leona Benally RMU Species Frequency

Species	Frequency by Transect	Percentage of Total Transects	Growth Habit	Duration	Nativity I=Introduced, N=Native	Sheep Forage Value (Most Limiting Season of Use)
Artemisia tridentata	8	88.89%	Shrub	Perennial	N	Emergency
Gutierrezia sarothrae	7	77.78%	Shrub	Perennial	N	Toxic
Elymus elymoides	5	55.56%	Graminoid	Perennial	N	Emergency
Achnatherum hymenoides	3	33.33%	Graminoid	Perennial	N	Desirable
Bromus tectorum	3	33.33%	Graminoid	Annual	I	Injurious

Table 5-29 Leona Benally RMU Species Composition

Species	**Sum Total Reconstructed Weight (pounds/acre)**	**Percentage of Total Weight in Community**	**Growth Habit**	**Duration**	**Nativity I=Introduced, N=Native**	**Sheep Forage Value (Most Limiting Season of Use)**
Artemisia tridentata	3,835.91	86.12%	Shrub	Perennial	N	Emergency
Salsola tragus	171.98	3.86%	Forb	Annual	I	Injurious
Pleuraphis jamesii	90.45	2.03%	Graminoid	Perennial	N	Emergency
Hesperostipa comata	72.24	1.62%	Graminoid	Perennial	N	Injurious
Gutierrezia sarothrae	68.85	1.55%	Shrub	Perennial	N	Toxic

The data for the Rex Kinsel RMU is based on a single transect and therefore the frequency for each species is 100 percent. This data may not fully represent the characteristics of the entire RMU. However some of the species found on this transect (*Pleuraphis jamesii, Bromus tectorum*) are frequent in the Red Valley community as a whole. *Pleuraphis jamesii* (galleta grass) is the only forage species listed among the top five contributors to biomass.

Table 5-30 Rex Kinsel RMU Species Frequency

Species	Frequency by Transect	Percentage of Total Transects	Growth Habit	Duration	Nativity I=Introduced, N=Native	Sheep Forage Value (Most Limiting Season of Use)
Atriplex confertifolia	1	100.00%	Shrub	Perennial	N	Injurious
Bromus tectorum	1	100.00%	Graminoid	Annual	I	Injurious
Descurainia pinnata	1	100.00%	Forb	Annual	N	Non Consumed
Lappula occidentalis	1	100.00%	Forb	Annual	N	Non Consumed
Pleuraphis jamesii	1	100.00%	Graminoid	Perennial	N	Emergency

Table 5-31 Rex Kinsel RMU Species Composition

Species	Sum Total Reconstructed Weight (pounds/acre)	Percentage of Total Weight in Community	Growth Habit	Duration	Nativity I=Introduced, N=Native	Sheep Forage Value (Most Limiting Season of Use)
Atriplex confertifolia	26.20	52.70%	Shrub	Perennial	N	Injurious
Lappula occidentalis	15.21	30.60%	Forb	Annual	N	Non Consumed
Bromus tectorum	6.07	12.21%	Graminoid	Annual	I	Injurious
Pleuraphis jamesii	2.03	4.08%	Graminoid	Perennial	N	Emergency
Descurainia pinnata	0.20	0.41%	Forb	Annual	N	Non Consumed

6. CONCLUSIONS AND RECOMMENDATIONS

Analysis of each grazing unit showed that a moderate amount of deterioration has occurred in ecological site located the higher elevations of the project area. This decline in the plant communities is largely a result of continuous grazing pressure and drought conditions. Shrub species have increased and desirable forage species have decreased, but extensive colonization by exotic species has not yet occurred. The primarily concerns are that shrub species like *Artemisia tridentata* (big sagebrush) and *Gutierrezia sarothrae* (broom snakeweed) will continue to increase and that the small populations of invasives like *Bromus tectorum* (cheatgrass) and *Salsola tragus* (prickly Russian thistle) will spread and become the dominate species. To help prevent this from occurring, it will be necessary to implement alternate grazing strategies and begin some range improvement projects. Simply reducing livestock numbers will not be sufficient to restore the rangeland to a more desirable condition. In most cases though, the amount of restoration work necessary will not need to be extensive as conditions are not far removed from where they should be. The following sections provide some recommendations pertaining to fencing, seasonal grazing, forage availability, the distribution of water sources, increasing water retention, and monitoring.

The lower regions of the project area are characterized by hot, dry conditions and saline soils. Moderate to severe degradation has occurred and populations of *Salsola tragus* (prickly Russian thistle) and *Bromus tectorum* (cheatgrass) are larger and more widespread. The main focus in these areas should be on capturing and retaining scarce water resources and encouraging the regrowth of salt and drought tolerant forage species. It may also be necessary to control *Bromus tectorum* (cheatgrass) as it has the ability to quickly outcompete native vegetation.

6.1 Drought

One of the greatest obstacles to overcome when restoring rangeland is precipitation. Local precipitation monitoring stations recorded lower than normal precipitation in 2012 and precipitation levels throughout the Southwest indicate the prevalence of drought conditions. It is therefore extremely important to maintain healthy plant communities, not only for forage purposes, but to reduce soil exposure and loss as well. To complicate matters, moisture arriving during the monsoon season is often in the form of severe thunderstorms which can produce several inches of rain at one time. The fairly high percentage of bare ground found in the lower reaches of the project area leads to accelerated water erosion. This increases soil loss while decreasing water retention. All rehabilitation efforts hinge upon having soils that are capable of supporting healthy plant communities. Thus, it is clear that the first steps that need to be taken are to prevent further erosion and rebuild soils where they have been lost. Along with this, it is important to collect accurate precipitation data. Calculations for annual production (and resulting stocking rates) would be more accurate if a comprehensive precipitation record was available for multiple locations throughout the District.

6.2 Soil and Grazing Management

Deeply eroded gullies and arroyos are the most difficult and cost prohibitive features to restore. In their immature form, the sides of the channels are usually very steep or even vertical, which makes it difficult for stabilizing vegetation to establish. An effective technique for decreasing slope gradient is to use earthmoving equipment to reshape or terrace the banks, thus creating substrates suitable for plant colonization. This method is particularly effective in arid regions where work can be completed prior to seasonal flows. Unfortunately, the cost and logistics involved with getting equipment into more remote locations can make this option prohibitive (Valentin et al. 2005).

Another option is to focus efforts upstream from deeply eroded channels. In areas where channels are just beginning to develop and the rate and volume of surface runoff is fairly low, effective countermeasures to erosion are simple, hand constructed rock check dams. In addition to capturing soil and preventing further loss, they also serve to redistribute water, especially during the monsoon season. Spreading runoff across the landscape and retaining water for longer periods leads to more plant growth and plant cover, which increases infiltration and soil moisture (Nichols et al. 2012). Seeding programs that utilize fast-growing, native pioneer species tend to produce better and quicker results when working to stabilize channel walls (Valentin et al. 2005).

Rebuilding soils requires a combination of erosion control, revegetation, and periodic disturbance of the soil surface. Revegetation will likely require reseeding programs in the dry, lowland areas. Seeding with species of *Sporobolus* (dropseed), *Atriplex* (saltbush), and *Sphaeralcea* (globemallow) is recommended as they are both salt and drought tolerant. This study found that much of the native plant community is still present within higher elevations of the project area. Production from native species may be low in many areas, but the components are still in place. Especially prevalent are perennial grass species like *Achnatherum hymenoides* (Indian ricegrass)*, Hesperostipa comata* (needle and thread), *Pleuraphis jamesii* (galleta grass), *Sporobolus* species (dropseed), and *Elymus elymoides* (bottlebrush squirreltail). Important forb and shrub species such as *Sphaeralcea* (globemallow) spp.*, Atriplex* species (saltbush)*,* and *Artemisia tridentata* (big sagebrush) are abundant as well. This indicates that with careful and proactive management, native species production and frequency should increase naturally without a lot of intervention. Areas with dense shrubs or trees may need to be thinned to release the native herbaceous component. Although shrub production is high throughout the study area, shrub populations are not always dense. In many cases, shrub growth stands out simply because there are few other species present in the community. The lack of native herbaceous production is due; in large part, to unmanaged, continuous grazing systems.

