Ecosphere Environmental Services

District 17
2012 Vegetation Inventory

Cornfields, Ganado, Greasewood, Kinlichee, Klagetoh, Steamboat and Wide Ruins Communities

Arizona

Prepared for:

Bureau of Indian Affairs
Fort Defiance Agency – Natural Resources

Revised May 2016

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

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Acronyms

ADW	air-dry weight
AUM	animal unit months
BIA	Bureau of Indian Affairs
Ecosphere	Ecosphere Environmental Services
ESD	Each ecological site description
ft^2	square foot
G	grams
GPS	Global Positioning System
HCPC	historic climax plant community
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
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 17, of the Fort Defiance Navajo Agency. Data were collected from 876 transects in six grazing units covering seven communities. Data collection occurred during August of 2012. Measurements were taken for biomass production, ground cover, and species composition. The data were analyzed to determine annual production, species frequency, condition class of the range resource 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 applied to the acreage of ecological sites within each community. Reductions were taken for slopes and distance to water.

Overall, the similarity of the ecological sites in the project area to their historical potential ranged from 0-43 percent. A moderate amount of deterioration has occurred on all ecological sites in each unit. The initial carrying capacities are lower than currently permitted.

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 District 17 of the Fort Defiance Navajo Agency. Species-specific vegetation data measurements included biomass production and cover. These data were also used to calculate frequency, annual production, and 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 this inventory was to provide baseline information about the existing range resource to enable resource managers and permittees to improve and/or maintain the condition of the range resource. The results of this inventory will enable recommendations for adjusted stocking rates in District 17, as well as 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 (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 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 as stated in the Agricultural and Range Management Handbook (2003) is outlined as follows:

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, or 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 approve the carrying capacities of their districts, as discussed in the Navajo grazing Regulations Handbook.

According to the District Grazing Committee Policy and Procedure Manual, the district grazing committee members are responsible for attending district grazing committee meetings and Chapter meetings, and for ensuring that permittees respect applicable laws, regulations, and policies. Individual grazing district committee members are directly accountable to their local chapters and administratively accountable to the Director of the NNDOA. The NNDOA is 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.

1.2.3 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 efficiently harvest 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; therefore, it is important 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 forage production 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, production and forage value data can be used to help determine how many animals should be allowed to graze in a 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.

Plant vigor and root development can be adversely affected when grazing occurs during periods of initial plant growth or during the time of seed 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 rates have 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 in the District 17 area. 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 geographically diverse and ranges from the ponderosa pine forests of the Defiance Plateau at 7,400 feet to the remote badlands at 5,400 feet near the southern project boundary. On the east side of the project area, the elevated Defiance Plateau gently slopes westward into the Pueblo Colorado Wash which connects and drains Ganado, Cornfields, and Greasewood, Arizona. This area is characterized by piñon-juniper woodlands, rock cliffs and outcrops, and saline flats in the low-lying areas. The western side of the project area is occupied by a perched mesa near the town of Steamboat, Arizona. This dissected mesa slopes southerly into the volcanic lands near Bidahochi, Arizona and eventually to the Painted Desert badlands of the southern project area.

The District 17 project area includes the communities of Klagetoh, Wide Ruins, Greasewood, Cornfields, Steamboat, Ganado, and Kinlichee and excludes private, U.S. Park Service and Commercial Forest lands. The communities of Cornfields, Ganado, Kinlichee, Klagetoh, Steamboat, and Wide Ruins are all located in Apache County, Arizona. Greasewood community is bisected by the Navajo/Apache County Line so that nearly equal parts are contained in the respective counties. Ganado community is bounded on the north by Beautiful (Chinle) Valley. East of this point is Kinlichee community and the project area nearly extends to its eastern boundary. The project area continues south to the eastern boundaries of Klagetoh and Wide Ruins communities, nearly to Chambers, AZ. From here the southern project area boundary turns westerly along the boundary between the Navajo Nation and Petrified Forest National Park. Further west lies the Painted Desert and Lower Greasewood community. The western boundary of Lower Greasewood also forms the western project boundary up to the western edge of Steamboat community. This is followed north to Balakai Mesa where the project boundary shifts easterly again to the edge of Beautiful (Chinle) Valley. Cornfields community is contained within this greater area. A map of the study area is provided in the map on the following page.

Acreages for each compartment were extracted from shapefiles provided by the Fort Defiance Agency. Using these shapefiles and the soil survey boundaries, the communities in District 17 covered 1,049,421 acres as shown in Table 2-1.

(Map goes here – use insert caption command)

Table 2-1 Acres by Unit and Community

Unit	Community	Acres
1 1	Klagetoh Wide Ruins	141,686.06 145,547.42
2	Greasewood	302,073.38
3	Cornfields	45,218.39
4	Steamboat	198,039.80
5	Ganado	83,662.04
6	Kinlichee	128,534.78
	Total	**1,044,761.88**

Acreage was excluded for the Commercial Forest which was inventoried separately. There are 103,077 acres of Commercial Forest in Unit 6 Kinlichee and 7,894 acres of Commercial Forest in Unit 1 Klagetoh.

2.2 Precipitation

An accurate precipitation monitoring system is essential to range management programs. Biomass production estimates 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 10 years of precipitation data from three gauging stations within District 17. These precipitation stations are the Hubble Trading Post, Steamboat, and Wood Springs. The precipitation data are provided as Appendix A.

2.3 Soils

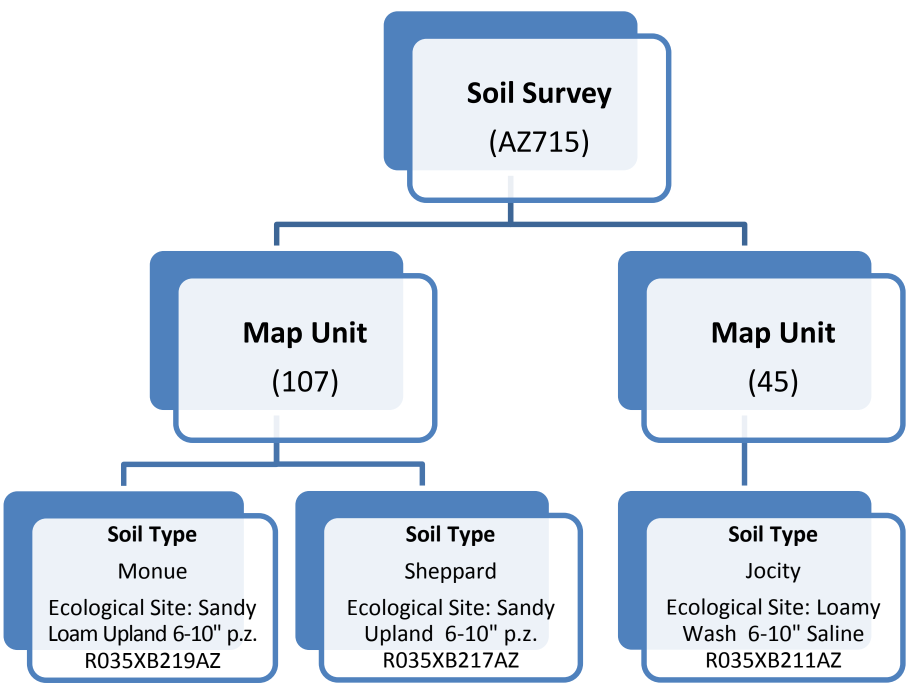
Knowledge of the soil properties in a particular area can help in predicting forage production. Soil properties such as texture, depth, moisture content, and capacity can dictate the type and amount of vegetation that will grow in that soil. The application of soil survey information is what enables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

Soil Surveys are carried out by the United States Department of Agriculture, Soil Conservation Service. The entire inventory area lies within survey AZ 715 Fort Defiance Area, Parts of Apache and Navajo Counties, Arizona and McKinley and San Juan Counties, New Mexico.

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.



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 17 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
F035XC322AZ *Juniperus osteosperma/Artemisia bigelovii-Purshia tridentata*
F035XC323AZ *Juniperus osteosperma/Artemisia tridentata* ssp. *wyomingensis*
F035XF602AZ *Juniperus osteosperma-Pinus edulis/Artemisia tridentata*
F035XF627AZ *Juniperus osteosperma-Pinus edulis/Artemisia tridentata*
F035XF628AZ *Juniperus osteosperma-Pinus edulis/Artemisia tridentata*
F035XF630AZ *Pinus edulis/Artemisia nova/Poa fendleriana*
F035XF633AZ *Pinus edulis/Cercocarpus montanus-Amelanchier utahensis*
F035XH811AZ *Pinus ponderosa/Quercus gambelii-Artemisia tridentata*
F035XH826AZ *Pinus ponderosa/Bouteloua gracilis-Muhlenbergia montana*
F035XH827AZ *Pinus ponderosa/Bouteloua gracilis-Muhlenbergia montana*
R035XA101AZ Breaks 10-14" p.z.
R035XA104AZ Clayey Bottom 10-14" p.z.
R035XA112AZ Loamy Bottom 10-14" p.z.
R035XA113AZ Loamy Upland 10-14" p.z.
R035XA117AZ Sandy Loam Upland 10-14" p.z.
R035XA118AZ Sandy Upland 10-14" p.z.
R035XA119AZ Shallow Loamy 10-14" p.z.
R035XB201AZ Mudstone/Sandstone Hills 6-10" p.z.
R035XB202AZ Clay Bottom, 6-10" p.z.
R035XB203AZ Clay Loam Upland, 6-10" p.z.
R035XB209AZ Loamy Bottom, 6-10" p.z.
R035XB210AZ Loamy Upland, 6-10" p.z.

Ecological Site
R035XB211AZ Loamy Wash 6-10" p.z. Saline
R035XB215AZ Sandstone/Shale Upland 6-10" p.z.
R035XB216AZ Sandy Bottom, 6-10" p.z.
R035XB217AZ Sandy Upland, 6-10" p.z.
R035XB219AZ Sandy Loam Upland 6-10" p.z.
R035XB220AZ Shale Uplands, 6-10" p.z.
R035XB222AZ Sandy Terrace 6-10" p.z.
R035XB225AZ Clayey Upland 6-10" p.z. Sodic
R035XB237AZ Clay Loam Terrace 6-10" p.z. Sodic
R035XC305AZ Clayey Bottom 10-14" p.z.
R035XC313AZ Loamy Upland, 10-14" p.z.
R035XC317AZ Sandy Loam Upland, 10-14" p.z.
R035XC320AZ Shale Hills 10-14" p.z.
R035XF605AZ Loamy Upland 13-17" p.z.
Riverwash
Badlands

F035XC322AZ Juniperus osteosperma/Artemisia bigelovii-Purshia tridentata

(Transects 4-135 and 5-059)

F035XC323AZ Juniperus osteosperma/Artemisia tridentata ssp. wyomingensis

(Transects 4-041 and W1-051)

F035XF602AZ Juniperus osteosperma-Pinus edulis/Artemisia tridentata

(Transects 6-023 and 6-100)

F035XF627AZ Juniperus osteosperma-Pinus edulis/Artemisia tridentata

(Transects 4-118 and K1-110)

F035XF628AZ Juniperus osteosperma-Pinus edulis/Artemisia tridentata

(Transects 5-041 and 6-045)

F035XF630AZ Pinus edulis/Artemisia nova/Poa fendleriana

(Transects 6-075 and K1-086)

F035XF633AZ Pinus edulis/Cercocarpus montanus-Amelanchier utahensis

(Transect 6-081)

F035XH811AZ Pinus ponderosa/Quercus gambelii-Artemisia tridentata

(Transects 6-032 and 6-012)

F035XH826AZ Pinus ponderosa/Bouteloua gracilis-Muhlenbergia Montana

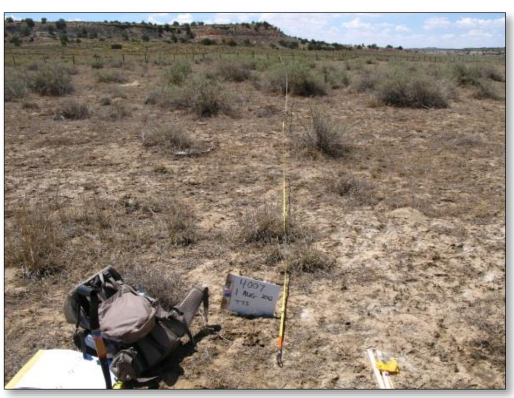
(Transect 6-040 and K1-024)

F035XH827AZ Pinus ponderosa/Bouteloua gracilis-Muhlenbergia montana

(Transects 6-071 and K1-083)

R035XA101AZ Breaks 10-14" p.z. (Transects 2-008 and 4-033)

R035XA104AZ Clayey Bottom 10-14" p.z. (Transect 4-007 and 5-016)



R035XA112AZ Loamy Bottom 10-14" p.z. (Transect 4-101 and 5-001)

R035XA113AZ Loamy Upland 10-14" p.z. (Transect 2-203 and W1-102)

R035XA117AZ Sandy loam upland 10-14" p.z. (Transect 2-003 and 4-061)

R035XA118AZ Sandy Upland 10-14" p.z. (Transects 2-118 and W1-072)

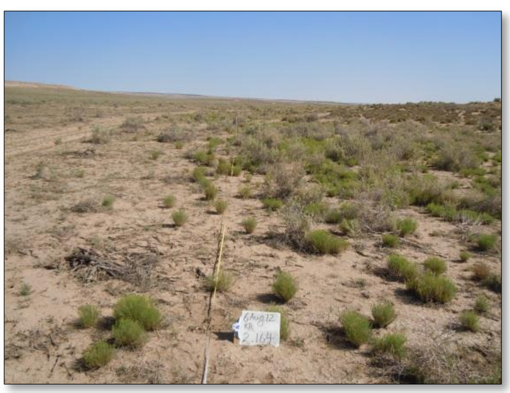
R035XA119AZ Shallow Loamy 10-14" p.z. (Transects 2-094 and 2-161)

