Land Management District 8

2013 Vegetation Inventory

Units 1, 2, 3, and 4 Arizona Portion

Oljato, Kayenta, Chilchinbeto, and Dennehotso Communities

Prepared for:

Bureau of Indian Affairs
Western Navajo Agency
Branch of Natural Resources

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ACRONYMS

2,4-D	2,4- dichlorophenoxyacetic acid
ADW	air-dry weight
AUM	animal unit months
BIA	Bureau of Indian Affairs
CRA	Common Resource Area
District	Land Management District
Ecosphere	Ecosphere Environmental Services
ESD	ecological site description
ft^2	square foot
GIS	geographic information systems
GPS	Global Positioning System
HCPC	historic climax plant community
lbs	pounds
MLRA	Major Land Resource Area
NDMC	National Drought Mitigation Center
NNDOA	Navajo Nation Department of Agriculture
NRCS	Natural Resources Conservation Service
p.z.	precipitation zone
PNC	potential natural community
SCS	Soil Conservation Service
SOW	Statement of Work
SUYL	sheep unit year long
USDA	United States Department of Agriculture
USDOI	United States Department of Interior
UTM	Universal Transverse Mercator

ABSTRACT

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The Bureau of Indian Affairs contracted Ecosphere Environmental Services to collect and compile rangeland vegetation data on portions of Land Management District 8 of the Western Navajo Agency. Data were collected from 729 transects in five grazing analysis units. Data collection occurred during September and October of 2013. Measurements were taken for biomass production, ground cover, and species composition. 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 provide an initial carrying capacity of the range resource.

Data were analyzed by the United States Department of Agriculture National Resources Conservation Service-named soil components within each grazing analysis unit. Carrying capacities and recommended stocking rates were calculated by grazing analysis unit using available forage. The data for each analysis unit were aggregated by soil component and applied to the acreage of each soil component within each grazing analysis unit. Stocking rates for each analysis unit were adjusted to account for steep slopes and distance to water.

Results indicate that the range resource in Land Management District 8 is in poor to fair condition. Russian thistle (*Salsola tragus*) is widespread in nearly every analysis unit and the overall percentage of bare ground is high. Portions of Black Mesa and adjacent grasslands are among the best-producing sites in the project area.

INTRODUCTION

1. INTRODUCTION

The Bureau of Indian Affairs (BIA) contracted Ecosphere Environmental Services (Ecosphere) to conduct understory rangeland vegetation inventories on the Arizona portion of Land Management District (District) 8 of the Western Navajo Agency. Species-specific vegetation data measurements included biomass production and cover. These data also were used to calculate annual production, species frequency, and carrying capacity. Information derived from these calculations can be used to guide management decisions, including stocking rates. This report provides 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 are critical to establishing quality range management practices. The purpose of this inventory is to provide baseline information about the existing range resource to enable land 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 8, as well as development of more comprehensive range management plans.

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 branch of Natural Resources in accordance with the Navajo Grazing Regulations (25 CFR §167). This BIA branch also maintains master livestock grazing records and issues grazing permits. All three programs (BIA, NNDOA, and Grazing Committees) coordinate their activities in an effort to utilize and manage the range resources.

1.2.1 BIA Agency Natural Resources

The BIA is responsible for complying with all federal and tribal statutes, orders, and regulations. According to the BIA, their obligation is “to protect and preserve the trust resources on the land, including the land itself, on behalf of the Indian landowners. Protection and preservation includes conservation, best management practices, and protection against misuse of the property. BIA uses the best scientific information available and reasonable and prudent conservation practices to manage trust and restricted Indian lands. Conservation practices must reflect tribal land management goals and objectives.” A summary of the BIA Range Policy as stated in the Range Management Handbook (United States Department of Interior [USDOI] BIA 2012) is outlined as follows:

- 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, 25 CFR 167 - Navajo Grazing Regulations, and 25 CFR 166 - Grazing Permits.
- Seek tribal participation in BIA agricultural 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.
- Investigate accidental, willful, and/or incidental trespass on Indian agricultural land.
- Provide leadership, training, and technical assistance to Indian landowners and permittees/lessees.
- Keep records that document the organization, functions, conduct of business, decisions, procedures, operations, and other activities undertaken in the performance of federal trust functions.
- Restrict the number of livestock grazed on Indian range units to the estimated grazing capacity of such ranges, and develop such other rules and regulations as may be necessary to protect the range from deterioration, prevent soil erosion, assure full utilization of the range, and like purposes.
- Ensure farming and grazing operations be conducted in accordance with recognized principles of sustained yield management, integrated resource management planning, and sound conservation practices.