Determining forage production based upon a normal precipitation allows managers to establish a “ceiling” or carrying capacity for their land. These determinations should not be used to generate stocking rates when precipitation is below normal, especially during drought conditions. In a continuous grazing system, it is difficult to prepare for times of scarce moisture. However, this situation can be partially mitigated by allowing managers to reduce and increase stock numbers based on current resource conditions. Ideally, permits would require an estimate of the current climate and production of the range resource at periodic intervals. Expected precipitation generally falls during late summer and through the winter. If precipitation is low during the winter, then it can be expected that spring and early summer production will also be low and livestock numbers should be adjusted accordingly. To aid in this process, managers should prioritize monthly data collection and record keeping so that valid information can be provided to the district grazing committees

The final part of rebuilding soil is to make sure that it undergoes periodic disturbance. This is where livestock play a very important role. The trampling effect of livestock works to incorporate manure and litter into the soil, which increases aeration and organic matter content. Hoof indentations also create microsites that encourage seedling growth and moisture retention. However, controlling the timing and duration of grazing is the key to reaping these benefits. Many of the ecological site descriptions for the project area recommend deferring grazing from late winter through early spring. This practice alone would do much to increase available forage. Other areas are better suited for winter/spring grazing and can be utilized to provide forage while less suitable areas are being rested. The data collected from this survey can help identify these areas. A critical part of grazing management is allowing the forage to grow before being grazed and allowing it to recoup following grazing. Fences greatly facilitate the process of pasture deferment, rest, and rotation. They are also valuable tools for excluding stray livestock, especially horses. Two major hurdles to fence construction are the common property aspect of the Navajo Reservation and financial constraint. Getting people involved at the chapter level may be one way of arriving at unanimous decisions to implement range improvement projects. Approaching permittees with specific, proactive improvement plans and the support for carrying out the plans would greatly help build the momentum necessary for enacting large-scale, long-term changes. NRCS programs like the Environmental Quality Incentives Program can aid in providing the technical and financial support needed for this to happen.

6.3 Shrub Composition

Shrubs play a valuable role in maintaining healthy, functioning rangelands, but the ratio of shrubs to forb and grass species is higher than it should be in many parts of the study area. The dominant shrubs are *Artemisia tridentata* (big sagebrush) and *Gutierrezia sarothrae* (broom snakeweed). In most cases, proper grazing management may be sufficient to encourage the reestablishment of native forbs and grasses. As the herbaceous component begins to flourish, woody species will cease to dominate and a more balanced plant community will develop. In other cases, it may be necessary to reduce shrub populations either by mechanical or chemical means. A number of mechanical methods have been used to control shrubs on rangelands including roller chopping, root-plowing, shredding, chaining, and bulldozing. These practices require relatively gentle terrain to implement and the cost of operating the equipment can be expensive, which limits their practicality in this area. There is also the danger of encouraging the spread of invasive species by removing large swaths of vegetation at one time (DiTomaso 2000).

Chemical control is cheaper than mechanical methods and can be more effective at thinning brush stands rather than eradicating them entirely. This is generally the more desirable route to take, as it leaves cover and browse for livestock and wildlife. Soil exposure is also much reduced, which decreases opportunities for exotic plants to invade the site (Olsen et al. 1994; DiTomaso 2000).The use of the herbicide tebuthiuron (Spike®, Scrubmaster® , Perflan®) which works to inhibit photosynthetic activity, has been quite successful in thinning dense stands of *Artemisia tridentata* (big sagebrush). Low rates of this chemical effectively thin the stand, while still leaving adequate cover and browse for wildlife species. Application rates ranging from 0.3 to 0.5 lbs of active ingredient per acre have proven to be both cost effective and suitable for creating a mix of shrubs, grasses, and forbs (Hooley 1991; Olsen et al. 1994). Tebuthiuron and Picloram (Tordon®, Grazon®) have proven to be effective in controlling *Gutierrezia sarothrae* (broom snakeweed) as well. However, most studies have found that at least 90 percent of the plants need to be killed to see significant increases in perennial forage species (Schmutz and Little 1970; Gesink et al. 1973; Sosebee et al. 1979; McDaniel and Duncan 1987). Consultation with experts is recommended prior to implementing shrub control measures to determine the best rates and timing for herbicide applications and to explore alternate control methods.

6.4 Exotic Species

The invasive forb, *Salsola tragus* (prickly Russian thistle), is fairly abundant in the saline lowland areas and is beginning to become established in the higher regions. This is a drought tolerant, disturbance-loving species that does well in sandy soils (Whitson et al. 2002). Although this plant is an invasive species, it does provide forage for sheep and cattle in its immature form and when softened by snow or rain (United States Department of Agriculture 1937). Consumption of large quantities of this plant has been known to cause diarrhea, especially in lambs, which can compromise the heath of animals already in a weakened condition (Cook et al. 1954). This can be an issue in areas where little else is growing and consumption is likely to be high. On the positive side, *Salsola tragus* (prickly Russian thistle) can also accelerate revegetation of disturbed areas by supporting the growth of soil mycorrhiza. Soil mycorrhiza are fungi that form associations with many native plant species. The fungi help the plants absorb more soil water and nutrients and, in return, receive carbohydrates from the roots of the plants. Certain mycorrhiza will invade the roots of *Salsola tragus* (prickly Russian thistle), but instead of forming an association with this plant, they will kill the infected roots and then move on to the roots of neighboring plants. In this manner, the fungi population increases while *Salsola tragus* (prickly Russian thistle) populations begin to decline (Allen and Allen 1988; Allen et al. 1989). The dead plants provide cover for seedlings of other species that are capable of forming associations with the newly established mycorrhiza colonies (Allen and Allen 1988; Grilz et al. 1988). Typically, *Salsola tragus* (prickly Russian thistle) will persist on a site for about two years and then will be replaced by various annual and biennial species. These plants continue to build up the soil substrate by maintaining soil mycorrhiza populations and adding organic matter to the soil as the plants die. *Salsola tragus* (prickly Russian thistle) also helps prepare a site by releasing oxalates into the soil. These chemicals work to change inorganic phosphorous into a soluble form that can be taken up by plants (Cannon et al. 1995). Phosphorus is often a limiting nutrient in the soil and by increasing its availability, favorable forage plants can become established at faster rates. *Salsola tragus* (prickly Russian thistle) can be controlled or even eradicated through various mechanical and chemical treatments (Young and Whitesides 1987; Burrill et al. 1989). However, this process is time consuming and expensive. Given the potential benefits of the plant, it is generally better to leave it and focus on encouraging the establishment of desirable, perennial species through proper grazing management and seeding treatments.