R035XB201AZ Breaks, 6-10" p.z. (Transects 2-013 and 2-212)

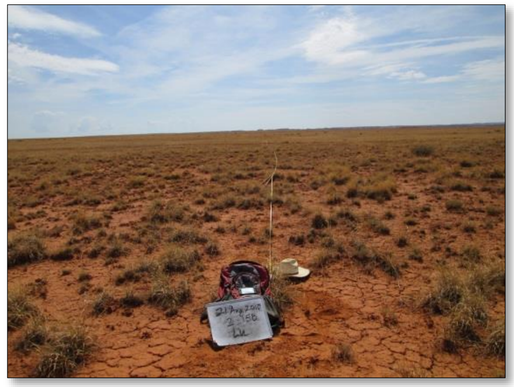
R035XB202AZ Clay Bottom, 6-10" p.z. (Transects 2-015 and 4-085)

R035XB203AZ Clay Loam Upland, 6-10" p.z. (Transects 2-001 and 4-153)

R035XB209AZ Loamy Bottom, 6-10" p.z. (Transects 2-164 and 2-237)



R035XB210AZ Loamy Upland, 6-10" p.z. (Transects 2-016 and 2-158)

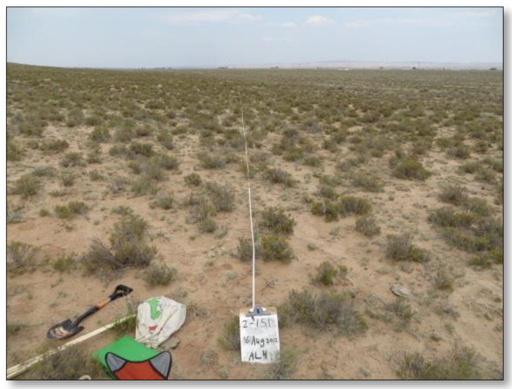


R035XB211AZ Loamy Wash 6-10" p.z. Saline (Transect 2-014)

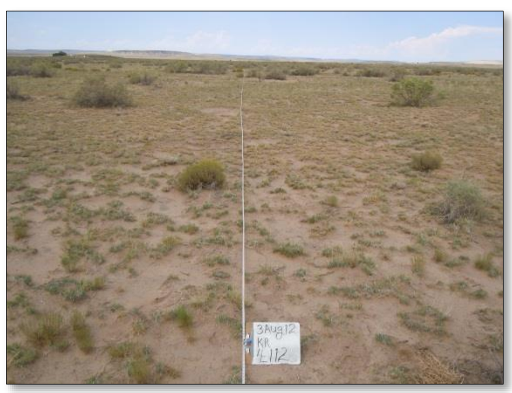
R035XB215AZ Sandstone/Shale Upland 6-10" p.z. (Transects 2-006 and 2-085)

R035XB216AZ Sandy Bottom, 6-10" p.z. (Transects 2-029 and 2-083)

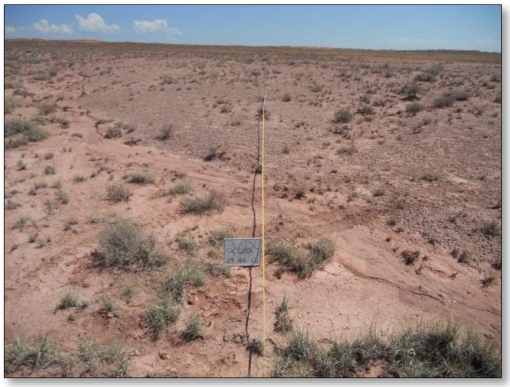
R035XB217AZ Sandy Upland, 6-10" p.z. (Transects 2-113 and 2-151)

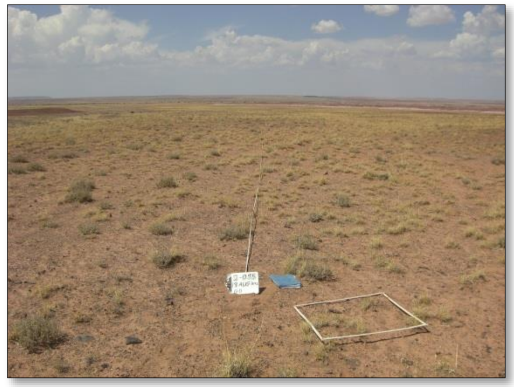


R035XB219AZ Sandy Loam Upland 6-10" p.z. (Transects 2-019 and 4-112)



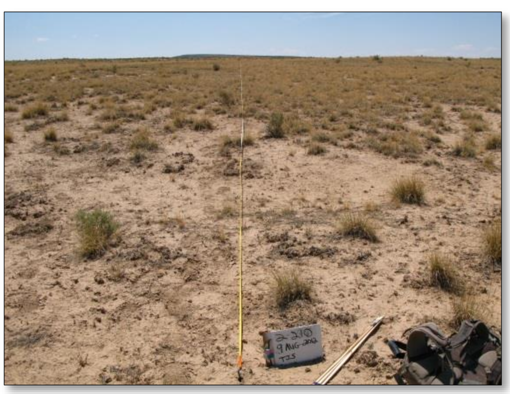
R035XB220AZ Shale Uplands, 6-10" p.z. (Transects 2-024 and 2-095)





R035XB222AZ Sandy Terrace 6-10" p.z. (Transects 2-194 and 2-243)

R035XB225AZ Clayey Upland 6-10" p.z. Sodic (Transect 2-210)



R035XB237AZ Clay Loam Terrace 6-10" p.z. Sodic (Transects 2-124 and 2-115)

R035XC305AZ Clayey Bottom 10-14" p.z. (Transect 6-016)

R035XC313AZ Loamy Upland, 10-14" p.z. (Transects 4-028 and 4-104)

R035XC317AZ Sandy Loam Upland, 10-14" p.z. (Transects 4-029 and 4-119)

R035XC320AZ Shale Hills 10-14" p.z. (Transects 5-062 and 4-049)

R035XF605AZ Loamy Upland 13-17" p.z. (Transects 6-054 and K1-017)

Riverwash (Transect 2-051)

Badlands (Transects 2-004 and 2-0123)

4. METHODOLOGY

The methods used to collect this data included protocols provided by the BIA and 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, with modifications approved by the BIA.

4.1 Field Methodology

4.1.1 Transect Establishment

Data collection in the field occurred between August 1 and August 30, 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 annual aboveground growth of vegetation.

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 (USDA), NRCS modified to standards outlined in the SOW, and with modifications generated from the pre-work conference. This 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) can be visually estimated with accuracy. The field team maintained proficiency by periodically harvesting and weighing to check estimates of production.

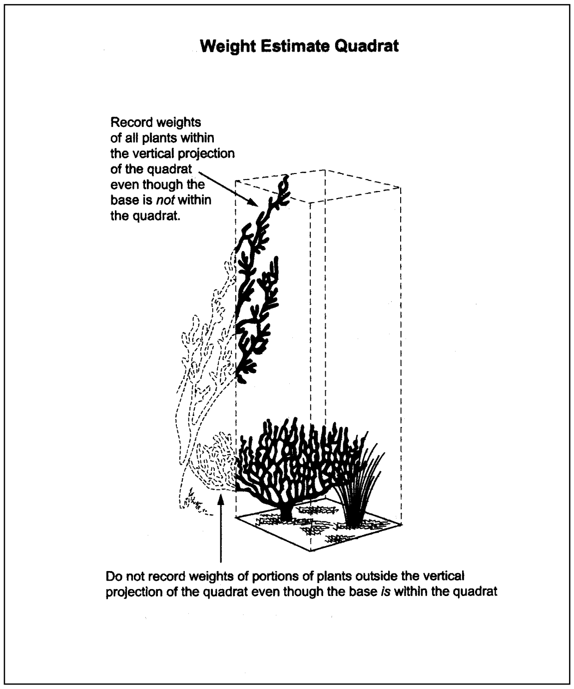
4.1.2.2 Double Sampling Methodology (Estimating and Harvesting)

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 clipped individually outside of the transect and recorded as plot 11.

Clipped 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. Two extended plots (0.1 acre) 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 be doubling the measurement. Large shrub plots were usually established in areas of tall, thick *Artemisia tridentate* (big sagebrush) or on *Sarcobatus vermiculatus* (greasewood) flats, or on rolling hills with *Purshia tridentata* (bitterbrush) and *Cercocarpus montanus* (mountain mahogany).

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 B. Also in Appendix B 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

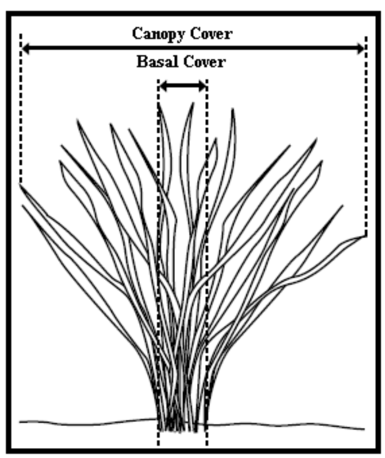
Ground cover measurements are used to quantify the amount of vegetation, organic litter, biological crusts, and exposed soil surface throughout an area. Cover is also important from a hydrologic perspective when examining basal and canopy (foliar) cover of perennial and annual species and litter cover. 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 C). 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 growth curve for that time of year, and multiplied by the percent of normal precipitation for the current water year. This may be more easily understood with the formula below:

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

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 sacaton) was estimated to weigh 10 grams (g), but the clipped weight was actually 9g, then all estimates of *Sporobolus airoides* (alkali sacaton) for that transect would be multiplied by 0.90. If the total estimated weight for estimates of *Sporobolus airoides* (alkali sacaton) on all plots in this transect was 80g, the resulting corrected weight would be 72g, as illustrated below:

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

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 clipped plots was collected in paper bags with tracking information recorded on the bags (date, transect identification, plot number, and species). Clipped, 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 clipped 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 clipped, an average %ADW was used that was generated from the same species in the same community. In the case of remaining species, the %ADW defaulted to one.

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

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 *Sporobolus airoides* (alkali sacaton) was recorded at a utilization factor of 90 percent un-grazed, then the amount of *Sporobolus airoides* (alkali sacaton) estimated would represent only 90 percent of the total.

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 *Sporobolus airoides* (alkali sacaton) 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. The growth curve used for many sites listed in MLRA 35 (6-10" sites) was:

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. The Hubble Trading Post, Steamboat, and Woodsprings Arizona weather stations precipitation percentage was used in the calculations to determine the percent of normal production. After July of 2012, the water year average was 73 percent compared to the previous 10 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 *Sporobolus airoides* (alkali sacaton), multiplied by the estimation correction factor for a corrected green weight of 72 grams. This corrected green weight of 72 grams is then multiplied by the reconstruction equation:

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

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

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

When actual values from the *Sporobolus airoides* (alkali sacaton) 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 (72g) multiplied by the reconstruction factor (1.094) results in a total reconstructed annual production 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 *Sporobolus airoides* (alkali sacaton). The value 78.74 represents the total reconstructed annual production of the species in pounds per acre.

Grams were also used to estimate the amount of shrub biomass in the large shrub plots. Each large shrub plot represents 1/100 of an acre (435.6 ft^2). There are 0.0022 pounds per gram, so the conversion factor for a 1/100-acre plot works out to 0.22 to convert grams to pounds per acre. Each transect has two large shrub plots (1/50 of an acre), so the conversion factor applied to the shrub weights was 0.11 (0.22/2 = 0.11). Grams from both plots were summed before applying the conversion factor. Alternatively, the same result can be achieved by dividing the total weight in grams by 454 as there are 454 grams in a pound. In this case, the result would be multiplied by 100 for one 1/100-acre plot. If multiple plots are used, the conversion factor of 100 is divided by the number of plots. For this survey, two 1/100 acre plots were used, so the conversion factor would be 50 (Habich 2001).

Example: 200g of Artemisia tridentata (big sagebrush) on two 1/100-acre shrub plots

Method 1: 200g x 0.11 = **22 lbs/acre**

Method 2: 200g/454 = 0.44
0.44 x 50 = **22 lbs/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:

*((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 *Sporobolus airoides* (alkali sacaton) occurred in six of the ten plots on a given transect, the frequency would be 60 percent. Frequency of species on each transect is included in the spreadsheet production data with this report. 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 pounds/acre of *Sporobolus airoides* (alkali sacaton).
2. Based on the information in the ESD, the "allowable" production for *Sporobolus airoides* (alkali sacaton) is 50 pounds/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 *Sporobolus airoides* (alkali sacaton) at 200 pounds/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 in included with the Excel data for this report. 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* (muttongrass) is considered preferred in the spring, but desirable during the remainder of the year. The District 17 range management currently allows for year round grazing so a single forage value is needed. The lowest value was chosen for each species to achieve a conservative estimate of the forage available and to avoid overgrazing during times of the year when forage palatability is lowest. For this inventory, we used sheep forage preference during the least palatable season, usually fall or winter.

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. Home sites, 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

<table>
<tr><th>Distance to Water/ Reduction</th><th>Slope/Reduction</th></tr>
<tr><td>0-1 Mile/0%</td><td>0-10%/0%</td></tr>
<tr><td>1-2 Miles/50%</td><td>11-30%/30%</td></tr>
<tr><td rowspan="2">>2 Miles/100%</td><td>31-60%/60%</td></tr>
<tr><td>>60%/100%</td></tr>
</table>

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.