1.2.2 District Grazing Committees

Districts, formally called Land Management Districts, were established in 1936 by the Soil Conservation Service (which became the Natural Resources Conservation Service [NRCS] in 1994) and adopted by the BIA.

Within each district are several grazing units, often coinciding with chapter boundaries. Chapter communities are locally organized entities similar to counties and are the smallest political unit;

there are 110 chapters on the Navajo Nation. District Grazing Committees consist of elected representatives from each grazing unit/chapter who are responsible for monitoring livestock grazing within their respective grazing units/chapters. District Grazing Committees approve the carrying capacities of their districts, as discussed in the Code of Federal Regulations, Part 167 – Navajo Grazing Regulations (USDOI 2012).

The periodic sampling of rangelands allows District Grazing Committees to evaluate the carrying capacity and resulting stocking rates of rangelands (Goodman 1982). 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 District Grazing 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 permits. In addition, the NNDOA and the District Grazing Committee are responsible for enforcement of range management and resolving grazing disputes.

1.2.3 Grazing Management Overview

Timing of grazing, movement and dispersal of livestock, and livestock numbers are factors that must be considered when optimizing livestock production. Prior to considering these factors, managers need 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 and Stuth 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 restrictions to forage availability such as fencing, long distances to water, or steep slopes. Once identified, total forage production can be adjusted for these inaccessible areas. An example of a management strategy that would result from this type of analysis would be to develop additional water sources in areas rarely visited by livestock because of the long distance to water. Section 6.5 explains how fencing can be used to more accurately manage forage production.

After likely foraging patterns have been ascertained, production and forage value data can be used to help determine the number of animals that could sustainably graze in a given pasture. Stocking rates are a trade-off between short-term and long-term benefits. Low stocking rates benefit individual animals, as more resources are available due to lowered competition with other animals. Conversely, high stocking rates can inhibit individual animals, but the increase in total livestock production allows for greater, short-term gains for the producer. The final stocking-rate decision must consider 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.

Stocking rates are correlated with the prevention of overgrazing. When livestock, wildlife, and feral horses graze and browse on a site, each selects its 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, invaders and noxious weeds replace the less valuable forage species.

Plant vigor and root development can be adversely affected when grazing occurs during initial plant growth or seed development. This will remain a problem for rangeland managers as long as livestock grazing permits are issued for year-round grazing. However, Holecheck et al. (1999) argue that stocking rates have a much greater impact on range condition than the season of use.

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 and carrying capacity to grazing areas should be used with care and in context to dynamic seasonal, topographic, and behavioral factors.

RESOURCE DESCRIPTIONS

2. Resource Descriptions

Knowledge of resource issues affecting rangeland health and productivity is essential to any management plan. Stocking rates, season of use, annual precipitation, soils, 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 District 8, Units 1, 2, 3, and 4; the Arizona areas of the Kayenta, Chilchinbeto, Dennehotso, and Oljato communities (excluding Monument Valley Tribal Park). The BIA divided the project area into 5 analysis units for data analysis. This information can be used to document future changes on the rangelands and assist with management decisions. The data can be applied to smaller compartments for grazing management.

2.1 Geographic Setting

The District 8 project area is located within the Colorado Plateau Major Land Resource Area (MLRA). The project area extends from the sand sheets near Monument Valley at 4,600 feet, up to piñon-juniper woodlands on Black Mesa at 8,000 feet. Mesas with deeply incised canyons characterize the western portion of the project area, including most of the Oljato and Kayenta communities. The Arizona portions of Monument Valley and vicinity are well known for the remnant Wingate sandstone buttes and mesas that have achieved international recognition. Rangelands in this area consist of sand sheets and stabilized dunes. Lands surveyed on the east side of the project area are similar, but also include expansive blackbrush communities; the Dennehotso community is located there. The Chilchinbeto community in the south has similar vegetation but includes a portion of Black Mesa that supports pockets of ponderosa pine (*Pinus ponderosa*) at the highest elevations. A map of the project area is provided in Figure 2-1.