The exotic annual grass, *Bromus tectorum* (cheatgrass) is another invasive species that is beginning to gain ground in the study area. *Bromus tectorum* (cheatgrass) is a difficult grass to control due to its ability to produce large quantities of seed, which either germinate in the fall or carry over in the seed bank to germinate in the following spring (Smith et al. 2008). Germination typically occurs well in advance of most native species, which works to deplete soil moisture (Floyd et al. 2006; Melgoza et al. 1990; Smith et al. 2008). Additionally, seedling emergence can occur under a variety of soil temperatures and plants germinating in the fall continue to experience root growth during the winter. This gives individuals a significant advantage the following spring (Beckstead et al 2007; Mack and Pike 1983; Meyer et al 2007; Thill et al. 1979). The best way to prevent the spread of *Bromus tectorum* (cheatgrass) is to reestablish viable native plant communities. In invaded areas, use of the herbicide imazapic (Plateau®) has proven to be very effective control measure. A moderate application rate (0.6 L ha^{-1}) was found to kill virtually all *Bromus tectorum* (cheatgrass) plants and seeds when applied in the fall to infestations in Zion Nation Park (Dela Cruz 2008, Brisbin et al. 2013). However, the control affected by this herbicide only provides a window of about 1-2 years. If alternate vegetation has not reestablished in sprayed areas at this time, it is very probable that *Bromus tectorum* (cheatgrass) will reoccupy the area. A good practice is to spray in the fall and apply seeding treatments in the following late winter/early spring season. The NRCS is a valuable resource for obtaining site specific seed mixes as well as technical and financial support.

Halogeton glomeratus (saltlover) is a noxious weed that readily invades and can come to dominate saline rangelands that have been depleted through continuous grazing (Cronin and Coburn 1965; Young et al. 1979). This plant can be successfully reduced by planting competitive species like *Agropyron desertorum* (desert wheatgrass) and *Bassia prostrata* (forage kochia) (Asay and Johnson 1987; Stevens and McArthur 1990). Heavy spring grazing is also linked to increases in *Halogeton glomeratus* (saltlover), which indicates that reducing grazing pressure at this time would be a beneficial practice (Whisenant and Wagstaff 1991).

6.5 Data Analysis and Monitoring

Analysis of the data revealed several patterns including high shrub density, several areas devoid of vegetative cover, and other areas that are maintaining good populations of key grass species like *Achnatherum hymenoides* (Indian ricegrass) and *Hesperostipa comata* (needle and thread). The next step is to use this data to identify specific locations that would benefit most from improvement measures and organize field visits to gain an “on-the-ground” perspective. Groups of transects that yielded low production and high counts of bare ground may be in severely eroded areas and great effort would be necessary to improve these sites. On the other hand, these groups of transects may just have a high potential for erosion and simple improvements could greatly enhance the soil and plant community. Using the data to pinpoint areas with the highest densities of shrubs would serve as a starting point for assessing whether chemical control measures are necessary. In some cases, it may be better to focus on grazing strategies and let natural succession run its course. Identifying places with high forage production can be helpful for implementing rotational grazing schemes. These areas would be able to withstand higher grazing pressures, while more fragile areas were being rested. Visits to these areas would allow managers to determine the feasibility of adding water sources if none are currently present. If the data from certain transects showed that native forage species were not present, it may be necessary to implement reseeding programs. Agriculture extension offices and the NRCS are good resources to use for help in determining appropriate seed mixes and finding seed sources. Using local, drought tolerant species that can germinate early, like *Sphaeralcea coccinea* (scarlet globemallow) and *Sporobolus cryptandrus* (sand dropseed), will speed up revegetation and increase the likelihood of success.

Grazing programs should make use of available tools. When it is possible to erect fences, they should be designed to ease the movement and exclusion of livestock, as dictated by the condition of the vegetation. Designating pastures where fences already exist, such as the highway fences that bisect grazing units, would also be useful for monitoring forage in those pastures. Currently, the forage on one of side the highway is applied to the carrying capacity on both sides of the highway. Separating the grazing units into pastures would allow for more site specific data collection and monitoring, as well as livestock management. In keeping with this, water sources and salt blocks can be situated to move animals out of some areas or to encourage them to use underutilized locations. In addition, the provided initial stocking rates and carrying capacities in this report should be used as a guide to be adjusted appropriately with consideration of forage value, the seasonal palatability of forage, and the variability of precipitation. For example, a conservative initial stocking rate is appropriate under drought conditions. If there is very little precipitation during the winter and early spring, stock numbers should not be permitted at the rate of a normal year production. The same is true when an area endures several years of precipitation below normal levels. However, the placement of the previously discussed check dams and other water catchment systems like ponding dikes can greatly offset the negative impacts associated with drought and lessen the need to cut livestock numbers.

After restoration efforts have begun, it is important to establish monitoring programs. Now that the initial baseline data has been collected, it is not necessary to sample vegetation at each transect. Instead, a smaller number of permanent transects and photo monitoring points can be set up at locations targeted for restoration and in representative areas for each range site. In addition to monitoring species composition and production, it would also be valuable to assess soil stability and hydrologic function. There are numerous references that can be utilized to develop monitoring programs and help interpret the results, such as the Monitoring Manuel for Grassland, Shrubland, and Savanna Ecosystems put out by the Arid Lands Research Program (Herrick et al. 2005) and the BLM’s Technical Reference 1734-6: Interpreting Indicators of Rangeland Health (Pellant et al. 2005).

Finally, an inventory and monitoring program specific to Range Management Units (RMUs) in the project area would assist with addressing forage, stocking rate, carrying capacity and range management that is particular to each RMU. The soils and ecological sites in each RMU should be identified and additional data should be gathered from those soils and ecological sites which were not represented in the current study. Since the RMUs are usually much smaller units than the grazing units, more site-specific data can be collected and individual monitoring programs can address issues that apply to each RMU.

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Appendix A

Precipitation Data

	Jan. '12	Feb. '12	Mar. '12	Apr. '12	May '12	June '12	July '12	Aug. '12	Sept. '12	October '11	Nov. '11	Dec. '11
Historical	1.063	1.064	1.037	1.011	0.444	0.335	1.180	1.585	1.468	1.202	0.597	0.922
2012	0.511	0.950	0.717	0.320	0.099	0.097	1.958	1.496	0.737	1.470	1.397	0.679
	107.20%	103.27%	97.25%	87.63%	83.68%	81.29%	75.82%	79.63%	74.93%	122.28%	159.33%	130.30%

Appendix B

New Correlations for Ecological Site Descriptions

Ecological Site Description

Major Land Resource Area - 37

San Juan River Valley, Mesas and Plateaus (Northern Desert) (ND-1)

New Mexico Site Description	New Mexico - Site Number The following documents require Adobe Acrobat.	Current Site Description	Current Site Number
Loamy	R037XA001NM (PDF; 656 KB)	Loamy	R035XB001NM
Sandy	R037XA002NM (PDF; 697 KB)	Sandy	R035XB002NM
Limy	R037XA003NM (PDF; 675 KB)	Limy	R035XB003NM
Clayey	R037XA004NM (PDF; 664 KB)	Clayey	R035XB004NM
Salt Flats	R037XA005NM (PDF; 655 KB)	Salt Flats	R035XB005NM
Shallow	R037XA006NM (PDF; 630 KB)	Shallow	R035XB006NM
Deep Sand	R037XA007NM (PDF; 627 KB)	Deep Sand	R035XB007NM
Sodic Slopes	R037XA008NM (PDF; 610 KB)	Sodic Slopes	R035XB008NM
Shale Hills	R037XA009NM (PDF; 569 KB)	Shale Hills	R035XB009NM
Cobbly Hills	R037XA010NM (PDF; 545 KB)	Cobbly Hills	R035XB010NM
Breaks	R037XA015NM (PDF; 274 KB)	Shale Hills 6-10"p.z. Sodic	R035XB268AZ
Clay Loam Terrace (sodic) 7-10"	R037XA016NM (PDF; 47 KB)	Clay Loam Terrace (sodic) 7-10"	R035XB016NM
Cobbly Slopes 6-10"	R037XA017NM (PDF; 239 KB)	Cobbly Slopes 6-10"	R035XB017NM
Loamy Bottom 6-10"	R037XA018NM (PDF; 240 KB)	Loamy Bottom 6-10"	R035XB018NM
Loamy Bottom Subirrigated	R037XA019NM (PDF; 240 KB)	Loamy Bottom 6-10" p.z. Perennial	R035XB269AZ
Loamy 6-10" terrace	R037XA020NM (PDF; 240 KB)	Loamy 6-10" terrace	R035XB020NM
Loamy Upland 7-10"	R037XA021NM (PDF; 44 KB)	Loamy Upland 7-10"	R035XB021NM