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

A total of 876 transects were read on the District 17 study area, which included the communities of Klagetoh, Wide Ruins, Greasewood, Cornfields, Steamboat, Ganado, and Kinlichee and excluded private, U.S. Park Service and Commercial Forest lands. The attributes collected at each transect were biomass production, ground cover, and species frequency. From the production data, annual forage production and initial stocking rates were calculated by ecological sites and soil types in soil map units within each analysis area. Carrying capacity was calculated by GIS analysis of the acres of each ecological site within each analysis area.

The results of the data analysis (Table 5-1) indicate the carrying capacity of the range resource is exceeded. The total size of the study area is 1,044,761.88 acres. Currently, there are 70,764 sheep units year long (SUYL) permitted in the project area. The results show an unadjusted carrying capacity of 12,728.25 SUYL in the entire study area. After slope and distance to water reductions were made, the carrying capacity was adjusted to 5,147.07 SUYL. This carrying capacity is the sum of the carrying capacities in each grazing unit, which in turn are the sum of carrying capacities of ecological sites. The carrying capacity is not consistent across a grazing unit 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.

Table 5-1. Carrying Capacity Results Summary

Grazing Unit	Initial Carrying Capacity (SUYL)	Adjusted Carrying Capacity (SUYL)
1 Klagetoh	1,597.24	629.77
1 Wide Ruins	2,022.84	941.04
2 Greasewood	3,360.38	1,762.89
3 Cornfields	347.51	146.92
4 Steamboat	2,891.37	964.97
5 Ganado	1,047.73	301.18
6 Kinlichee	1,461.18	400.30
District 17 Project Area	12,728.25	5,147.07

5.1 Description of Results by Community

The results of this study have been broken down into the following categories: carrying capacity, stocking rates, similarity indices, available forage, ground cover, and species frequency. We first present a short discussion of the categories as they apply to each of the communities in order to present an overall picture of prevailing conditions. Following this is a more detailed analysis of the results as they apply to each grazing unit.

5.1.1 Initial Stocking Rates and Carrying Capacity

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 Similarity Index

Similarity indices are only possible for those ecological sites with developed ecological site descriptions. The average similarity index values are fairly high throughout the project area and some transects in the Greasewood unit had values in the 60-70 range. 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.

5.1.3 Available Forage Production

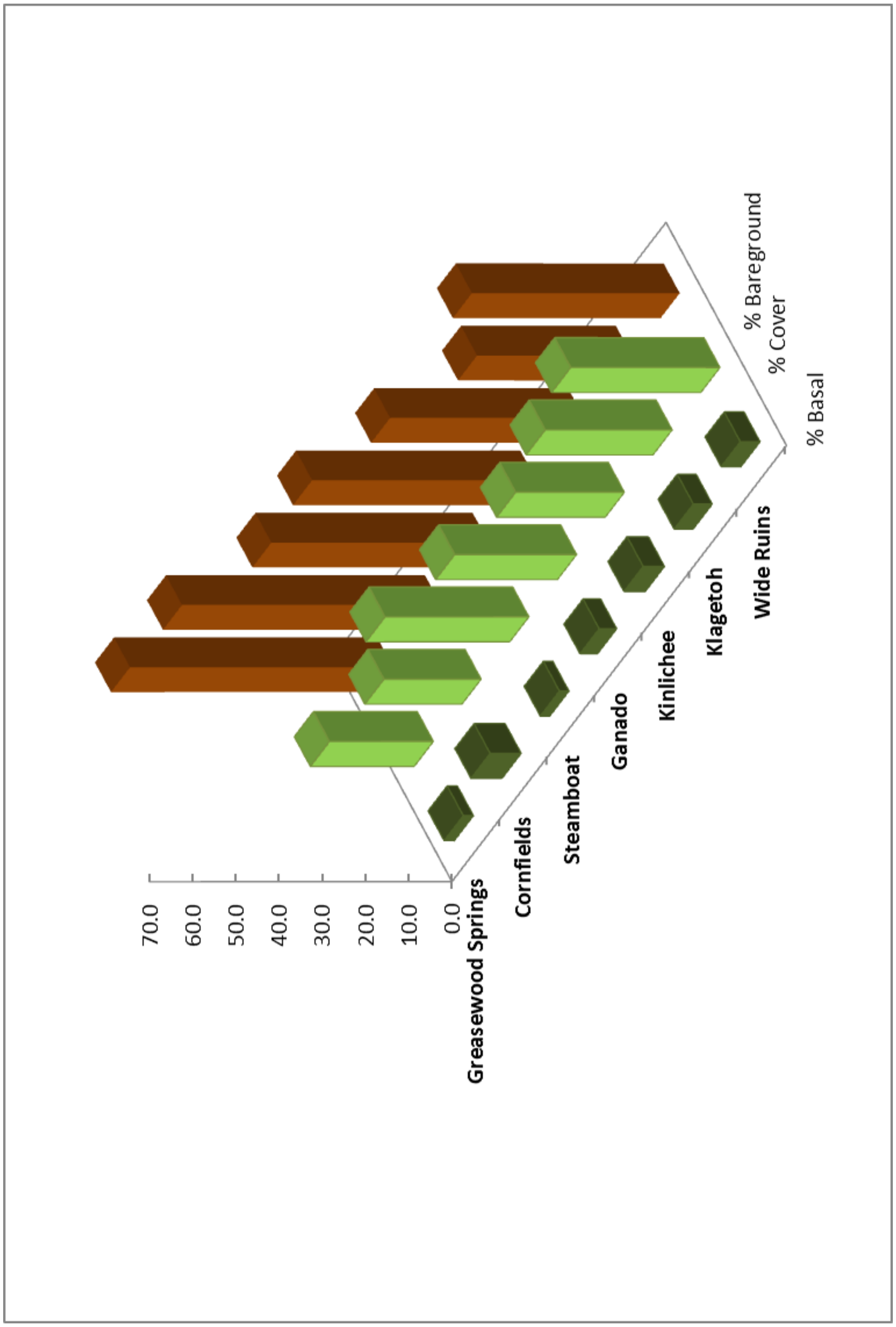
Available forage is the portion of the total reconstructed production classified as preferred, desirable, and emergency forage. It is this quantity that is used to calculate stocking rates. Forage production is moderate to high throughout a large portion of the District 17 project area. A few of the drier, clayey hills ecological sites are low in production and have a high erosion potential. The highest average production of available forage, by compartment, is in the Steamboat and Ganado units (37 lbs/acre), followed by Wide Ruins (34 lbs/acre), Greasewood Springs (28 lbs/acre), Klagetoh (27 lbs/acre), Kinlichee (26 lbs/acre), and Cornfields (20lbs/acre).

In the available forage and stocking rate table associated with each grazing 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.

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 17 is included for comparison (Figure 5-1). The most represented ground cover category across the project area is bare ground. The highest bare ground figures are from the drier, southern end of the project area in the Greasewood and Cornfields grazing units. The lowest numbers were found in the Klagetoh and Kinlichee units. Overall, the percentage of bare ground is manageable and can be reduced if steps are taken to improve forage cover. The largest concerns are the areas in the south with exposed clay soils that are highly susceptible to erosion.

Figure 5-1. Point Intercept Results by Grazing Unit



5.1.5 Frequency and Composition

The five most common species recorded on transects in each analysis area are presented here 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. Composition is reported by the total amount of reconstructed production of each species in the analysis area. Several species are repeatedly found in the top five across most grazing units. These include *Bouteloua gracilis* (blue grama), *Gutierrezia sarothrae* (broom snakeweed), *Chrysothamnus greenei* (Greene rabbitbrush), *Artemisia tridentata* (big sagebrush), and *Pleuraphis jamesii* (galleta grass).

5.2 Unit 1 Klagetoh

There are a total of 119 transects in the Klagetoh Unit. Table 5-2 presents the total acreage for the grazing unit, the acres analyzed and remaining acres, the carrying capacity and the adjusted carrying capacity. Table 5-3 shows the minimum and maximum stocking rates and the associated ecological sites, found within this analysis area. Table 5-4 displays the breakdown of ecological site, number of transects within an ecological site, production associated with the reference state for each ecological site, average reconstructed production derived from transect data, average available forage, stocking rate (Acres/SUYL), the total acres associated with each ecological site and the carrying capacity. Five ecological sites had no transects located within them and so could not be analyzed, resulting in 2.0 percent of the acreage in Klagetoh being excluded from the analysis. An additional 1.1 percent was excluded due to a lack of any NRCS correlated ecological sites. Further field analysis of these areas could provide site specific forage data which would contribute to carrying capacity.

Table 5-2. Unit 1 Klagetoh Carrying Capacity Analysis

Total Acres	Analyzed Acres (# of Ecological Sites)	Remaining Acres (# of Ecological Sites)	Carrying Capacity SUYL	Adjusted Carrying Capacity SUYL
141,686.06	137,267.42 (10)	4,418.64 (5)	1,597.24	629.77

Table 5-3. Unit 1 Klagetoh Initial 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
Unit 1 Klagetoh	534.25	F035XH811AZ - Sandy Loam Upland 17-25" p.z. (1 Transect)	54.90	R035XA117AZ Sandy Loam Upland 10-14. (6 Transects)

The majority of transects are located within the Sandstone Upland (F035XF627AZ) and Sandy Loam Upland (F035XF628AZ) ecological sites. The lowest stocking rate is associated with the Sandy Loam Upland 17-25” (F035XH811AZ) derived from a single transect. Additional data from this ecological site would help refine the stocking rate.

Table 5-4. Unit 1 Klagetoh Available Forage and Stocking Rates by Analyzed Ecological Site

Ecological Site	# of Transects	Total Production in Reference State (Lbs/Acre)	Average Reconstructed Production (Lbs/Acre)	Available Forage (lbs/acre)	Stocking Rate (Acres/ SUYL)	Total Acres
F035XC323AZ (ESD Unavailable)	12	N/A	234.71	26.91	88.07	18193.9
F035XF627AZ Sandstone Upland 13-17"	26	730	116.73	13.35	177.51	24179.4
F035XF628AZ Sandy Loam Upland 13-17"	39	500	265.02	35.37	67.00	47526.1
F035XF630AZ Loamy Shallow 13-17"	13	315	240.37	24.05	98.54	17950.2
F035XH811AZ Sandy Loam Upland 17-25"	1	564	106.98	4.44	534.25	3063.35
F035XH826AZ Sandstone Upland 17-25"	3	526	144.42	7.77	305.10	3403.72
F035XH827AZ Sandstone Hills 17-25"	5	390	147.12	12.52	189.24	3510.05
R035XA113AZ Loamy Upland 10-14"	2	608	269.75	33.25	71.27	1236.57
R035XA117AZ Sandy Loam Upland 10-14"	6	760	293.95	43.17	54.90	6987.64
R035XF605AZ Loamy Upland 13-17"	11	600	293.85	37.73	62.81	11216.3
Unable to assign	1	N/A	48.14	6.25	379.20	1620.02

The highest similarity index values were reported for transects in the Sandy Loam Upland (F035XF628AZ) and Loamy Upland (R035XF605AZ) ecological sites. Sandy Loam Upland (F035XF628AZ) is a woodland site that ranges between 50-60 percent canopy cover of pinyon and juniper in the historic climax community. The understory typically consists of 30-50 percent grasses, 30-40 percent shrubs, and 5-10 percent forbs. Dominant forage species include *Achnatherum hymenoides* (Indian ricegrass), *Bouteloua gracilis* (blue grama), *Elymus elymoides* (bottlebrush squirrel tail), *Poa fendleriana* (muttongrass), *Artemisia tridentata* (big sagebrush), and *Purshia tridentata* (antelope bitterbrush). Fire will push these sites towards a community that is dominated by shrubs and grasses while heavy grazing pressure will greatly reduce the native understory and increase tree density. Heavy grazing usually results in an understory community dominated by *Gutierrezia sarothrae* (broom snakeweed) and *Bouteloua gracilis* (blue grama). Over half of the transects in this ecological site have similarity index values between 25 and 47 percent. These higher scores are being driven primarily by *Artemisia tridentata* (big sagebrush) and *Bouteloua gracilis* (blue grama) production. *Gutierrezia sarothrae* (broom snakeweed) is a prevalent species, but is not dominant. Forb and grass diversity is fairly high across the transects as well. This current assemblage of plant species and their associated production indicates that this ecological site is somewhere between the historic climax community and the community typically found under continuous heavy grazing.

Loamy Upland (R035X605AZ) sites are composed primarily of a mix of *Artemisia tridentata* (big sagebrush), *Pascopyrum smithii* (western wheatgrass), and *Bouteloua gracilis* (blue grama) in the historic climax state. Under sever disturbance, *Artemisia tridentata* and annual species will increase and forage grasses will decrease. Much like the Sandy Loam Upland (F035XF628AZ) site, this site appears to be moving towards the plant community associated with heavy grazing, but is still maintaining some degree of species diversity and forage production.

The Sandstone Upland (F035XF627AZ) is another common ecological site found in this grazing unit. The historic plant community consists of a mix of shrubs, grasses, and forbs underneath a 35-45 percent canopy of pinyon and juniper. Grazing pressure will reduce desirable shrubs and grasses and cause increases in less desirable species. Transects in this site all had low similarity index values. This situation is reflected in the plant community which is dominated by *Artemisia tridentata* (big sagebrush), *Purshia stansburiana* (Stansbury cliffrose), and *Bouteloua gracilis* (blue grama).