The project area is located within Apache and Navajo counties, Arizona. The western boundary of the project area is adjacent to Navajo National Monument. This boundary runs north to the Utah border, then east to Chinle Wash; the project area does not include Utah lands. Chinle Wash forms the eastern boundary, which then runs south near the town of Rock Point where it bends southwest passing Chilchinbeto and north to Black Mesa. The southern boundary trends west until it meets lands leased by Peabody Energy on Black Mesa. From the Kayenta Mine, the project boundary turns north to meet at Navajo National Monument.

The project area has five grazing analysis units covering 827,211 acres. Acreages for each analysis unit were extracted from shapefiles provided by the BIA Western Navajo Agency. Acreage for each analysis unit is provided in Section 5.

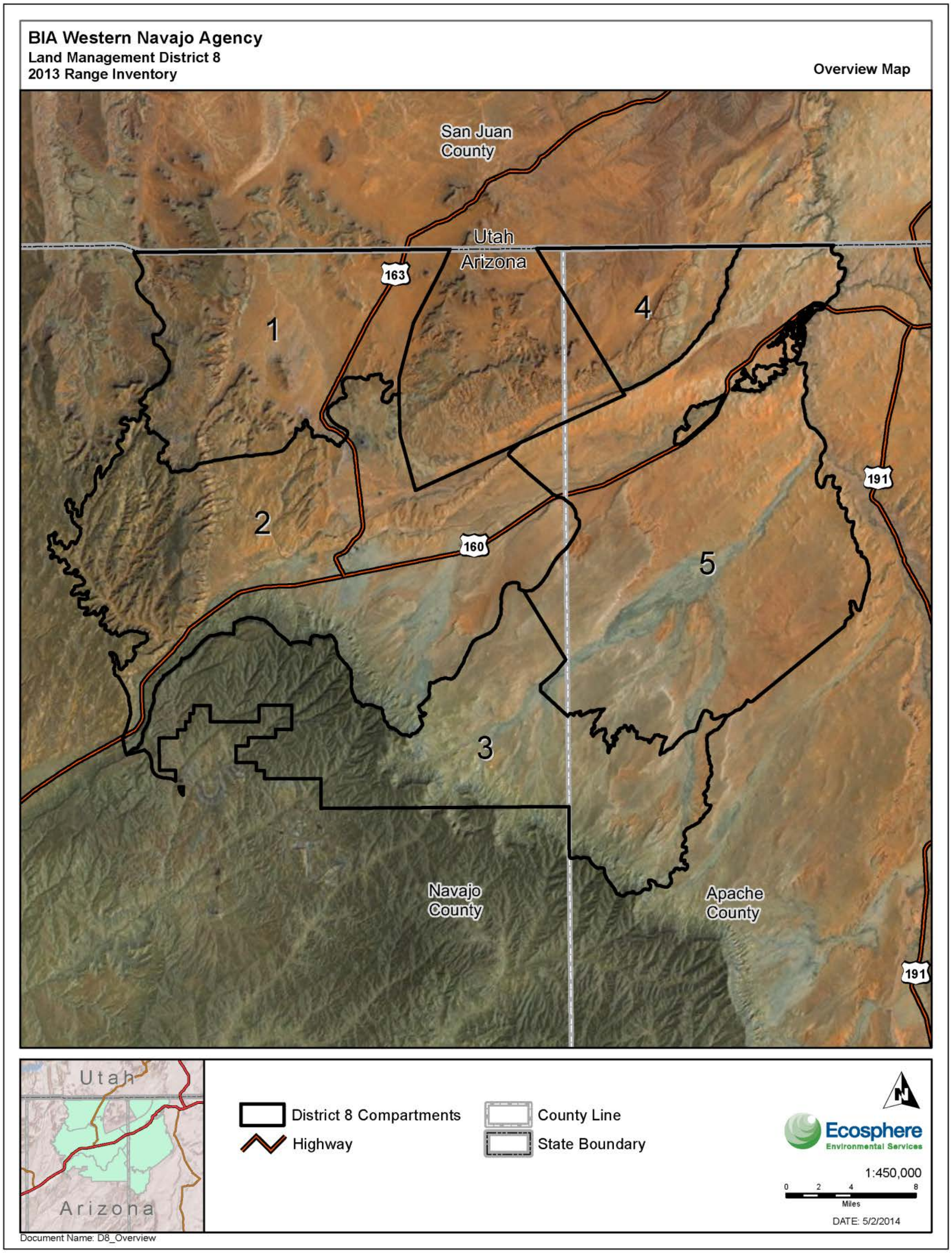


Figure 2-1. Overview of the Project Area

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 measured plant community for 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. The Navajo Nation Division of Water Resources manages the corresponding data. Fifteen precipitation gauges with complete data sets located throughout the Western Navajo Agency were averaged to provide a measurement for the 2013 water year up until the time of data collection.