Loamy Upland Sodic	R037XA022NM (PDF; 47 KB)	Loamy Upland Sodic	R035XB022NM
Porcelanite Hills	R037XA023NM (PDF; 253 KB)	Porcelanite Hills 6-10" p.z.	R035XB270AZ
Saline Bottom 6-10"	R037XA024NM (PDF; 254 KB)	Saline Bottom 6-10"	R035XB024NM
Saline Sodic Upland	R037XA025NM (PDF; 248 KB)	Loamy Upland 6-10" p.z. Saline Sodic	R035XB271AZ
Salt Meadow	R037XA026NM (PDF; 242 KB)	Loamy Bottom 6-10" p.z. Perennial. Saline	R035XB272AZ
Sandstone Upland	R037XA027NM (PDF; 48 KB)	Sandstone Upland 6-10" p.z. Very Shallow	R035XB204AZ
Sandy Bottom 6-10"	R037XA028NM (PDF; 55 KB)	Sandy Bottom 6-10"	R035XB028NM
Sandy Bottom, Subirrigation	R037XA029NM (PDF; 48 KB)	Sand Bottom 6-10" p.z. Perennial	R035XB273AZ
Sandy Loam Upland 6-10"	R037XA030NM (PDF; 48 KB)	Sandy Loam Upland 6-10"	R035XB030NM
Sandy Loam Upland Gravelly	R037XA031NM (PDF; 254 KB)	Sandy Loam Upland 6-10" p.z. Limy, Gravelly	R035XB267AZ
Sandy Loam Upland Saline	R037XA032NM (PDF; 286 KB)	Sandy Loam Upland 6-10" p.z. Saline	R035XB274AZ
Sandy Loam Upland 6-10" Sodic	R037XA033NM (PDF; 236 KB)	Sandy Loam Upland 6-10" Sodic	R035XB033NM
Sandy Terrace 6-10" Sodic	R037XA034NM (PDF; 241 KB)	Sandy Terrace 6-10" Sodic	R035XB034NM
Sandy Upland 6-10"	R037XA035NM (PDF; 51 KB)	Sandy Upland 6-10"	R035XB035NM
Silty Fan	R037XA036NM (PDF; 249 KB)	Loamy Fan 6-10" p.z.	R035XB275AZ
Silty Shallow	R037XA037NM (PDF; 264 KB)	Siltstone Upland 6-10" p.z. Saline	R035XB276AZ
Silty Shallow Calcareous	R037XA038NM (PDF; 262 KB)	Siltstone Upland 6-10" p.z. Limy	R035XB277AZ
Silty Upland	R037XA039NM (PDF; 247 KB)	Loamy Upland 6-10" p.z. Saline, Gypsic	R035XB278AZ
Silty Upland Sodic	R037XA040NM (PDF; 258 KB)	Clay Loam Upland 6-10" p.z. Sodic, Gypsic	R035XB279AZ

Appendix C

Plant List and Collections

Code	**GenusSpecies**	**Growth**	**SheepForagePref**	**Family**
AMARA	Amaranthus sp.	Forb	Unknown	Amaranthaceae
RHTR	Rhus trilobata	Shrub	Not consumed	Anacardiaceae
CYMOP2	Cymopterus sp.	Forb	Toxic	Apiaceae
LOMAT	Lomatium sp.	Forb	Not consumed	Apiaceae
ASIN14	Asclepias involucrata	Forb	Toxic	Asclepiadaceae
ASCLE	Asclepias sp.	Forb	Toxic	Asclepiadaceae
ACMI2	Achillea millefolium	Forb	Not consumed	Asteraceae
AMAC2	Ambrosia acanthicarpa	Forb	Not consumed	Asteraceae
ANTEN	Antennaria sp.	Forb	Unknown	Asteraceae
ARBI3	Artemisia bigelovii	Subshrub/Shrub	Unknown	Asteraceae
ARCA12	Artemisia campestris	Forb	Unknown	Asteraceae
ARDR4	Artemisia dracunculus	Subshrub	Desirable	Asteraceae
ARFR4	Artemisia frigida	Shrub	Desirable	Asteraceae
ARLU	Artemisia ludoviciana	Subshrub	Emergency	Asteraceae
ARNO4	Artemisia nova	Shrub	Desirable	Asteraceae
ARTEM	Artemisia sp.	Shrub	Desirable	Asteraceae
ARTR2	Artemisia tridentata	Shrub	Emergency	Asteraceae
ARTRW8	Artemisia tridentata var. wyomingensis	Subshrub/Shrub	Emergency	Asteraceae
BADI	Bahia dissecta	Forb	Unknown	Asteraceae
BRLO	Brickellia longifolia	Subshrub	Unknown	Asteraceae
BRMI	Brickellia microphylla	Subshrub	Unknown	Asteraceae
BROB	Brickellia oblongifolia	Forb	Unknown	Asteraceae
CHST	Chaenactis stevioides	Forb	Unknown	Asteraceae
CHER2	Chaetopappa ericoides	Forb	Not consumed	Asteraceae
CHDE2	Chrysothamnus depressus	Subshrub	Emergency	Asteraceae
CHGR6	Chrysothamnus greenei	Shrub	Emergency	Asteraceae
CHRYS9	Chrysothamnus sp.	Shrub	Unknown	Asteraceae
CHVI8	Chrysothamnus viscidiflorus	Shrub	Emergency	Asteraceae
CIRSI	Cirsium sp.	Forb	Unknown	Asteraceae
ERNA10	Ericameria nauseosa	Shrub	Not consumed	Asteraceae
ERAP	Erigeron aphanactis	Forb	Not consumed	Asteraceae
ERCO27	Erigeron concinnus	Forb	Not consumed	Asteraceae
ERDI4	Erigeron divergens	Forb	Unknown	Asteraceae
ERFL	Erigeron flagellaris	Forb	Unknown	Asteraceae
ERIGE2	Erigeron sp.	Forb	Not consumed	Asteraceae
GRSQ	Grindelia squarrosa	Forb	Not consumed	Asteraceae
GUMI	Gutierrezia microcephala	Subshrub	Unknown	Asteraceae
GUSA2	Gutierrezia sarothrae	Shrub	Injurious	Asteraceae
HEVI4	Heterotheca villosa	Subshrub/Shrub	Not consumed	Asteraceae
HYFI	Hymenopappus filifolius	Forb	Not consumed	Asteraceae
HYMEN4	Hymenopappus sp.	Forb	Desirable	Asteraceae
HYRI	Hymenoxys richardsonii	Forb	Unknown	Asteraceae
HYMEN7	Hymenoxys sp.	Forb	Desirable	Asteraceae
ISRU2	Isocoma rusbyi	Subshrub	Unknown	Asteraceae
MACA2	Machaeranthera canescens	Forb	Not consumed	Asteraceae
MAGR2	Machaeranthera grindelioides	Forb/Subshrub	Not consumed	Asteraceae
MACHA	Machaeranthera sp.	Forb	Unknown	Asteraceae
MATA2	Machaeranthera tanacetifolia	Forb	Not consumed	Asteraceae
OXAC4	Oxytenia acerosa	Forb	Toxic	Asteraceae
PAMU11	Packera multilobata	Forb	Not consumed	Asteraceae