Table 5-5. Unit 1 Klagetoh Similarity Index

Analysis Area	Maximum Similarity Index (%)	Minimum Similarity Index (%)	Median Similarity Index (%)
Unit 1 Klagetoh	40.41	1.83	17.17

The percentage of bare ground in this grazing unit is higher than expected, but still indicative of good ground cover. Many of the ecological sites have a piñon-juniper canopy coupled with a fairly intact understory community. The trees, especially the *Juniperus* species, provide a lot of litter and the abundance of the sod forming grasses like *Bouteloua gracilis* (blue grama) and *Pleuraphis jamesii* (galleta grass) in the understory in all ecological sites greatly reduces areas of bare ground. The Klagetoh unit has the lowest percentage of bare ground in all of the project area. The canopy cover is somewhat lower than expected given the low percentage of bare ground. However, this number makes sense in light of the tree cover. Even in the historic climax communities for the forested ecological sites, understory vegetation is somewhat sparse in comparison to non-forested sties.

Table 5-6. Unit 1 Klagetoh Point Intercept Cover Results

Analysis Unit	Basal (%)	Canopy (%)	Bareground (%)
Unit 1 Klagetoh	4.4	29.4	35.9

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 Klagetoh grazing unit. *Bouteloua gracilis* (blue grama) was found virtually every transect and *Pleuraphis jamesii* (galleta grass) occurred in close to half of all transects. Three composite shrub species, *Gutierrezia sarothrae* (broom snakeweed), *Artemisia tridentata* (big sagebrush), and *Chrysothamnus greenei* (Greene rabbitbrush) also occur frequently as well as the annual forb, *Portulaca oleracea* (little hogweed). *Portulaca oleracea* (little hogweed) is a mat forming species that is commonly found in the interspaces of *Artemisia tridentata* (big sagebrush) shrublands when perennial grasses and forbs are absent or scarce.

Along with frequency, it is 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 Klagetoh analysis until. *Bouteloua gracilis* (blue grama) and *Pleuraphis jamesii* (galleta grass) are both top contributors to biomass as well being widespread across the grazing unit. These two grasses are sod formers and will increase under grazing pressure. Their abundance is therefore not necessarily a sign of healthy rangeland, but they do provide forage to livestock and wildlife, especially before drying out, and are valuable species for building soils and reducing erosion. The most significant producer of biomass is blue grama. This species, along with *Gutierrezia sarothrae* (broom snakeweed) and big sagebrush, are common species associated with ecological sites present in this unit, but are generally more abundant than would be expected in the reference communities.

Table 5-7. Unit 1 Klagetoh 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)
Bouteloua gracilis	114	95.80%	Graminoid	Perennial	N	Emergency
Gutierrezia sarothrae	104	87.39%	Shrub	Perennial	N	Toxic
Artemisia tridentata	73	61.34%	Shrub	Perennial	N	Emergency
Pleuraphis jamesii	53	44.54%	Graminoid	Perennial	N	Emergency
Chrysothamnus greenei	39	32.77%	Shrub	Perennial	N	Emergency

Portulaca oleracea	39	32.77%	Forb	Annual	I	Unknown

Table 5-8. Unit 1 Klagetoh Species Composition by Weight

Species	Total Reconstructed Weight (lbs/acre)	Percentage of Total Weight in Community	Growth Habit	Duration	Nativity I=Introduced, N=Native	Sheep Forage Value (Most Limiting Season of Use)
Bouteloua gracilis	9531.34	36.42%	Graminoid	Perennial	N	Emergency
Artemisia tridentata	8635.74	33.00%	Shrub	Perennial	N	Emergency
Gutierrezia sarothrae	1407.13	5.38%	Shrub	Perennial	N	Toxic
Pleuraphis jamesii	1003.44	3.83%	Graminoid	Perennial	N	Emergency
Opuntia polyacantha	756.74	2.89%	Cactus	Perennial	N	Not Consumed

5.3 Unit 1 Wide Ruins

There are a total of 122 transects in the Wide Ruins Unit. Table 5-9 presents the total acreage for the grazing unit, the acres analyzed and remaining acres, the carrying capacity and the adjusted carrying capacity.

Table 5-10 shows the minimum and maximum stocking rates and the associated ecological sites, found within this analysis area.

Table 5-11 displays the breakdown of ecological site, number of transects within an ecological site, production associated with the reference state for each ecological site, average reconstructed production derived from transect data, average available forage, stocking rate (Acres/SUYL), the total acres associated with each ecological site and the carrying capacity. Seven ecological sites had no transects located within them and so could not be analyzed, resulting in 2.2 percent of the acreage in Klagetoh being excluded from the analysis. An additional 0.6 percent was excluded due to a lack of any NRCS correlated ecological sites. Further field analysis of these areas could provide site specific forage data which would contribute to carrying capacity.

Table 5-9. Unit 1 Wide Ruins Carrying Capacity Analysis

Total Acres	Analyzed Acres (# of Ecological Sites)	Remaining Acres (# of Ecological Sites)	Carrying Capacity SUYL	Adjusted Carrying Capacity SUYL
145,547.42	**141,387.33 (16)**	**4,160.1 (7)**	**2,022.82**	**941.04**

Table 5-10. Unit 1 Wide Ruins Initial 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
Unit 1 Wide Ruins	3,636.12	R035XB201AZ Mudstone/Sandstone Hills 6-10" p.z. (1 Transect)	24.04	R035XB210AZ Loamy Upland, 6-10" (1 Transect)

Table 5-11. Unit 1 Wide Ruins Available Forage and Stocking Rates by Analyzed Ecological Site

Ecological Site	Number of Transects	Total Production in Reference State (Lbs/Acre)	Average Reconstructed Production (Lbs/Acre)	Average Available Forage Per Acre	Acres/SUYL	Total Acres
F035XC323AZ (ESD Unavailable)	13	N/A	281.58	48.38	48.99	17353.06
F035XF627AZ Sandstone Upland 13-17”.	12	730	205.23	20.93	113.24	10131.94
F035XF628AZ Sandy Loam Upland 13-17"	17	500	216.50	30.02	78.95	18639.55
F035XF630AZ Loamy Shallow 13-17"	1	315	79.62	19.79	119.79	13384.59
R035XA101AZ Breaks 10-14"	2	673	49.77	3.13	757.75	1878.98
R035XA112AZ Loamy Bottom 10-14"	3	1691	221.19	34.91	67.88	3675.37
R035XA113AZ Loamy Upland 10-14"	15	608	342.42	46.43	51.04	18450.42
R035XA117AZ Sandy Loam Upland 10-14”	33	760	248.33	25.95	91.32	36533.08
R035XA118AZ Sandy Upland 10-14"	8	504	420.47	52.71	44.97	9686.19
R035XB201AZ Mudstone/Sandstone Hills	1	342	6.79	0.65	3636.12	202.02
R035XB203AZ Clay Loam Upland 6-10"	4	538	215.30	32.21	73.58	3136.94
R035XB209AZ Loamy Bottom, 6-10"	1	1632	193.74	39.61	59.83	246.79
R035XB210AZ Loamy Upland, 6-10"	1	538	622.59	98.58	24.04	1266.61
R035XB219AZ Sandy Loam Upland 6-10"	1	663	109.38	13.36	177.34	2563.30
R035XB222AZ Sandy Terrace 6-10"	3	409	178.38	38.45	61.63	1299.49
R035XF605AZ Loamy Upland 13-17"	5	600	375.02	49.67	47.71	2938.97
Unable to assign	2	N/A	22.91	2.70	879.41	940.95

On average, the highest similarity scores were associated with the Loamy Upland 10-14" (R035XA113AZ) and Sandy Loam Upland (R035XA117AZ) ecological sites. A majority of transects fall within the latter of these two sites. The historic climax community for the Loamy Upland 10-14" (R035XA113AZ) site is a mix of warm season, short to mid-grasses and sub shrubs. Common species include *Bouteloua gracilis* (blue grama), *Bouteloua eriopoda* (black grama), *Pleuraphis jamesii* (galleta grass), *Lycurus phleoides* (common wolfstail), *Achnatherum hymenoides* (Indian ricegrass), *Krascheninnikovia lanata* (winterfat), and *Chrysothamnus greenei* (Greene rabbitbrush). The larger shrub, *Atriplex canescens* (fourwing saltbush) can be fairly common as well. Under continuous grazing, this site will see increases in *Bouteloua gracilis* (blue grama), *Pleuraphis jamesii* (galleta grass), *Chrysothamnus greenei* (Greene rabbitbrush), and *Gutierrezia sarothrae* (broom snakeweed) while more desirable grasses and shrubs decrease. This description fits well with the current state encountered in the field. The danger associated with continued disturbance at this site is the introduction of exotic weed species, especially *Bromus tectorum* (cheatgrass) and *Salsola tragus* (prickly Russian thistle). However, at the time of the survey, no exotics weeds were discovered.

The Sandy Loam Upland (R035XA117AZ) site has a historic climax state very similar to the Loamy Upland 10-14" (R035XA113AZ) site, but dominant grasses also include *Sporobolus cryptandrus* (sand dropseed), *Sporobolus airoides* (alkali sacaton), and *Sporobolus cryptandrus* (spike dropseed) and *Atriplex canescens* (fourwing saltbush) makes up a larger portion of the community as well. The present community is missing many of the more desirable species like *Bouteloua eriopoda* (black grama), but the species mentioned above are all present and abundant. *Bouteloua gracilis* (blue grama) is also a common species found on transects. This site will continue to lose desirable species under continuous grazing and eventually will come to be completely dominated by shrubs and exotics or become invaded by *Juniperus* species.

Table 5-12. Unit 1 Wide Ruins Similarity Index

Analysis Area	Maximum Similarity Index (%)	Minimum Similarity Index (%)	Median Similarity Index (%)
Unit 1 Wide Ruins	55.75	1.54	15.03

Canopy cover is fairly high in this unit and the percent of bare ground is average for the project area. Efforts towards increasing desirable forage species would also increase the continuity between individual plants and help reduce the amount of bare ground.

Table 5-13. Unit 1 Wide Ruins Point Intercept Cover Results

Analysis Unit	Basal (%)	Canopy (%)	Bare Ground (%)
Unit 1 Wide Ruins	4.5	34.5	48.1

Three of the most frequent species are perennial grasses. Two of these species, *Bouteloua gracilis* (blue grama) and *Pleuraphis jamesii* (galleta grass) are also among the top five contributors of biomass. Top producing and frequently occurring shrub species include *Artemisia tridentata* (big sagebrush), *Chrysothamnus greenei* (Greene's rabbitbrush), and *Cylindropuntia whipplei* (Whipple cholla). These observations support the idea that this grazing unit has declined due to grazing disturbances, but has not declined to the point that shrubs and exotics have become the dominant species.

Table 5-14. Unit 1 Wide Ruins 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)
Bouteloua gracilis	108	88.52%	Graminoid	Perennial	N	Emergency
Sporobolus cryptandrus	76	62.30%	Graminoid	Perennial	N	Not consumed
Gutierrezia sarothrae	72	59.02%	Shrub	Perennial	N	Toxic
Chrysothamnus greenei	68	55.74%	Shrub	Perennial	N	Emergency
Pleuraphis jamesii	64	52.46%	Graminoid	Perennial	N	Emergency

Table 5-15. Unit 1 Wide Ruins Species Composition by Weight

Species	Total Reconstructed Weight (lbs/acre)	Percentage of Total Weight in Community	Growth Habit	Duration	Nativity I=Introduced, N=Native	Sheep Forage Value (Most Limiting Season of Use)
Bouteloua gracilis	12486.31	39.52%	Graminoid	Perennial	N	Emergency
Pleuraphis jamesii	3154.20	9.98%	Graminoid	Perennial	N	Emergency
Artemisia tridentata	10898.23	9.60%	Shrub	Perennial	N	Emergency
Chrysothamnus greenei	1464.28	4.64%	Shrub	Perennial	N	Emergency
Cylindropuntia whipplei	1402.31	4.44%	Cactus	Perennial	N	Not Consumed

5.4 Unit 2 Greasewood

The Greasewood grazing unit contains 251 transects. Table 5-16 presents the total acreage for the grazing unit, the acres analyzed and remaining acres, the carrying capacity and the adjusted carrying capacity. Table 5-17 shows the minimum and maximum stocking rates and the associated ecological sites, found within this analysis area.

Table 5-18 displays the breakdown of ecological site, number of transects within an ecological site, production associated with the reference state for each ecological site, average reconstructed production derived from transect data, average available forage, stocking rate (Acres/SUYL), the total acres associated with each ecological site and the carrying capacity. Five ecological sites could not be analyzed due to a lack of transects in those areas, which resulted in 2,638.46 acres, or 0.9 percent of the grazing unit, excluded from the analysis. Also, 36,884.16 acres (12.21 percent) had no NRCS correlation with any ecological site. Further field analysis of these areas could provide site specific forage data to contribute to increased carrying capacity.