2.3 Soils

Knowledge of the soil properties in a particular area can help predict 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 enables rangeland managers to provide estimates of forage production in a given pasture.

“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” (USDOI BIA 2012).

The vegetation inventory project area is located within the boundary of a soil survey produced by the United States Department of Agriculture (USDA), Natural Resources Conservation Service. The entire inventory area lies within survey AZ711, Soil Survey of Navajo Mountain Area, Arizona, Parts of Apache, Coconino, and Navajo Counties (Ham 2008).

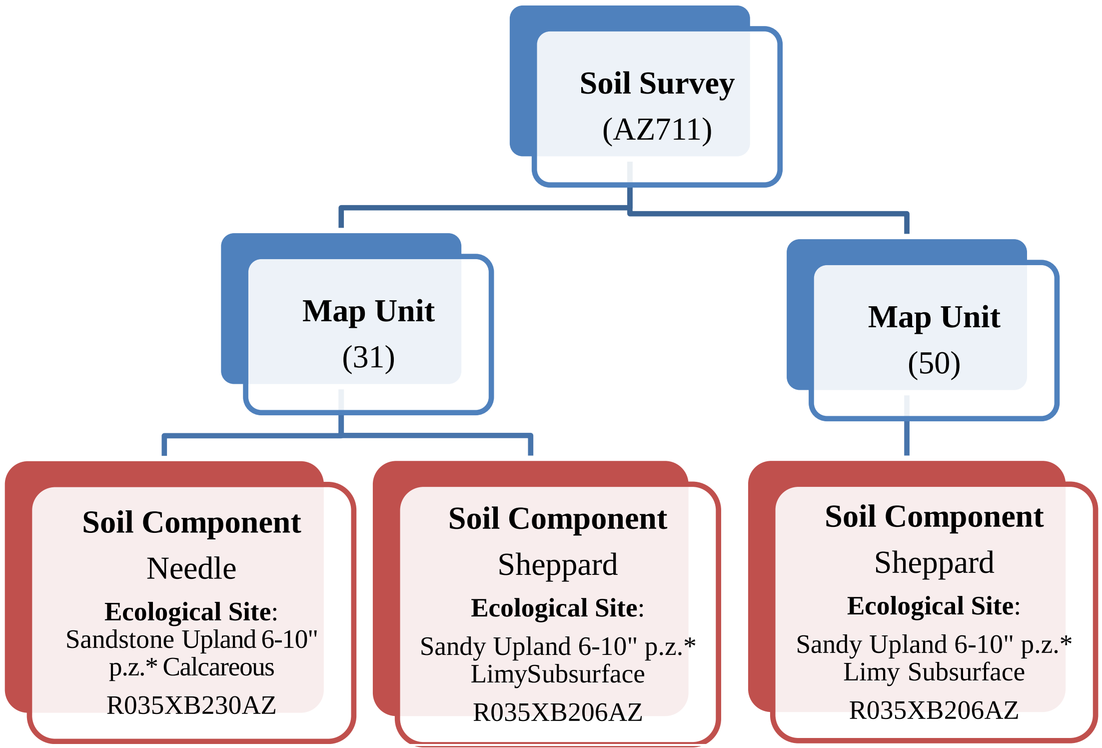
Soil surveys are used to create soil map units. A soil map unit is delineated by soils, landscape position (floodplain, terrace, alluvial fan, etc.), and slope. The major soil or soils found in a soil map unit are referred to as a soil component. Each soil map unit is named for the major soil component contained in the unit or for a soil complex consisting of two to three major components. Components found in one soil map unit can occur in other soil map units, but the slopes and landscape position may be different.