PANEN	Packera neomexicanus var. neomexicanus	Subshrub/Shrub	Unknown	Asteraceae
PEPU7	Petradoria pumila	Forb	Unknown	Asteraceae
PEPUG	Petradoria pumila ssp. graminea	Forb	Unknown	Asteraceae
SCSCS5	Scabrethia scabra	Forb	Not consumed	Asteraceae
SEFL3	Senecio flaccidus	Forb	Unknown	Asteraceae
SENEC	Senecio sp.	Forb	Unknown	Asteraceae
STAR10	Stenotus armerioides	Forb	Unknown	Asteraceae
STEX	Stephanomeria exigua	Forb	Unknown	Asteraceae
TAOF	Taraxacum officinale	Forb	Not consumed	Asteraceae
TECA2	Tetradymia canescens	Shrub	Toxic	Asteraceae
TEAC	Tetraneuris acaulis	Forb	Not consumed	Asteraceae
TEACA2	Tetraneuris acaulis var. acaulis	Forb	Not consumed	Asteraceae
TEAR4	Tetraneuris argentea	Forb	Not consumed	Asteraceae
THME	Thelesperma megapotamicum	Forb	Unknown	Asteraceae
THELE	Thelesperma sp	Forb	Unknown	Asteraceae
TOAN	Townsendia annua	Forb	Unknown	Asteraceae
TOIN	Townsendia incana	Forb	Unknown	Asteraceae
TOWNS	Townsendia sp.	Forb	Not consumed	Asteraceae
MARE11	Mahonia repens	Subshrub	Not consumed	Berberidaceae
CRCI3	Cryptantha cineria	Forb	Not consumed	Boraginaceae
CRCI2	Cryptantha circumcissa	Forb	Not consumed	Boraginaceae
CRCR3	Cryptantha crassisepala	Forb	Not consumed	Boraginaceae
CRMI5	Cryptantha minima	Forb	Not consumed	Boraginaceae
CRYPT	Cryptantha sp.	Forb/Subshrub	Not consumed	Boraginaceae
LAOC3	Lappula occidentalis	Forb	Not consumed	Boraginaceae
LAPPU	Lappula sp.	Forb	Not consumed	Boraginaceae
TILA6	Tiquilia latior	Forb/Subshrub	Unknown	Boraginaceae
ALYSS	Alyssum sp.	Forb	Unknown	Brassicaceae
ARPE2	Arabis perennans	Forb	Not consumed	Brassicaceae
ARPU	Arabis puberula	Forb	Not consumed	Brassicaceae
ARABI2	Arabis sp.	Forb	Desirable	Brassicaceae
DEPI	Descurainia pinnata	Forb	Not consumed	Brassicaceae
DESO2	Descurainia sophia	Forb	Not consumed	Brassicaceae
DESCU	Descurainia sp.	Forb	Unknown	Brassicaceae
DIWI2	Dimorphocarpa wislizeni	Forb	Unknown	Brassicaceae
DRABA	Draba sp.	Forb	Unknown	Brassicaceae
ERYSI	Erysimum sp.	Forb	Not consumed	Brassicaceae
LEFR2	Lepidium fremontii	Shrub	Unknown	Brassicaceae
LEPID	Lepidium sp.	Forb	Not consumed	Brassicaceae
LESQU	Lesquerella sp.	Forb	Not consumed	Brassicaceae
PHRE9	Physaria rectipes	Forb	Unknown	Brassicaceae
SIAL2	Sisymbrium altissimum	Forb	Not consumed	Brassicaceae
STPI	Stanleya pinnata	Forb	Not consumed	Brassicaceae
STLO4	Streptanthella longirostris	Forb	Unknown	Brassicaceae
STCO6	Streptanthus cordatus	Forb	Unknown	Brassicaceae
CYLIND	Cylindropuntia sp.	Cactus	Not consumed	Cactaceae
ECHIN3	Echinocereus sp.	Cactus	Not consumed	Cactaceae
ESVI2	Escobaria vivipara	Cactus	Not consumed	Cactaceae
MAMMI	Mammillaria sp.	Cactus	Not consumed	Cactaceae
OPPH	Opuntia phaeacantha	Cactus	Not consumed	Cactaceae
OPPO	Opuntia polyacantha	Cactus	Not consumed	Cactaceae

OPUNT	Opuntia sp.	Cactus	Not consumed	Cactaceae
SCLER10	Sclerocactus sp.	Cactus	Not consumed	Cactaceae
CALOC	Calochortus sp.	Forb	Not consumed	Calochortaceae
SYOR2	Symphoricarpos oreophilus	Shrub	Not consumed	Caprifoliaceae
ARFE3	Arenaria fendleri	Forb	Unknown	Caryophyllaceae
ARENA	Arenaria sp.	Forb	Not consumed	Caryophyllaceae
PAMY	Paxistima myrsinites	Shrub	Desirable	Celastraceae
ATCA2	Atriplex canescens	Shrub	Desirable	Chenopodiaceae
ATCO	Atriplex confertifolia	Shrub	Not consumed	Chenopodiaceae
ATCO4	Atriplex corrugata	Subshrub	Unknown	Chenopodiaceae
ATCU	Atriplex cuneata	Subshrub	Unknown	Chenopodiaceae
ATGA2	Atriplex garrettii	Shrub	Unknown	Chenopodiaceae
ATOB	Atriplex obovata	Subshrub/Shrub	Unknown	Chenopodiaceae
ATRIP	Atriplex sp.	Shrub	Unknown	Chenopodiaceae
BAAM4	Bassia americana	Subshrub	Desirable	Chenopodiaceae
CHENO	Chenopodium sp.	Forb	Unknown	Chenopodiaceae
HAGL	Halogeton glomeratus	Forb	Toxic	Chenopodiaceae
BASC5	Kochia scoparia = Bassia scoparia	Forb	Injurious	Chenopodiaceae
KRLA2	Krascheninnikovia lanata	Subshrub	Preferred	Chenopodiaceae
SATR12	Salsola tragus	Forb	Injurious	Chenopodiaceae
SAVE4	Sarcobatus vermiculatus	Shrub	Not consumed	Chenopodiaceae
SUMO	Suaeda moquinii	Subshrub/Shrub	Not consumed	Chenopodiaceae
COAR4	Convolvulus arvensis	Forb	Not consumed	Convolulaceae
CAREX	Carex sp.	Graminoid	Desirable	Cyperaceae
SHRO	Shepherdia rotundifolia	Shrub	Unknown	Elaeagnaceae
EPCU	Ephedra cutleri	Shrub	Desirable	Ephedraceae
EPHED	Ephedra sp.	Shrub	Desirable	Ephedraceae
EPTO	Ephedra torreyana	Shrub	Desirable	Ephedraceae
EPVI	Ephedra viridis	Shrub	Desirable	Ephedraceae
CHCH5	Chamaesyce chaetocalyx	Subshrub	Unknown	Euphorbiaceae
CHAMA15	Chamaesyce sp.	Forb	Unknown	Euphorbiaceae
EUPHO	Euphorbia sp.	Forb	Unknown	Euphorbiaceae
ASCA9	Astragalus calycosus	Forb	Not consumed	Fabaceae
ASCE	Astragalus ceramicus	Forb	Toxic	Fabaceae
ASDE3	Astragalus desperatus	Forb	Toxic	Fabaceae
ASMOT	Astragalus mollissimus var. thompsoniae	Forb	Unknown	Fabaceae
ASSA2	Astragalus sabulonum	Forb	Unknown	Fabaceae
ASTRA	Astragalus sp.	Forb	Toxic	Fabaceae
LATHY	Lathyrus sp.	Forb	Unknown	Fabaceae
LUAR3	Lupinus argenteus	Forb	Not consumed	Fabaceae
LUPU	Lupinus pusillus	Forb	Toxic	Fabaceae
LUPIN	Lupinus sp.	Forb	Toxic	Fabaceae
OXYTR	Oxytropis sp.	Forb	Toxic	Fabaceae
TRIFO	Trifolium sp.	Forb	Not consumed	Fabaceae
QUTU2	Quercus turbinella	Shrub	Unknown	Fagaceae
GERAN	Geranium sp.	Forb	Not consumed	Geraniaceae
FERU	Fendlera rupicola	Shrub	Unknown	Hydrangeaceae
PHMI4	Philidelphus microphyllus	Shrub	Emergency	Hydrangeaceae
PHCR	Phacelia crenulata	Forb	Unknown	Hydrophyllaceae
PHACE	Phacelia sp.	Forb	Unknown	Hydrophyllaceae
JULO	Juncus longistylis	Graminoid	Not consumed	Juncaceae