Table 5-16. Unit 2 Greasewood Carrying Capacity Analysis

Total Acres	Analyzed Acres (# of Ecological Sites)	Remaining Acres (# of Ecological Sites)	Carrying Capacity SUYL	Adjusted Carrying Capacity SUYL
302,073.38	221,022.6 (23)	39,522.62 (5)	3,417.28	1,762.89

Table 5-17. Unit 2 Greasewood Initial 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
Unit 2 Greasewood	837.28	R035XA104AZ Clayey Bottom 10-14" p.z.	34.27	R035XF605AZ Loamy Upland 13-17"

Table 5-18. Unit 2 Greasewood Available Forage and Stocking Rates by Analyzed Ecological Site

Ecological Site	Number of Transects	Total Production in Reference State (Lbs/Acre)	Average Reconstructed Production (Lbs/Acre)	Average Available Forage Per Acre (Lbs/Acre)	Acres/SUYL	Total Acres
Badlands	10	N/A	28.10	3.38	701.90	33725.11
F035XC322AZ Sandstone Upland 10-14"	1	538	326.24	45.25	52.38	459.04
F035XC323AZ (ESD Unavailable)	9	N/A	378.31	42.19	56.18	16630.53
F035XF628AZ Sandy Loam Upland 13-17”	2	500	182.18	23.37	101.42	1882.93
R035XA101AZ Breaks 10-14"	7	673	205.51	18.78	126.20	6170.63
R035XA104AZ Clayey Bottom 10-14"	1	2850	809.29	2.83	837.28	166.69
R035XA113AZ Loamy Upland 10-14"	5	608	253.76	33.43	70.90	16461.89
R035XA117AZ Sandy Loam Upland 10-14"	27	760	268.59	37.35	63.46	18861.82
R035XA118AZ Sandy Upland 10-14"	2	504	310.52	19.68	120.45	1733.04
R035XA119AZ Shallow Loamy 10-14"	2	625	207.76	30.75	77.08	1308.28
R035XB201AZ Mudstone/Sandstone Hills	19	342	138.86	17.42	136.04	8704.41
R035XB202AZ Clay Bottom, 6-10"	16	2263	266.23	45.37	52.23	9435.49
R035XB203AZ Clay Loam Upland, 6-10"	52	538	200.69	28.90	82.02	60732.13
R035XB209AZ Loamy Bottom, 6-10"	4	1632	130.00	26.35	89.93	6764.55
R035XB210AZ Loamy Upland, 6-10"	17	538	250.40	41.84	56.65	19258.13
R035XB211AZ Loamy Wash 6-10" Saline	1	1100	31.93	3.37	704.26	238.74
R035XB215AZ Sandstone/Shale Upland 6-10”	3	345	138.34	17.98	131.80	2699.14
R035XB216AZ Sandy Bottom, 6-10"	6	900	278.29	46.72	50.73	9496.78
R035XB217AZ Sandy Upland, 6-10"	3	443	259.41	39.59	59.86	3836.36
R035XB219AZ Sandy Loam Upland 6-10"	25	663	164.13	26.41	89.75	37930.07
R035XB220AZ Shale Uplands, 6-10"	24	139	107.04	14.49	163.52	29532.12
R035XB222AZ Sandy Terrace 6-10"	3	409	235.03	37.05	63.97	4772.28
R035XB225AZ Clayey Upland 6-10" Sodic	1	140	311.23	46.70	50.75	2461.26
R035XB237AZ Clay Loam Terrace 6-10"	2	490	199.55	12.27	193.09	2178.92
R035XC320AZ Shale Hills 10-14"	2	367	53.88	7.75	305.73	279.66
R035XF605AZ Loamy Upland 13-17"	1	600	472.61	69.15	34.27	555.86
Riverwash	1	N/A	38.55	3.27	724.87	1158.58
Unable to assign	5	N/A	54.34	8.61	275.26	1996.09

A number of transects fall within the Shale Uplands (R035XB220AZ) ecological site. The transects in this site mostly have low similarity indices (median 16.53), but there are few with values in the forties and fifties and a single transect with a value over 74. This is a fairly dry site and contains a mix of perennial grasses like *Achnatherum hymenoides* (Indian ricegrass), *Elymus elymoides* (bottlebrush squirreltail), *Hesperostipa comata* (needle and thread), *Pleuraphis jamesii* (galleta grass), and *Sporobolus airoides* (alkali sacaton). Common shrubs are *Atriplex confertifolia* (shadscale) and *Atriplex obovata* (mound saltbush). This site is most sensitive to grazing during the winter and spring. Continuous grazing during this period will replace the cool season grasses like *Hesperostipa comata* (needle and thread) and *Elymus elymoides* (bottlebrush squirreltail) with lower forage value grasses and shrubs. The plant communities found at most transects are lacking the higher quality forage species, but still match fairly close to the historic climax community.

Another ecological site, Clay Loam Upland (R035XB203AZ), also has high similarity index values. This site was historically composed of perennial short to mid-grass species with scattered shrubs. As the site deteriorates, species like *Pleuraphis jamesii* (galleta grass), *Salsola tragus* (prickly Russian thistle), *Sarcobatus vermiculatus* (black greasewood), and various annual forbs will begin to increase or invade. Currently, many of the desirable, cool-season grass species are either absent or in decline, but few invasive species were detected. As with the Shale Uplands (R035XB220AZ) ecological site, grazing through the winter and spring will have the greatest negative impact on the vegetative community.

The majority of the lowest similarity scores were found within the Sandstone/Mudstone Hills (R035XB201AZ) ecological site. This site is typically dominated by warm season bunchgrasses mixed with *Artemisia bigelovii* (Bigelow sagebrush), *Atriplex* species (saltbush), and large perennial forbs such as *Eriastrum wilcoxii* (Wilcox's woollystar) and *Stanleya pinnata* (desert princesplume). The concern with this site is its potential for erosion following disturbance. The steep slopes and low water-holding capacity of the soils makes it imperative that adequate ground cover is maintained. As the grasses decrease due to drought and grazing, shrubs will initially increase, but they do not provide sufficient cover to prevent erosion. After the native plant community decreases, a cycle of erosion and invasion begins. Typical invaders at this site are annual *Eriogonum* species (buckwheat), *Bromus tectorum* (cheatgrass), and *Salsola tragus* (prickly Russian thistle). At this time, only a small fraction of the plant community consists of invasive species, but many transects are in areas with extremely high amounts of bare ground.

Table 5-19. Unit 2 Greasewood Similarity Index

Analysis Area	Maximum Similarity Index (%)	Minimum Similarity Index (%)	Median Similarity Index (%)
Unit 2 Greasewood	74.46	0.00	16.53

This unit has the highest percentage of bare ground in the project area. This fact is of greatest concern in ecological sites like Sandstone/Mudstone Hills (R035XB201AZ) that are highly susceptible to erosion. The low canopy cover value increases the concern that areas of the project site may be experiencing or will soon experience accelerated erosion.

Table 5-20. Unit 2 Greasewood Point Intercept Cover Results

Analysis Unit	Basal (%)	Canopy (%)	Bare Ground (%)
Unit 2 Greasewood	2.3	24.0	60.9

The two most commonly occurring species and top contributors to biomass are *Pleuraphis jamesii* (galleta grass) and *Bouteloua gracilis* (blue grama). *Achnatherum hymenoides* (Indian ricegrass) was also widespread throughout the grazing unit as well as *Gutierrezia sarothrae* (broom snakeweed) and *Chrysothamnus greenei* (Greene rabbitbrush). The perennial bunchgrass, *Sporobolus airoides* (alkali sacaton) is also one of the top five producers of biomass as well the desirable shrub, *Atriplex canescens* (fourwing saltbush). Overall, this grazing unit contains many of the species associated with the historical climax communities, but declines in the vegetation are evident in the increase of warm season, sod forming grasses and relatively high percentage of bare ground.

Table 5-21. Unit 2 Greasewood 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	159	63.35%	Graminoid	Perennial	N	Emergency
Bouteloua gracilis	132	52.59%	Graminoid	Perennial	N	Emergency
Achnatherum hymenoides	113	45.02%	Graminoid	Perennial	N	Desirable
Gutierrezia sarothrae	105	41.83%	Shrub	Perennial	N	Toxic
Chrysothamnus greenei	98	39.04%	Shrub	Perennial	N	Emergency

Table 5-22. Unit 2 Greasewood Species Composition by Weight

Species	Total Reconstructed Weight (lbs/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	9733.27	19.40%	Graminoid	Perennial	N	Emergency
Bouteloua gracilis	9271.99	18.48%	Graminoid	Perennial	N	Emergency
Sporobolus airoides	7877.72	15.70%	Graminoid	Perennial	N	Emergency
Atriplex canescens	4566.48	9.10%	Shrub	Perennial	N	Desirable
Achnatherum hymenoides	2534.10	5.05%	Graminoid	Perennial	N	Desirable

5.5 Unit 3 Cornfields

There are 38 Transects located in the Cornfields grazing unit. Table 5-23 presents the total acreage for the grazing unit, the acres analyzed and remaining acres, the carrying capacity and the adjusted carrying capacity. Table 5-24 shows the minimum and maximum stocking rates and the associated ecological sites, found within this analysis area. Table 5-25 displays the breakdown of ecological site, number of transects within an ecological site, production associated with the reference state for each ecological site, average reconstructed production derived from transect data, average available forage, stocking rate (Acres/SUYL), the total acres associated with each ecological site and the carrying capacity. Nine ecological sites could not be analyzed due to a lack of transects in those areas, which resulted in 6.5 percent of the grazing unit being excluded from the analysis. An additional 1,023.54 acres (2.3 percent) had no NRCS correlation with any ecological site. Further field analysis of these areas could provide site specific forage data to contribute to increased carrying capacity.

Table 5-23. Unit 3 Cornfields Carrying Capacity Analysis

Total Acres	Analyzed Acres (# of Ecological Sites)	Remaining Acres (# of Ecological Sites)	Carrying Capacity SUYL	Adjusted Carrying Capacity SUYL
45,218.39	41,252.68 (8)	3,965.71(9)	347.51	146.92

Table 5-24. Unit 3 Cornfields Initial 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
Unit 3 Cornfields	4383.61	R035XA104AZ - Clayey Bottom 10-14" p.z. (1 Transect)	85.23	R035XF605AZ Loamy Upland 13-17" p.z. (15 Transects)

Table 5-25. Unit 3 Cornfields Available Forage and Stocking Rates by Analyzed Ecological Site

Ecological Site	Number of Transects	Total Production in Reference State (Lbs/Acre)	Average Reconstructed Production (Lbs/Acre)	Average Available Forage Per Acre (Lbs/Acre)	Acres/SUYL	Total Acres
F035XC323AZ (ESD Unavailable)	3	N/A	140.06	20.00	118.52	7925.48
F035XF628AZ Sandy Loam Upland 13-17"	10	500	173.91	18.95	125.08	11025.48
R035XA104AZ Clayey Bottom 10-14"	1	2850	44.85	0.54	4383.61	1455.71
R035XA112AZ Loamy Bottom 10-14"	1	1691	167.66	2.23	1064.73	2141.46
R035XA113AZ Loamy Upland 10-14"	2	608	103.02	13.08	181.22	923.57
R035XA117AZ Sandy Loam Upland 10-14”	3	760	389.02	17.76	133.45	4733.83
R035XC320AZ Shale Hills 10-14"	2	367	87.64	3.99	594.54	860.04
R035XF605AZ Loamy Upland 13-17"	15	600	218.39	27.81	85.23	12187.11
Unable to assign	1	N/A	107.50	11.91	198.99	1023.54

There were no similarity indices higher than 40.04 in Cornfields. All similarity index values above 20 percent come from the Loamy Upland 13-17” (R035XF605AZ) and Sandy Loam Upland (R035XF628AZ) ecological sites. The current species assemblage found at the Sandy Loam Upland (F035XF628AZ) site is indicative of the community found following continuous grazing pressure. Shrub species like *Artemisia tridentata* (big sagebrush) and *Chrysothamnus greenei* (Greene rabbitbrush) are prevalent, warm season grasses such as *Bouteloua gracilis* (blue grama) and *Pleuraphis jamesii* (galleta grass) have increased and exotic species, mainly *Salsola tragus* (prickly Russian thistle) have started to invade. However, at this time *Salsola tragus* (prickly Russian thistle) is not particularly widespread.

The Loamy Upland (R035X605AZ) site is moving towards the plant community associated with heavy grazing pressure, but is still maintaining some degree of species diversity and forage production. The two primary components of the historic climax community, *Artemisia tridentata* (big sagebrush) and *Bouteloua gracilis* (blue grama), have definitely increased beyond their ideal parameters, but exotic species have not yet begun to invade the site and several, desirable cool-season grasses are still present.

Table 5-26. Unit 3 Cornfields Similarity Index

Analysis Area	Maximum Similarity Index (%)	Minimum Similarity Index (%)	Median Similarity Index (%)
Unit 3 Cornfields	40.04	1.18	15.21

The Cornfields Unit has the second highest percentage of bare ground in the project area. A number of the ecological sites have a high percentage of ground cover, but sites like Clayey Bottom (R035XA104AZ) have much lower percentages and make up a large portion of the grazing unit.

Table 5-27. Unit 3 Cornfields Point Intercept Cover Results

Analysis Unit	Basal (%)	Canopy (%)	Bare Ground (%)
Unit 3 Cornfields	7.2	22.5	59.9

Four of the top five most frequently occurring species are also among the top five most productive species. The prevalence of sod forming grasses and composite shrub species is typical of rangeland that has undergone a lot of grazing pressure, but has not yet declined to the point that invasive exotics have become abundant. The high production of *Cylindropuntia whipplei* (Whipple Cholla) comes primarily from the Sandy Loam Upland (R035XA117AZ) ecological site. Data from the transects located within this site indicate that production of available forage is fairly high, but the large population of *Cylindropuntia whipplei* (Whipple Cholla) is a cause for concern as this species will tend to increase in overgrazed pastures.