DRPA2	Dracocephalum parviflorum	Forb	Unknown	Lamiaceae
ALLIU	Allium sp.	Forb	Not consumed	Liliaceae
YUAN2	Yucca angustissima	Subshrub/Shrub	Injurious	Liliaceae
YUBA	Yucca baccata	Subshrub/Shrub	Injurious	Liliaceae
YUCCA	Yucca sp.	Subshrub/Shrub	Injurious	Liliaceae
LIAR3	Linum aristatum	Forb	Unknown	Linaceae
LIPU4	Linum puberulum	Forb	Not consumed	Linaceae
LINUM	Linum sp.	Forb	Unknown	Linaceae
MEAL6	Mentzelia albicaulis	Forb	Not consumed	Loasaceae
MEMU3	Mentzelia multiflora	Forb	Not consumed	Loasaceae
MENTZ	Mentzelia sp.	Forb	Unknown	Loasaceae
SPLE	Sphaeralcea leptophylla	Forb	Unknown	Malvaceae
SPAM2	Sphaeralcea ambigua	Forb	Not consumed	Malvaceae
SPCO	Sphaeralcea coccinea	Forb	Not consumed	Malvaceae
SPCOC	Sphaeralcea coccinea ssp. coccinea	Forb	Not consumed	Malvaceae
SPGR2	Sphaeralcea grossulariifolia	Forb	Not consumed	Malvaceae
SPPA2	Sphaeralcea parvifolia	Forb	Unknown	Malvaceae
SPHAE	Sphaeralcea sp.	Forb	Not consumed	Malvaceae
ABFR2	Abronia fragrans	Forb	Not consumed	Nyctaginaceae
ABRON	Abronia sp.	Forb	Unknown	Nyctaginaceae
MILI3	Mirabilis linearis	Forb	Unknown	Nyctaginaceae
MIMU	Mirabilis multiflora	Forb	Unknown	Nyctaginaceae
VEBR	Verbena bracteata	Forb	Unknown	Nyctaginaceae
FRAN2	Fraxinus anomala	Shrub/Tree	Unknown	Oleaceae
OEPA	Oenothera pallida	Forb	Unknown	Onagraceae
OENOT	Oenothera sp.	Forb	Not consumed	Onagraceae
ORLU	Orobanche ludoviciana	Forb	Unknown	Orobanchaceae
PLOV	Plantago ovata	Forb	Unknown	Plantaginaceae
PLPA2	Plantago patagonica	Forb	Not consumed	Plantaginaceae
ACHY	Achnatherum hymenoides	Graminoid	Desirable	Poaceae
ACSP12	Achnatherum speciosum	Graminoid	Desirable	Poaceae
AGCR	Agropyron cristatum	Graminoid	Emergency	Poaceae
AGROP2	Agropyron sp.	Graminoid	Unknown	Poaceae
ARAR6	Aristida arizonica	Graminoid	Unknown	Poaceae
ARPU9	Aristida purpurea	Graminoid	Not consumed	Poaceae
ARIST	Aristida sp.	Graminoid	Not consumed	Poaceae
BOER4	Bouteloua eriopoda	Graminoid	Unknown	Poaceae
BOGR2	Bouteloua gracilis	Graminoid	Emergency	Poaceae
BROMU	Bromus sp.	Graminoid	Unknown	Poaceae
BRTE	Bromus tectorum	Graminoid	Injurious	Poaceae
DISTI	Distichlis sp.	Graminoid	Not consumed	Poaceae
ELEL5	Elymus elymoides	Graminoid	Unknown	Poaceae
ELIN6	Elymus interruptus	Graminoid	Unknown	Poaceae
ELYMU	Elymus sp.	Graminoid	Unknown	Poaceae
ERTR13	Eremopyrum triticeum	Graminoid	Unknown	Poaceae
HECO26	Hesperostipa comata	Graminoid	Injurious	Poaceae
HENE5	Hesperostipa neomexicana	Graminoid	Injurious	Poaceae
MOSQ	Monroa squarrosa	Graminoid	Not consumed	Poaceae
MUTO2	Muhlenbergia torreyi	Graminoid	Unknown	Poaceae
MUPU2	Muhlengergia pungens	Graminoid	Unknown	Poaceae
PASM	Pascopyrum smithii	Graminoid	Desirable	Poaceae