Table 5-28. Unit 3 Cornfields 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)
Bouteloua gracilis	34	89.47%	Graminoid	Perennial	N	Emergency
Artemisia tridentata	30	78.95%	Shrub	Perennial	N	Emergency

Species	Frequency by Transect	Percentage of Total Transects	Growth Habit	Duration	Nativity I=Introduced, N=Native	Sheep Forage Value (Most Limiting Season of Use)
Chrysothamnus greenei	28	73.68%	Shrub	Perennial	N	Emergency
Gutierrezia sarothrae	23	60.53%	Shrub	Perennial	N	Toxic
Pleuraphis jamesii	20	52.63%	Graminoid	Perennial	N	Emergency

Table 5-29. Unit 3 Cornfields Species Composition by Weight

Species	Total Reconstructed Weight (lbs/acre)	Percentage of Total Weight in Community	Growth Habit	Duration	Nativity I=Introduced, N=Native	Sheep Forage Value (Most Limiting Season of Use)
Bouteloua gracilis	2082.86	28.52%	Graminoid	Perennial	N	Emergency
Artemisia tridentata	1757.19	24.06%	Shrub	Perennial	N	Emergency
Cylindropuntia whipplei	1336.54	18.30%	Cactus	Perennial	N	Not Consumed
Chrysothamnus greenei	833.01	11.41%	Shrub	Perennial	N	Emergency
Gutierrezia sarothrae	386.14	5.29%	Shrub	Perennial	N	Toxic

5.6 Unit 4 Steamboat

The Steamboat unit contains 166 Transects.

Table 5-30 presents the total acreage for the grazing unit, the acres analyzed and remaining acres, the carrying capacity and the adjusted carrying capacity. Table 5-31 shows the minimum and maximum stocking rates and the associated ecological sites found within the analysis unit. Table 5-32 displays the breakdown of ecological site, number of transects within an ecological site, production associated with the reference state for each ecological site, average reconstructed production derived from transect data, average available forage, stocking rate (Acres/SUYL), the total acres associated with each ecological site and the carrying capacity. Six ecological sites could not be analyzed due to a lack of transects in those areas, which resulted in 2,427.97 acres, or 1.2 percent of the grazing unit, being excluded from the analysis. An additional 5,259.83 acres (2.7 percent) had no NRCS correlation with any ecological site. Further field analysis of these areas could provide site specific forage data to contribute to increased carrying capacity.

Table 5-30. Unit 4 Steamboat Carrying Capacity Analysis

Total Acres	Analyzed Acres (# of Ecological Sites)	Remaining Acres (# of Ecological Sites)	Carrying Capacity SUYL	Adjusted Carrying Capacity SUYL
198,039.80	19,0352 (21)	7,687.81 (6)	2,891.37	964.97

Table 5-31. Unit 4 Steamboat Initial 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
Unit 4 Steamboat	31583.39	F035XF630AZ - Loamy Shallow 13-17" p.z. (1 Transect)	18.72	R035XC320AZ Shale Hills 10-14" (1 transect)

Table 5-32. Unit 4 Steamboat Available Forage and Stocking Rates by Analyzed Ecological Site

Ecological Site	Number of Transects	Total Production in Reference State (Lbs/Acre)	Average Reconstructed Production	Average Available Forage Per Acre (Lbs/Acre)	Acres/SUYL	Total Acres
F035XC322AZ Sandstone Upland 10-14"	3	450	261.79	37.22	63.67	2932.92
F035XC323AZ (ESD Unavailable)	26	N/A	239.65	26.32	90.03	37781.43
F035XF627AZ Sandstone Upland 13-17"	4	730	96.47	11.52	205.79	2979.67
F035XF630AZ Loamy Shallow 13-17"	1	315	9.86	0.08	31583.39	1006.55
R035XA101AZ Breaks 10-14"	10	681.7	211.01	23.83	99.47	11167.23
R035XA104AZ Clayey Bottom 10-14"	9	2850	379.42	40.66	58.29	9899.29
R035XA112AZ Loamy Bottom 10-14"	21	1691	424.79	67.03	35.36	13481.70
R035XA113AZ Loamy Upland 10-14"	15	608	324.03	37.85	62.61	16980.10
R035XA117AZ Sandy Loam Upland 10-14"	21	760	304.92	38.93	60.88	29069.09
R035XA118AZ Sandy Upland 10-14"	2	504	636.10	63.11	37.55	1595.29
R035XB202AZ Clay bottom, 6-10"	4	2263	201.85	32.70	72.47	3256.44

Ecological Site	Number of Transects	Total Production in Reference State (Lbs/Acre)	Average Reconstructed Production	Average Available Forage Per Acre (Lbs/Acre)	Acres/SUYL	Total Acres
R035XB203AZ Clay Loam Upland, 6-10"	3	538	180.95	25.81	91.83	3853.26
R035XB209AZ Loamy Bottom, 6-10"	2	1632	202.42	25.40	93.29	2326.03
R035XB210AZ Loamy Upland, 6-10"	9	538	123.32	16.01	148.02	10847.13
R035XB216AZ Sandy Bottom, 6-10"	2	900	111.11	12.47	190.02	3123.98
R035XB219AZ Sandy Loam Upland 6-10"	9	663	185.96	18.11	130.89	13497.42
R035XB222AZ Sandy Terrace 6-10"	1	409	197.33	35.52	66.72	3545.10
R035XC313AZ Loamy Upland, 10-14"	11	871	351.60	48.92	48.44	8840.17
R035XC317AZ Sandy Loam Upland, 10-14"	5	630	397.93	55.38	42.79	8311.05
R035XC320AZ Shale Hills 10-14"	1	367	611.55	126.63	18.72	2032.53
R035XF605AZ Loamy Upland 13-17"	4	600	364.22	52.26	45.35	3825.62
Unable to assign	3	N/A	104.66	13.14	180.41	5259.33

The three main ecological sites most similar to their historic climax community are Loamy Upland 13-17" (R035XF605AZ), Loamy Upland 10-14" (R035XA113AZ), and Sandy Loam Upland (R035XA117AZ). All sites have more warm season grasses and shrub species than the historic community, but the diversity of more desirable cool season grasses is fairly high. Two exotic invasives, *Salsola tragus* (prickly Russian thistle) and *Bromus tectorum* (cheatgrass), were found on a few transects, but they are not widespread at this time.

The lowest similarity index values (less than 3) were reported on 11 transects from 8 different ecological sites. The Loamy Shallow (F035XF630AZ) ecological site has the lowest production. However, only one transect fell within this site, so this information may not reflect overall conditions. Production from this transect was very low and the list of recorded species included *Ephedra* species (jointfir), *Yucca baccata* (banana yucca), *Penstemon* species (beardtongue), and *Astragalus* species (milkvetch). This site is historically dominated by a 55-65 percent canopy of pinyon-juniper and can have a wide diversity of forbs in the understory along with *Bouteloua gracilis* (blue grama), *Elymus elymoides* (bottlebrush squirreltail), and *Poa fendleriana* (muttongrass). The current lack of plant diversity indicates that the transect is located in areas that have endured severe grazing pressure.

Table 5-33. Unit4 Steamboat Similarity Index

Analysis Area	Maximum Similarity Index (%)	Minimum Similarity Index (%)	Median Similarity Index (%)
Unit 4 Steamboat	43.01	0.41	14.66

Canopy cover is fairly high in this unit and the percent of bare ground is average for the project area. Efforts towards increasing desirable forage species, especially in the areas with pinyon-juniper woodland, would help lower the percentage of bare ground.

Table 5-34. Unit 4 Steamboat Point Intercept Cover Results

Analysis Unit	Basal (%)	Canopy (%)	Bare Ground (%)
Unit 4 Steamboat	2.2	33.3	50.3

The composition of frequently occurring species and those that are producing the most biomass is consistent with rangeland that has undergone continuous grazing pressure. However, forage production is still fairly high and invasive species are not yet a problem within this grazing unit.

Table 5-35. Unit 4 Steamboat 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)
Bouteloua gracilis	128	77.11%	Graminoid	Perennial	N	Emergency
Gutierrezia sarothrae	115	69.28%	Shrub	Perennial	N	Toxic
Pleuraphis jamesii	98	59.04%	Graminoid	Perennial	N	Emergency
Chrysothamnus greenei	91	54.82%	Shrub	Perennial	N	Emergency
Achnatherum hymenoides	76	45.78%	Graminoid	Perennial	N	Desirable

Table 5-36. Unit 4 Steamboat Species Composition by Weight

Species	Total Reconstructed Weight (lbs/acre)	Percentage of Total Weight in Community	Growth Habit	Duration	Nativity I=Introduced, N=Native	Sheep Forage Value (Most Limiting Season of Use)
Bouteloua gracilis	11759.12	24.71%	Graminoid	Perennial	N	Emergency
Artemisia tridentata	6323.33	13.29%	Shrub	Perennial	N	Emergency
Pleuraphis jamesii	4844.67	10.18%	Graminoid	Perennial	N	Emergency
Chrysothamnus greenei	4342.43	9.12%	Shrub	Perennial	N	Emergency
Atriplex canescens	2528.91	5.31%	Shrub	Perennial	N	Desirable

5.7 Unit 5 Ganado

There are a total of 72 transects in the Ganado grazing unit. The following tables show the carrying capacity, minimum and maximum stocking rates and the associated ecological sites, found within this analysis area and also the breakdown of ecological site, number of transects within an ecological site, production associated with the reference state for each ecological site, average reconstructed production derived from transect data, average available forage, stocking rate (Acres/SUYL), the total acres associated with each ecological site and the carrying capacity. In this grazing unit there were a high number of ecological sites (12) that could not be analyzed due to a lack of transects in those areas. This resulted in 9,401.62 acres, or 11.2 percent of the grazing unit, being excluded from the analysis. An additional 3,542.04 acres (4.2 percent) had no NRCS correlation with any ecological site. Further field analysis of these areas could provide site specific forage data to contribute to increased carrying capacity.

Table 5-37. Unit 5 Ganado Carrying Capacity Analysis

Total Acres	Analyzed Acres (# of Ecological Sites)	Remaining Acres (# of Ecological Sites)	Carrying Capacity SUYL	Adjusted Carrying Capacity SUYL
83,662.04	64154.5 (16)	12,943.66 (12)	1,047.14	301.18

Table 5-38. Unit 5 Ganado Initial 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
Unit 5 Ganado	1080.39	F035XF602AZ (ESD Unavailable) (1 Transect)	26.36	R035XF605AZ Loamy Upland 13-17" p.z. (9 Transects)

Table 5-39. Unit 5 Ganado Available Forage and Stocking Rates by Analyzed Ecological Site

Ecological Site	Number of Transects	Total Production in Reference State (Lbs/Acre)	Average Reconstructed Production (Lbs/Acre)	Average Available Forage Per Acre (Lbs/Acre)	Acres/SUYL	Total Acres
F035XC322AZ Sandstone Upland 10-	2	450	217.38	36.95	64.15	3724.81
F035XC323AZ (ESD Unavailable)	5	N/A	177.00	20.07	118.06	5438.43
F035XF602AZ (ESD Unavailable)	1	N/A	22.22	2.19	1080.39	351.82
F035XF628AZ Sandy Loam Upland 13-	2	500	321.29	37.99	62.39	2375.45
R035XA104AZ Clayey Bottom 10-14"	5	2850	285.72	41.17	57.57	5441.81
R035XA112AZ Loamy Bottom 10-14"	7	1691	337.77	50.36	47.06	6791.67
R035XA113AZ Loamy Upland 10-14"	4	608	259.79	29.84	79.42	2332.51
R035XA117AZ Sandy Loam Upland	6	760	231.70	27.63	85.77	6261.00
R035XB202AZ Clay Bottom, 6-10"	2	2263	164.50	28.29	83.78	1518.48
R035XB203AZ Clay Loam Upland, 6-	2	538	72.64	8.72	271.86	2951.42
R035XB209AZ Loamy Bottom, 6-10"	1	1632	14.27	3.46	685.61	1084.63
R035XB210AZ Loamy Upland, 6-10"	6	538	181.57	29.70	79.80	9601.79
R035XB217AZ Sandy Upland, 6-10"	1	443	199.88	35.03	67.66	2491.31
R035XB219AZ Sandy Loam Upland 6-	14	663	143.63	17.60	134.62	12298.60
R035XC320AZ Shale Hills 10-14"	4	367	413.01	62.44	37.96	2508.09
R035XF605AZ Loamy Upland 13-17"	9	600	609.24	89.92	26.36	5546.54
Unable to assign	1	N/A	113.20	5.63	420.96	3291.88

Similarity index values are highest in several ecological sites, most notably the Loamy Upland 13-17" (R035XF605AZ) and Shale Hills (R035XC320AZ). The historic community for the Shale Hills (R035XC320AZ) site consists of perennial grasses mixed with a fair amount of forbs and shrubs. As the site deteriorates, increases will be seen in *Pleuraphis jamesii* (galleta grass) and invasive species like *Bromus tectorum* (cheatgrass) and other annual plants will begin to colonize. Currently there are some invasive species present, but the majority of the plant community is comprised of perennial grasses like *Pleuraphis jamesii* (galleta grass), *Bouteloua gracilis* (blue grama), and *Sporobolus airoides* (alkali sacaton). *Atriplex* species (saltbush) and *Gutierrezia sarothrae* (broom snakeweed) are also common. The Loamy Upland 13-17" (R035XF605AZ) site is currently dominated by *Artemisia tridentata* (big sagebrush) and *Bouteloua gracilis* (blue grama) which is a typical modification of the historic plant community following continuous grazing.

Table 5-40. Unit 5 Ganado Similarity Index

Analysis Area	Maximum Similarity Index (%)	Minimum Similarity Index (%)	Median Similarity Index (%)
Unit 5 Ganado	54.23	0.01	14.57

Ground cover is average for the project area. Efforts to restore ecological sites to conditions more closely resembling those associated with the historical conditions will increase ground cover and reduce the extent of bare ground.

Table 5-41. Unit 5 Ganado Point Intercept Cover Results

Analysis Unit	Basal (%)	Canopy (%)	Bare Ground (%)
Unit 5 Ganado	4.0	28.2	51.9

The desirable grass, *Achnatherum hymenoides* (Indian ricegrass) is widespread throughout the analysis area and the desirable shrub *Atriplex canescens* (fourwing saltbush) is among the top five contributors of biomass. Overall, the dominant species indicate that the unit is in a moderate state of deterioration most likely due to continuous grazing and drought conditions.

Table 5-42. Unit 5 Ganado 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)
Bouteloua gracilis	61	84.72%	Graminoid	Perennial	N	Emergency
Pleuraphis jamesii	50	69.44%	Graminoid	Perennial	N	Emergency
Gutierrezia sarothrae	43	59.72%	Shrub	Perennial	N	Toxic
Chrysothamnus greenei	41	56.94%	Shrub	Perennial	N	Emergency
Achnatherum hymenoides	29	40.28%	Graminoid	Perennial	N	Desirable

Table 5-43. Unit 5 Ganado Species Composition by Weight

Species	Total Reconstructed Weight (lbs/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	4652.85	24.18%	Shrub	Perennial	N	Emergency
Bouteloua gracilis	4049.15	21.04%	Graminoid	Perennial	N	Emergency
Chrysothamnus greenei	2060.49	10.71%	Shrub	Perennial	N	Emergency
Pleuraphis jamesii	1772.68	9.21%	Graminoid	Perennial	N	Emergency
Atriplex canescens	1348.49	7.01%	Shrub	Perennial	N	Desirable

5.8 Unit 6 Kinlichee

There are 108 transects located within the Kinlichee grazing unit. Table 5-44 presents the total acreage for the grazing unit, the acres analyzed and remaining acres, the carrying capacity and the adjusted carrying capacity. Table 5-45 shows the minimum and maximum stocking rates and the associated ecological sites, found within this analysis area.

Table 5-46 displays the breakdown of ecological site, number of transects within an ecological site, production associated with the reference state for each ecological site, average reconstructed production derived from transect data, average available forage, stocking rate (Acres/SUYL), the total acres associated with each ecological site and the carrying capacity. Six ecological sites could not be analyzed due to a lack of transects in those areas, which resulted in 1,599.63 acres, or 1.2 percent of the grazing unit, being excluded from the analysis. An additional 2,780.19 acres (2.2 percent) had no NRCS correlation with any ecological site. Further field analysis of these areas could provide site specific forage data to contribute to increased carrying capacity.

Table 5-44. Unit 6 Kinlichee Carrying Capacity Analysis

Total Acres	Analyzed Acres (# of Ecological Sites)	Remaining Acres (# of Ecological Sites)	Carrying Capacity SUYL	Adjusted Carrying Capacity SUYL
128,534.78	124,155 (14)	4,379.82 (6)	1,461.18	400.30

The overall carrying capacity for this unit was 1,461.18 SUYL. The amount of acres necessary to support one sheep unit per year ranges from 56 to 1,121. The most productive ecological site is Loamy Slopes 13-17" (F035XF633AZ). The lowest stocking rate was recorded for the F035XF602AZ site. The majority of transects fell within the Sandy Loam Upland 13-17" (F035XF628AZ), Loamy Upland 13-17" (R035XF605AZ), and Sandstone Upland 13-17” (F035XF627AZ) ecological sites. All three sites have fairly high stocking rates and carrying capacities.

Table 5-45. Unit 6 Kinlichee Initial 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
Unit 6 Kinlichee	1,121.41	F035XF602AZ (ESD Unavailable) (6 Transects)	56.67	F035XF633AZ Loamy Slopes 13-17" (1 Transect)

Table 5-46. Unit 6 Kinlichee Available Forage and Stocking Rates by Analyzed Ecological Site

Ecological Site	Number of Transects	Total Production in Reference State (Lbs/Acre)	Average Reconstructed Production (Lbs/Acre)	Average Available Forage Per Acre (Lbs/Acre)	Acres/SUYL	Total Acres
F035XC323AZ (ESD Unavailable)	1	N/A	213.85	31.83	74.46	1178.86

Ecological Site	Number of Transects	Total Production in Reference State (Lbs/Acre)	Average Reconstructed Production (Lbs/Acre)	Average Available Forage Per Acre (Lbs/Acre)	Acres/SUYL	Total Acres
F035XF602AZ (ESD Unavailable)	6	N/A	48.64	2.11	1121.41	6260.08
F035XF627AZ Sandstone Upland	18	730	153.88	13.60	174.24	14422.75
F035XF628AZ Sandy Loam	31	500	284.19	37.86	62.60	39264.05
F035XF630AZ Loamy Shallow 13-	4	315	280.13	26.96	87.92	7234.84
F035XF633AZ Loamy Slopes 13-	1	452	324.71	41.82	56.67	2583.94
F035XH811AZ Sandy Loam	2	564	95.23	10.03	236.37	4811.62
F035XH826AZ Sandstone Upland	7	526	157.01	16.20	146.30	5346.25
F035XH827AZ Sandstone Hills	1	390	144.91	6.50	364.34	2059.08
R035XA104AZ Clayey Bottom 10-	1	2850	161.37	13.22	179.26	707.26
R035XA112AZ Loamy Bottom 10-	1	1691	34.94	5.66	419.01	1130.83
R035XA117AZ Sandy Loam	3	760	181.45	29.87	79.36	2920.70
R035XC305AZ Clayey Bottom 10-	3	1155	11.20	2.00	1185.19	4755.02
R035XF605AZ Loamy Upland 13-	26	600	267.22	36.74	64.51	31479.70
Unable to assign	3	N/A	25.75	3.26	726.99	2780.19

The highest similarity indices were between 40.7 and 41.6. The highest similarity index was in the Sandy Loam Upland 13-17" (F035XF628) forested ecological site. The other 5 transects were located in the Loamy Upland 13-17" (R035XF605AZ) ecological site, which also had the second highest total production.

Table 5-47. Unit 6 Kinlichee Similarity Index

Analysis Area	Maximum Similarity Index (%)	Minimum Similarity Index (%)	Median Similarity Index (%)
Unit 6 Kinlichee	41.84	0.00	14.95

Table 5-48. Unit 6 Kinlichee Point Intercept Cover Results

Analysis Unit	Basal (%)	Canopy (%)	Bare Ground (%)
Unit 6 Kinlichee	4.9	25.1	44.9

Composite shrubs and sod forming grasses make up a large portion of the plant communities in this grazing unit. Overall, the dominant species indicate that the unit is in a moderate state of deterioration most likely due to continuous grazing and drought conditions.

Table 5-49. Unit 6 Kinlichee 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
Bouteloua gracilis	95	87.96%	Graminoid	Perennial	N	Emergency
Artemisia tridentata	72	66.67%	Shrub	Perennial	N	Emergency
Chrysothamnus greenei	56	51.85%	Shrub	Perennial	N	Emergency
Gutierrezia sarothrae	56	51.85%	Shrub	Perennial	N	Toxic
Chaetopappa ericoides	54	50.00%	Forb	Perennial	N	Not consumed

Table 5-50. Unit 6 Kinlichee Species Composition by Weight

Species	Total Reconstructed Weight (lbs/acre)	Percentage of Total Weight in	Growth Habit	Duration	Nativity I=Introduced, N=Native	Sheep Forage Value (Most Limiting Season of Use)
Artemisia tridentata	10563.18	46.40%	Shrub	Perennial	N	Emergency
Bouteloua gracilis	5844.03	25.67%	Graminoid	Perennial	N	Emergency
Chrysothamnus greenei	866.17	3.80%	Shrub	Perennial	N	Emergency
Opuntia sp.	486.18	2.14%	Cactus	Perennial	N	Not Consumed
Gutierrezia sarothrae	358.30	1.57%	Shrub	Perennial	N	Toxic

6. Conclusions and Recommendations

Analysis of each grazing unit showed that overall, a moderate amount of deterioration has occurred in every ecological site. This decline in the plant communities is largely a result of continuous grazing pressure and drought conditions. However, the expected pattern of increasing brush and extensive colonization by exotic species has not yet occurred. The primarily concerns are that undesirable species like *Opuntia* species (prickly pear) 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 start to outcompete the desirable native 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.

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 much 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 lower, 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). Water retention and seeding programs are particularly important considerations for the highly erodible clayey hills portions of the project area.

Rebuilding soils requires a combination of erosion control, revegetation, and periodic disturbance of the soil surface. Revegetation may require reseeding programs in some parts. However, this study found that much of the native plant community is still present within the vast majority of the project area. Production from native species may be low in many areas, but the components are still in place. Especially visible are perennial grass species like *Achnatherum hymenoides* (Indian ricegrass)*, Pleuraphis jamesii* (galleta grass), *Bouteloua gracilis* (blue grama), and *Sporobolus* (dropseed grass) species. Important forb and shrub species such as *Sphaeralcea* (globemallow) species*,* and *Atriplex canescens* (fourwing saltbush) are fairly 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. The lack of native herbaceous diversity is due, in large part, to unmanaged continuous grazing systems.

Determining forage production based upon a normal precipitation year 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 help 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 obstacles to fence construction are the common property aspect of the Navajo Reservation and financial constraint. A common sentiment encountered while performing the vegetation surveys was that people want to improve the land, but they aren't receiving help or don't know where to ask for help. 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. Many of the grazing units have areas that are dominated by *Artemisia tridentata* (big sagebrush), *Gutierrezia sarothrae* (broom snakeweed), and *Chrysothamnus greenei* (Greene rabbitbrush). 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) and *Chrysothamnus greenei* (Greene rabbitbrush) 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 Forage Values

Range managers that issue permits in the District 17 area need to recognize species within the individual permit areas, and know their forage values, to more finely tune the stocking rates. For example, if a permitted area only has palatable species available to livestock in the spring and summer and there is no forage available during the fall and winter seasons, the area will likely be overgrazed at the end of the year and resources could suffer permanent damage. This is why it's safer to start with stocking rates based upon forage available throughout the year, as this study used. Seasonal grazing would allow for additional livestock during spring and summer when forage is palatable. For example, *Bouteloua gracilis* is desirable forage in the spring and summer, but is only used as emergency forage in the fall and winter. In the data for this project it was labeled as its winter value of emergency forage. This results in a conservative estimate of available forage. Seasonal grazing would allow for additional livestock during spring and summer when forage is palatable.

The forage values for a limited number species may be listed in the ESDs. The comprehensive list used to assign forage values for this inventory is included with the digital data for this report and should be referenced by rangeland managers to assess seasonal availability of forage.

6.5 Data Analysis and Monitoring

Analysis of the data revealed several patterns including areas of high shrub density, a few areas lacking in ground cover, and other sites 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 ecological 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

Hubble Wx Station

Water Year	Month 10	Month 11	Month 12	Month 1	Month 2	Month 3	Month 4	Month 5	Month 6	Month 7	Month 8	Month 9
2001	3.30	0.58	0.19	1.05	0.45	1.08	0.80	1.10	0.00	1.15	2.55	0.15
2002	0.30	0.30	1.00	0.00	0.20	0.20	0.40	0.00	0.20	1.20	1.20	3.40
2003	0.75	0.75	1.00	0.10	1.50	1.50	0.35	0.20	0.00	1.40	0.80	1.80
2004	1.80	0.80	0.50	0.70	0.70	0.50	0.50	0.10	0.70	0.70	0.80	2.60
2005	1.00	1.50	0.60	2.30	2.50	1.10	1.10	0.20	0.20	0.10	2.40	1.20
2006	0.60	0.00	0.00	0.30	0.09	1.11	0.40	0.00	0.12	0.58	4.80	1.10
2007	3.29	0.00	0.40	0.49	0.88	1.12	0.70	1.50	0.05	0.35	4.72	
2008	0.25	0.00	0.35	1.85	1.70	0.00	0.10	0.58	0.32	1.95	0.97	1.30
2009	0.58	0.52	2.39	0.08	1.21	0.45	0.70	1.42	0.53	0.35	0.00	0.30
2010	0.50	0.00	1.31	3.64	0.40	1.44	0.86	0.48	0.00	1.02	3.40	1.60
2011	0.60	0.32	1.29	0.80	1.20			0.80	0.00	1.27	0.95	1.60
Historical Avg.	1.18	0.43	0.82	1.03	0.98	0.85	0.59	0.58	0.19	0.92	2.05	1.51
2012	1.10	1.00	0.52	0.18	0.24	0.56	0.33	0.10	0.28	1.43	1.87	0.85
2012 Cumulative % of average precipitation	0.93	1.30	1.08	0.81	0.68	0.68	0.67	0.62	0.65	0.76	**0.79**	0.76

NOTE - Month 10 of water year 2001 is actually October of 2000

Steamboat Wx Station

Water Year		Month 10	Month 11	Month 12	Month 1	Month 2	Month 3	Month 4	Month 5	Month 6	Month 7	Month 8	Month 9
	2001	2.95	0.52	0.17	0.81	0.21	0.49	0.20	0.00	0.40	1.08	1.32	0.35
	2002	0.15	0.08	0.57	0.35	0.15	0.00	0.35	0.05	0.10	0.70	0.90	2.90
	2003	0.50	0.20	0.45	0.05	0.80	1.70	0.00	0.20	0.00	1.20	1.80	1.95
	2004	0.75	0.65	0.60	0.35	0.65	0.20	1.35	0.33	0.00	1.05	0.95	2.80
	2005	0.40	2.05	0.35	2.80	2.20	0.95	1.40	0.10	0.10	1.05	3.55	1.00
	2006	1.10	0.00	0.00	0.60	0.00	0.60	0.40	0.00	0.10	0.80	3.58	1.62
	2007	1.70	0.00	0.75	0.20	0.81	0.81	0.33	1.05	0.50	1.70	1.45	1.45
	2008	0.10	0.00	2.20	1.47	1.03	0.02	0.08	1.10	0.00	1.70	1.50	2.20
	2009	0.50	0.60	1.50	0.18	0.73	0.49	0.35	0.80	0.70	0.61	0.00	0.64
	2010	0.24	0.00	1.09	2.92	0.39	0.52	0.23	0.23	0.07	1.00	5.10	1.13
	2011	0.49	0.19	1.22	0.40	0.52	0.48	0.30	0.75	0.00	2.60	0.80	2.45
Historical Avg.		0.81	0.39	0.81	0.92	0.68	0.57	0.45	0.42	0.18	1.23	1.90	1.68
	2012	1.49	1.22	0.65	0.05	0.23	0.32	0.30	0.00	0.00	0.72	2.38	1.35
2012 Cumulative % of average precipitation		1.85	2.26	1.67	1.16	1.01	0.95	0.92	0.84	0.81	0.77	**0.88**	0.87