PLJA	Pleuraphis jamesii	Graminoid	Emergency	Poaceae
POFE	Poa fendleriana	Graminoid	Desirable	Poaceae
POPR	Poa pratensis	Graminoid	Desirable	Poaceae
POSE	Poa secunda	Graminoid	Emergency	Poaceae
POA	Poa sp.	Graminoid	Desirable	Poaceae
POVI9	Polypogon viridis	Graminoid	Unknown	Poaceae
SPAI	Sporobolus airoides	Graminoid	Emergency	Poaceae
SPCO4	Sporobolus contractus	Graminoid	Emergency	Poaceae
SPCR	Sporobolus cryptandrus	Graminoid	Not consumed	Poaceae
SPORO	Sporobolus sp.	Graminoid	Unknown	Poaceae
VUOC	Vulpia octoflora	Graminoid	Not consumed	Poaceae
GISI	Gilia sinuata	Forb	Unknown	Polemoniaceae
GILIA	Gilia sp.	Forb	Unknown	Polemoniaceae
IPAG	Ipomopsis aggregata	Forb	Not consumed	Polemoniaceae
IPLO2	Ipomopsis longiflora	Forb	Unknown	Polemoniaceae
IPPU4	Ipomopsis pumila	Forb	Not consumed	Polemoniaceae
LEPU	Leptodactylon pungens	Subshrub	Not consumed	Polemoniaceae
PHHO	Phlox hoodii	Forb	Emergency	Polemoniaceae
PHLO2	Phlox longifolia	Forb	Not consumed	Polemoniaceae
PHLOX	Phlox sp.	Forb	Not consumed	Polemoniaceae
POSU2	Polygala subspinosa	Subshrub/Shrub	Unknown	Polygalaceae
ERAL4	Eriogonum alatum	Forb/Subshrub	Not consumed	Polygonaceae
ERCE2	Eriogonum cernuum	Forb	Emergency	Polygonaceae
ERCO14	Eriogonum corymbosum	Shrub	Unknown	Polygonaceae
ERDE6	Eriogonum deflexum	Forb	Emergency	Polygonaceae
ERLE9	Eriogonum leptocladon	Subshrub	Unknown	Polygonaceae
ERLE10	Eriogonum leptophyllum	Subshrub	Unknown	Polygonaceae
ERMI4	Eriogonum microthecum	Shrub	Emergency	Polygonaceae
ERRA3	Eriogonum racemosum	Forb	Not consumed	Polygonaceae
ERIOG	Eriogonum sp.	Forb	Not consumed	Polygonaceae
ERUMS2	Eriogonum umbellatum var. subaridum	Subshrub	Emergency	Polygonaceae
POLYG4	Polygonum sp.	Forb	Not consumed	Polygonaceae
RUHY	Rumex hymenosepalus	Forb	Not consumed	Polygonaceae
POOL	Portulaca oleracea	Forb	Unknown	Portulacaceae
ANSE4	Androsace septentrionalis	Forb	Unknown	Primulaceae
CETE5	Ceratocephala testiculata	Forb	Unknown	Ranunculaceae
DESC	Delphinium scaposum	Forb	Not consumed	Ranunculaceae
DELPH	Delphinium sp.	Forb	Not consumed	Ranunculaceae
ERCI6	Erodium cicutarium	Forb	Not consumed	Ranunculaceae
THFE	Thalictrum fendleri	Forb	Not consumed	Ranunculaceae
AMUT	Amelanchier utahensis	Shrub	Desirable	Rosaceae
CEIN7	Cercocarpus intricatus	Shrub	Emergency	Rosaceae
CEMO2	Cercocarpus montanus	Shrub	Desirable	Rosaceae
CORA	Coleogyne ramosissima	Shrub	Unknown	Rosaceae
PRVI	Prunus virginiana	Shrub	Injurious	Rosaceae
PUST	Purshia stansburiana	Shrub	Desirable	Rosaceae
PUTR2	Purshia tridentata	Shrub	Desirable	Rosaceae
GALIU	Galium sp.	Forb	Not consumed	Rubiaceae
COUMP	Comandra umbellata var. pallida	Forb/Subshrub	Not consumed	Santalaceae
CALI4	Castilleja linariifolia	Forb	Not consumed	Scrophulariaceae
CORDY	Cordylanthus sp.	Forb	Unknown	Scrophulariaceae

PECE	Pedicularis centranthera	Forb	Unknown	Scrophulariaceae
PEAM	Penstemon ambigua	Subshrub	Not consumed	Scrophulariaceae
PEEA	Penstemon eatonii	Forb	Not consumed	Scrophulariaceae
PELI2	Penstemon linarioides	Forb	Not consumed	Scrophulariaceae
PENST	Penstemon sp.	Forb	Not consumed	Scrophuliaceae
LYPA	Lycium pallidum	Forb	Unknown	Solanaceae
PHYSA	Physalis sp.	Forb	Unknown	Solanaceae
PHYSA2	Physaria sp.	Forb	Unknown	Solanaceae
SOLAN	Solanum sp.	Forb	Unknown	Solanaceae
UNK1	Unknown spp	x	Unknown	x

Line#	family	scientificName	scientificNameAuthorsh	recordedBy	associatedCollectors	recordNumber	eventDate	substrate	Line#
1	Cyperaceae	Carex aurea	Nutt.	G. Rink		11417	7/6/2012		1
2	Cyperaceae	Carex specuicola	J.T. Howell	G. Rink		11418	7/6/2012		2
3	Gentianaceae	Centaurium calycosum	(Buckl.) Fern.	G. Rink		11419	7/6/2012		3
4	Fabaceae	Astragalus lonchocarpus	Torr.	G. Rink		11420	7/7/2012	clay soil	4
5	Cyperaceae	Carex aurea	Nutt.	G. Rink		11421	7/7/2012		5
6	Juncaceae	Juncus longistylis	Torr.	G. Rink		11422	7/7/2012		6
7	Chenopodiaceae	Atriplex	L.	G. Rink		11425	7/10/2012	(Mancos?) Shale slopes	7
8	Chenopodiaceae	Atriplex obovata	Moq.	G. Rink	K. Routsen	11428	7/16/2012		8

associatedTaxa
Tamarix, Ericameria nauseosa, Juniperus osteosperma, Sisyrinchium demissum, Carex praegracilis, Juncus ziphioides, Eleocharis, Scirpus, Veronica, Ranunculus cymbalaria
Tamarix, Ericameria nauseosa, Juniperus osteosperma, Sisyrinchium demissum, Carex praegracilis, Juncus ziphioides, Eleocharis, Scirpus, Veronica, Ranunculus cymbalaria
Tamarix, Ericameria nauseosa, Juniperus osteosperma, Sisyrinchium demissum, Carex praegracilis, Juncus ziphioides, Eleocharis, Scirpus, Veronica, Ranunculus cymbalaria
Pinus edulis, Juniperus osteosperma, Artemisia tridentata, Thelypodium
Juncus longistylis, Sisyrinchium demissum, Ranunculus cymbalaria, Eleocharis, Veronica
Juncus longistylis, Sisyrinchium demissum, Ranunculus cymbalaria, Eleocharis, Veronica
Atriplex corrugata
Achnatherum speciosum, Bromus tectorum, Erodium cicutarium, Sporobolis airoides, Atriplex confertifolia

Line#	stateProvince	county	locality	decimalLatitude	decimalLongitude	geodeticDatum	verbatimCoordinates
1	Arizona	Apache	Spring in Pine Wash north of Red Rock Valley Trading Post	36.711998	-109.130674	Nad 27	12s 666963E 4064350N
2	Arizona	Apache	Spring in Pine Wash north of Red Rock Valley Trading Post	36.711998	-109.130674	Nad 27	12s 666963E 4064350N
3	Arizona	Apache	Spring in Pine Wash north of Red Rock Valley Trading Post	36.711998	-109.130674	Nad 27	12s 666963E 4064350N
4	Arizona	Apache	About 10 miles northwest of Red Rock Valley Trading Post	36.711998	-109.130674	Nad 27	12s 666963E 4064350N
5	Arizona	Apache	small spring on the south side of Black Rock Wash on the south side of the Carrizo Mountains, north of Red Rock Valley Trading Post	36.750272	-109.092202	Nad 27	12s 670315E 4068664N
6	Arizona	Apache	small spring on the south side of Black Rock Wash on the south side of the Carrizo Mountains, north of Red Rock Valley Trading Post	36.750272	-109.092202	Nad 27	12s 670315E 4068664N
7	New Mexico	San Juan	About 2 miles north of Sanostee	36.453849	-108.919878	Nad 27	12s 686413E 4036098N
8	New Mexico	San Juan	Isolated butte about two miles northwest of Sanostee	36.436033	-108.907699	Nad 83	12s 687543E 4034347N

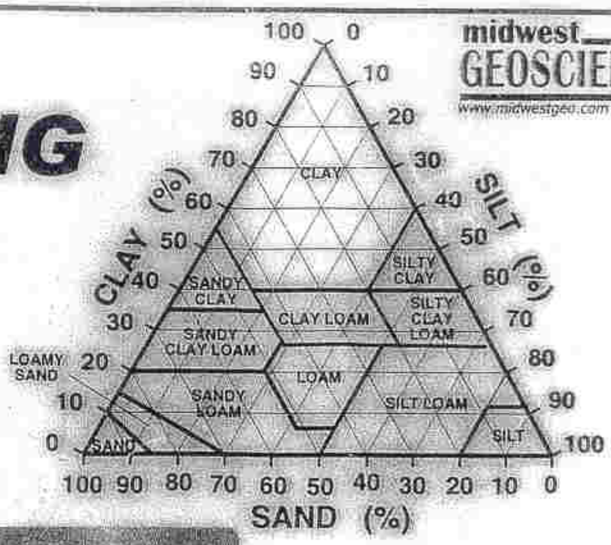
minimumElevationInMe	verbatimElevation
1940	6350ft
1940	6350ft
1940	6350ft
1890	6200ft
1940	6350ft
1940	6350ft
1930	6320ft
1890	6200ft

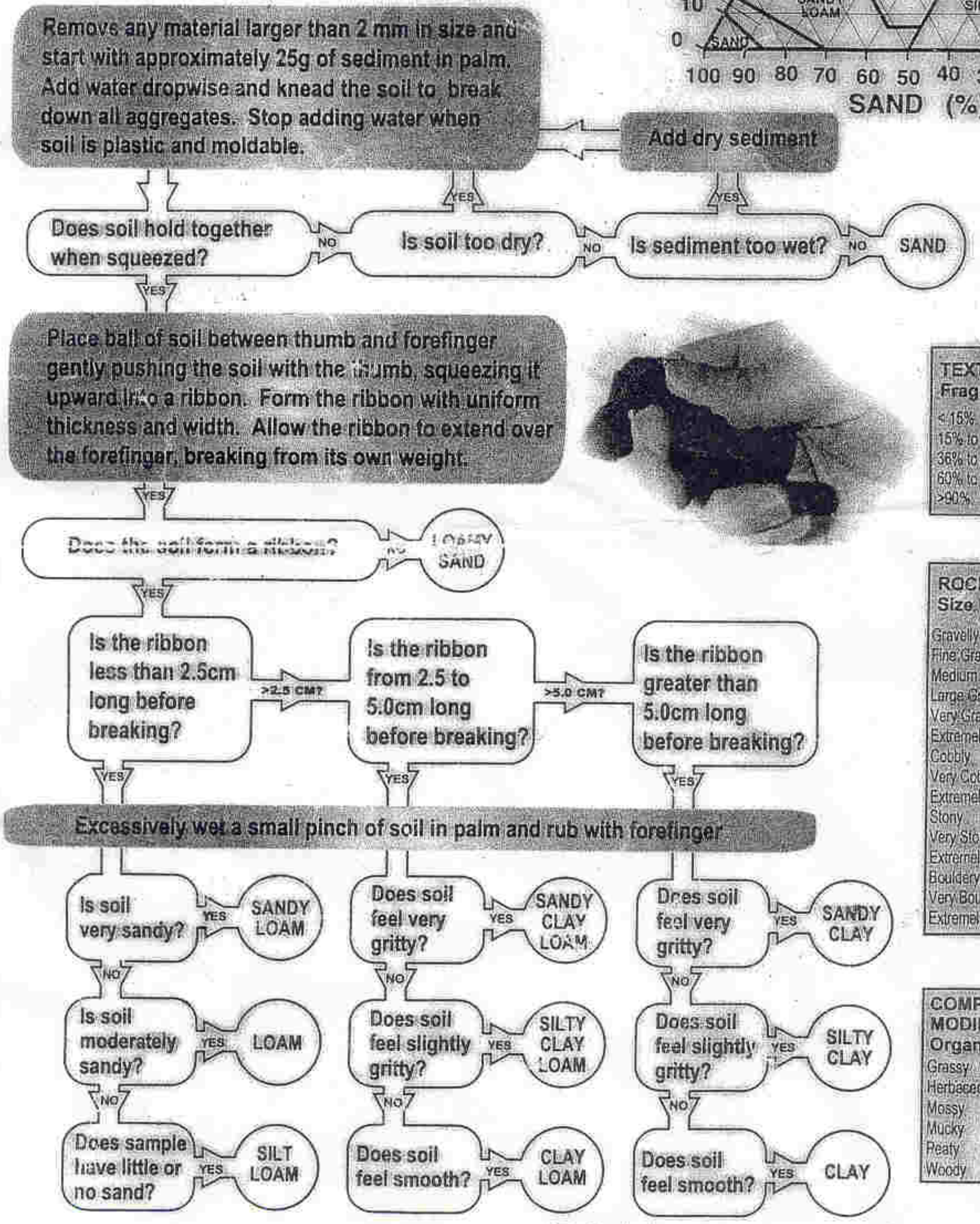
Appendix D

Soil Texture Flow Chart

USDA SOIL TEXTURING FIELD FLOW CHART

midwest GEOSCIENCES group
www.midwestgeo.com





Remove any material larger than 2 mm in size and start with approximately 25g of sediment in palm. Add water dropwise and knead the soil to break down all aggregates. Stop adding water when soil is plastic and moldable.

Add dry sediment

Does soil hold together when squeezed? NO → Is soil too dry? (YES → Add water dropwise) NO → Is sediment too wet? (YES → Add dry sediment) NO → SAND

YES

Place ball of soil between thumb and forefinger gently pushing the soil with the thumb, squeezing it upward into a ribbon. Form the ribbon with uniform thickness and width. Allow the ribbon to extend over the forefinger, breaking from its own weight.

YES

Does the soil form a ribbon? NO → LOAMY SAND

YES

Is the ribbon less than 2.5cm long before breaking? >2.5 CM? → Is the ribbon from 2.5 to 5.0cm long before breaking? >5.0 CM? → Is the ribbon greater than 5.0cm long before breaking?

YES

Excessively wet a small pinch of soil in palm and rub with forefinger

Is soil very sandy? YES → SANDY LOAM
NO
Is soil moderately sandy? YES → LOAM
NO
Does sample have little or no sand? YES → SILT LOAM

Does soil feel very gritty? YES → SANDY CLAY LOAM
NO
Does soil feel slightly gritty? YES → SILTY CLAY LOAM
NO
Does soil feel smooth? YES → CLAY LOAM

Does soil feel very gritty? YES → SANDY CLAY
NO
Does soil feel slightly gritty? YES → SILTY CLAY
NO
Does soil feel smooth? YES → CLAY

TEXTURE MODIFIERS
Fragment Content % by Volume

<15%	No modifier
15% to <35%	Add modifer
36% to <60%	Add "very" with modifier
60% to 90%	Add "extremely" with modifier
>90%	No modifer: use Size Class only

ROCK FRAGMENT MODIFIERS
Size Class & Quantity

Gravelly	>15% but <35% gravel
Fine Gravelly	>15% but <35% fine gravel
Medium Gravelly	>15% but <35% med. gravel
Large Gravelly	>15% but <35% large gravel
Very Gravelly	<35% but <60% gravel
Extremely Gravelly	>60% but <90% gravel
Cobbly	>15% but <35% cobbles
Very Cobbly	<35% but <60% cobbles
Extremely Cobbly	>60% but <90% cobbles
Stony	>15% but <35% stones
Very Stony	<35% but <60% stones
Extremely Stony	>60% but <90% stones
Bouldery	>15% but <35% boulders
Very Bouldery	<35% but <60% boulders
Extremely Bouldery	>60% but <90% boulders

COMPOSITIONAL TEXTURE MODIFIERS
Organic Class

Grassy	> 15% grassy fibers
Herbaceous	> 15% herbaceous fibers
Mossy	>15% moss fibers
Mucky	Minerals >10% but <17% fibers
Peaty	Minerals >10% but >17% fibers
Woody	>15% wood fragments or fiber