NOTE - Month 10 of water year 2001 is actually October of 2000

Wood Springs Wx Station

Water Year		Month 10	Month 11	Month 12	Month 1	Month 2	Month 3	Month 4	Month 5	Month 6	Month 7	Month 8	Month 9
	2001	1.97	0.53	0.20	1.06	0.58	1.10	0.72	0.81	0.59	1.20	2.90	0.50
	2002	0.30	0.10	1.20	0.00	0.20	0.10	0.50	0.00	0.10	1.30	0.70	2.60
	2003	1.40	0.70	0.60	0.00	1.80	1.30	0.30	0.30	0.00	1.80	0.60	1.90
	2004	1.10	1.00	0.50	1.00	0.80	0.40	1.00	0.10	0.50	1.30	0.20	2.90
	2005	1.00	1.30	0.60	2.97	2.03	1.50	1.10	0.25	0.25	1.60	3.00	1.20
	2006	0.80	0.03	0.00	0.27	0.15	1.05	0.50	0.00	0.20	0.80	3.30	3.31
	2007	1.00	0.50	0.00	0.61			1.40	0.65	0.00	0.97	2.05	0.65
	2008	0.15	0.05	2.60	1.65	0.75	0.80	0.20	0.50	0.60	1.30	1.15	2.75
	2009	1.10	0.60	2.00	0.21	1.14	0.36	0.84	1.13	0.48	0.30	0.00	0.60
	2010	0.58	0.05	0.93	2.57	0.70	1.17	0.83	0.37	0.16	1.41	2.89	1.30
	2011	0.54	0.24	1.16	0.51	1.00			1.13	0.01	1.30	1.80	1.36
Historical Avg.		0.90	0.46	0.89	0.99	0.92	0.86	0.74	0.48	0.26	1.21	1.69	1.73
	2012	1.25	0.62	0.45	0.23	0.24	0.43	0.28	0.07	0.26	1.27	2.30	0.80
2012 Cumulative % of average precipitation		1.38	1.37	1.03	0.79	0.67	0.64	0.61	0.57	0.59	0.66	**0.79**	0.74

NOTE - Month 10 of water year 2001 is actually October of 2000

Appendix B — Plant List & Collection

Code	GenusSpecies	Growth	SheepForagePref	Family
AMARA	Amaranthus sp.	Forb	Unknown	Amaranthaceae
ASCU9	Asclepias cutleri	Forb	Toxic	Apocynaceae
ANPA4	Antennaria parvifolia	Forb	Unknown	Asteraceae
ARBI3	Artemisia bigelovii	Subshrub/Shrub	Unknown	Asteraceae
ARCA14	Artemisia carruthii	Shrub	Desirable	Asteraceae
ARDR4	Artemisia dracunculus	Subshrub	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
BADI	Bahia dissecta	Forb	Unknown	Asteraceae
CHER2	Chaetopappa ericoides	Forb	Not consumed	Asteraceae
CHDE2	Chrysothamnus depressus	Subshrub	Emergency	Asteraceae
CHGR6	Chrysothamnus greenei	Shrub	Emergency	Asteraceae
CHMO2	Chrysothamnus molestus	Shrub	Unknown	Asteraceae
ERNA10	Ericameria nauseosa	Shrub	Not consumed	Asteraceae
ERIGE2	Erigeron sp.	Forb	Not consumed	Asteraceae
GUSA2	Gutierrezia sarothrae	Subshrub	Toxic	Asteraceae
HYMEN4	Hymenopappus sp.	Forb	Desirable	Asteraceae
HYMEN7	Hymenoxys sp.	Forb	Desirable	Asteraceae
ISOCO	Isocoma sp.	Shrub	Unknown	Asteraceae
MACHA	Machaeranthera sp.	Forb/Subshrub	Unknown	Asteraceae
MATA2	Machaeranthera tanacetifolia	Forb	Not consumed	Asteraceae
PECTI	Pectis sp.	Forb	Unknown	Asteraceae
PEPUG	Petradoria pumila ssp. graminea	Forb	Unknown	Asteraceae
SENEC	Senecio sp.	Forb	Unknown	Asteraceae
MAFR3	Mahonia fremontii	Subshrub	Not consumed	Berberidaceae
CRBA4	Cryptantha bakeri	Forb/Subshrub	Not consumed	Boraginaceae
CRYPT	Cryptantha sp.	Forb/Subshrub	Not consumed	Boraginaceae
LAPPU	Lappula	Forb	Unknown	Boraginaceae
LAOC3	Lappula occidentalis	Forb	Not consumed	Boraginaceae
ARPE2	Arabis perennans	Forb	Not consumed	Brassicaceae
ARABI2	Arabis sp.	Forb	Desirable	Brassicaceae
DESCU	Descurainia sp.	Forb	Unknown	Brassicaceae
ERCA14	Erysimum capitatum	Forb	Not consumed	Brassicaceae
ERRE4	Erysimum repandum	Forb	Unknown	Brassicaceae
LESQU	Lesquerella sp.	Forb	Not consumed	Brassicaceae
NOMO2	Noccaea montana	Forb	Unknown	Brassicaceae
SIAL2	Sisymbrium altissimum	Forb	Unknown	Brassicaceae
SISYM	Sisymbrium sp.	Forb	Unknown	Brassicaceae
CYWH	Cylindopuntia whipplei	Cactus	Not consumed	Cactaceae
CYLIN2	Cylindropuntia	Cactus	Injurious	Cactaceae
ECHIN2	Echinocactus sp.	Cactus	Injurious	Cactaceae
OPPO	Opuntia polyacantha	Cactus	Injurious	Cactaceae
OPUNT	Opuntia sp.	Cactus	Not consumed	Cactaceae
AREA	Arenaria eastwoodiae	Subshrub	Unknown	Caryophyllaceae

ARENA	Arenaria sp.	Subshrub	Unknown	Caryophyllaceae
ATCA2	Atriplex canescens	Shrub	Desirable	Chenopodiaceae
ATCO	Atriplex confertifolia	Shrub	Not consumed	Chenopodiaceae
ATRIP	Atriplex sp.	Shrub	Unknown	Chenopodiaceae
CHAL7	Chenopodium album	Forb	Not consumed	Chenopodiaceae
KRLA2	Krascheninnikovia lanata	Subshrub	Preferred	Chenopodiaceae
SATR12	Salsola tragus	Forb	Injurious	Chenopodiaceae
SAVE4	Sarcobatus vermiculatus	Shrub	Not consumed	Chenopodiaceae
SUAED	Suaeda	Subshrub	Not consumed	Chenopodiaceae
SUAED	Suaeda sp.	Subshrub	Unknown	Chenopodiaceae
TROC	Tradescantia occidentalis	Forb	Unknown	Commelinaceae
TRPI	Tradescantia pinetorum	Forb	Unknown	Commelinaceae
TRADE	Tradescantia sp.	Forb	Unknown	Commelinaceae
CAGE	Carex geophila	Graminoid	Not consumed	Cyperaceae
CAREX	Carex sp.	Graminoid	Desirable	Cyperaceae
CYFE2	Cyperus fendleranus	Forb	Unknown	Cyperaceae
EPCU	Ephedra cutleri	Shrub	Preferred	Ephedraceae
TRRA5	Tragia ramosa	Forb/Subshrub	Unknown	Euphorbaceae
CHCH5	Chamaesyce chaetocalyx	Subshrub	Unknown	Euphorbiaceae
CHAMA15	Chamaesyce sp.	Forb	Unknown	Euphorbiaceae
EUPHO	Euphorbia sp.	Forb	Unknown	Euphorbiaceae
ASKE	Astragalus kentrophyta	Forb	Toxic	Fabaceae
ASTRA	Astragalus sp.	Forb	Toxic	Fabaceae
LOTUS	Lotus sp.	Forb	Unknown	Fabaceae
LOUT3	Lotus utahensis	Forb	Unknown	Fabaceae
LOWR	Lotus wrightii	Forb	Unknown	Fabaceae
PAFI4	Parryella filifolia	Shrub	Unknown	Fabaceae
SPHAE	Sphaeralcea sp.	Forb	Not consumed	Malvaceae
MESC	Menodora scabra	Forb	Unknown	Oleaceae
PLANT	Plantago sp.	Forb	Not consumed	Plantaginaceae
BOGR2	Bouteloua gracilis	Graminoid	Emergency	Poaceae
BRTE	Bromus tectorum	Graminoid	Injurious	Poaceae
ELEL5	Elymus elymoides	Graminoid	Unknown	Poaceae
HECO26	Hesperostipa comata	Graminoid	Injurious	Poaceae
MOSQ	Monroa squarrosa	Graminoid	Not consumed	Poaceae
MUHLE	Muhlenbergia sp.	Graminoid	Emergency	Poaceae
PASM	Pascopyrum smithii	Graminoid	Desirable	Poaceae
PIMI	Piptatheropsis micrantha	Graminoid	Desirable	Poaceae
PLJA	Pleuraphis jamesii	Graminoid	Emergency	Poaceae
POFE	Poa fendleriana	Graminoid	Desirable	Poaceae
SPCR	Sporobolus cryptandrus	Graminoid	Not consumed	Poaceae
SPFL2	Sporobolus flexuosus	Graminoid	Unknown	Poaceae
ERIAS	Eriastrum sp.	Forb	Unknown	Polemoniaceae
IPMU3	Ipomopsis multiflora	Forb	Unknown	Polemoniaceae
PHAU3	Phlox austromontana	Forb	Not consumed	Polemoniaceae
ERAL4	Eriogonum alatum	Subshrub, Forb	Not consumed	Polygonaceae
ERIOG	Eriogonum sp.	Forb	Not consumed	Polygonaceae

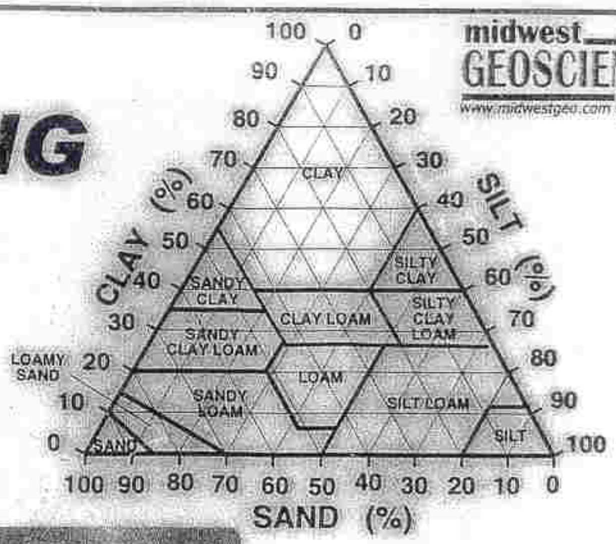
ERIOG	Eriogonum sp.	Forb	Unknown	Polygonaceae
ERUMS2	Eriogonum umbellatum var. subaridum	Subshrub	Emergency	Polygonaceae
POLYG4	Polygonum sp.	Forb	Not consumed	Polygonaceae
PHPA29	Phemeranthus parviflorus	Forb	Unknown	Portulacaceae
PHEME	Phemeranthus sp.	Forb	Unknown	Portulacaceae
POHA5	Portulaca halimoides	Forb	Unknown	Portulacaceae
POOL	Portulaca oleracea	Forb	Unknown	Portulacaceae
ERCI6	Erodium cicutarium	Forb	Not consumed	Ranunculaceae
CASTI2	Castilleja sp.	Forb	Not consumed	Scrophulariaceae
PENST	Penstemon sp.	Forb	Not consumed	Scrophulariaceae
CHCO2	Chamaesaracha coronopus	Subshrub	Unknown	Solanaceae
LYPA	Lycium pallidum	Forb	Unknown	Solanaceae
NICOT	Nicotiana sp.	Forb	Unknown	Solanaceae
SOLAN	Solanum sp.	Forb	Unknown	Solanaceae
UNKK1	Unknown sp.	Unknown	Unknown	Unknown

institution(	family	scientificNa	scientificNa	recordedBy	associated(	recordNum	eventDate	substrate	associatedT	stateProvir	county
ASC	Asteraceae	Chrysothar	(Blake) L.C.	G. Rink		11426	7/16/2012		Pinus eduli	Arizona	Apache
ASC	Cyperaceae	Carex filifol	Nutt.	G. Rink		11427	7/16/2012	Fine soil ur	Pinus eduli	Arizona	Apache

locality	decimalLat	decimalLor	geodeticDa	verbatimC(	verbatimC(	minimumE	verbatimElevation
About four miles northwest of Gaı	35.73311	-109.613	Nad 83	12s 625465E	3955234l	2000	6570ft
About four miles northwest of Gaı	35.746	-109.611	Nad 83	12s 625562E	3956666l	2040	6680ft

Appendix C — Soil Texture Chart

USDA SOIL TEXTURING FIELD FLOW CHART



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) → 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 modifier
36% to <60%	Add "very" with modifier
60% to 90%	Add "extremely" with modifier
>90%	No modifier; 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