The written soil survey contains descriptions of each soil map unit starting with a general description including elevation, frost-free period, mean annual precipitation, and mean annual air temperature. This is followed by a breakdown of the proportion of each soil component found within a unit. Soil component specifics are listed and include the landscape setting, soil properties and qualities, typical soil profile, and interpretive groups. Interpretive groups pertain to land capability, such as soil hydrology, whether it is irrigated and ecological sites.

Ecological sites are directly associated with soil components; they are differentiated from each other based on soils, hydrology, and the composition and production associated with the characteristic plant community. Analysis of rangeland production typically is based upon ecological sites; in District 8, however, ecological sites have been described only for a small percentage of the soil components. Therefore, the analysis for this project is one step removed from ecological sites – data were analyzed by soil components. When ecological sites have been described and published for all of the soils, the data analyzed by components can be correlated with the ecological sites.

This soil survey is Order III mapped, meaning it includes soil components and plant communities at association or complex levels (called map units). Within each soil map unit, finer levels (called soil components) are described, but not mapped. Each soil map unit contains one, two, or three soil components within it. Each soil component is correlated with a specific ecological site. However, ecological sites cannot be mapped directly from Order III soil map information because they are not correlated with the soil map units; ecological sites are correlated with the finer levels of unmapped soil components. Mapping at this Order III scale will include only the dominant component, not the exact components or ecological sites in the soil map unit. Figure 2-2 illustrates the hierarchy of *unmapped* soil components 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. The soil survey and map units (indicated in blue) are mapped. The soil components and correlated ecological sites (indicated in red) are unmapped.

It is worth noting that biological soil crusts, which can provide a vital component for healthy, functioning soils, occur occasionally throughout the project 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).



*p.z. = precipitation zone

Figure 2-2. Soil Survey Hierarchy

2.3.1 Soil Components

Table 2-1 lists the soil components found in District 8. Descriptions of each component, including percentage of each soil map unit (MUSYM) can be found in the Appendix.

Table 2-1. Soil Components

Soil Component	MUSYM	Acres (Excluding Non-Rangeland)
Aneth	1	1,924
Aneth Family	14	22,156
Arabrab	2	27,797
Arches	3	5,094
Berryhill Family	7	173
Bispen*	20	873
Councelor	8	17,921
Denazar	9	74,321
Eslendo Family*	11	759
Gish	13	2,864
Gotho	14,61	62,041
Hawaikuh	8	4,480
Lindrith	2	6,949
Lithic Haplogypsids	16	4,557
Lithic Torriorthents	9,45	34,535
Lybrook	17	1,367
Marcou	1,18,19	12,950
Massadona	51	25,635
Mathis	42	6,832
Mespun	20,22	14,143
Mido	28	1,292
Moclom	8	15,681
Moenkopie Family	60	1,820
Monue	30,51	25,731
Nakai	62	10
Nalcase	22,42,48	16,942
Needle	45,52,57,58,60	36,470
Parkwash	37	7,190
Pensom*	3,11	1,403
Pinepoint	37	10,065
Pits*	66	4

Soil Component	MUSYM	Acres (Excluding Non-Rangeland)
Radnik	28	273
Reef	13,39	2,910
Riverwash*	28,40	263
Rizno*	41	284
Rock Outcrop	22,37,42,45,52,56,57,67	110,234
Sanfeco	47	9
Santrick	48	2,011
Sheppard	9,18,19,40,47,49,51,52,53,54,57,58	144,847
Simel	11	456
Tewa	61	4
Torriorthents	56	2,949
Tsaya Family*	57	1,213
Tsosie*	17	456
Typic Calcigypsids	1	1,924
Typic Haplargids	54	5,050
Typic Haplogypsids	16	2,278
Typic Natrargids	19	4,037
Typic Torriorthents	60	2,547
Urban Land*	61,62	97
Ustic Torriorthents	66,67	57,661
Vessilla	2	27,797
Wayneco	41	221
Zukan*	39	18
Total		**808,972**

* Component does not contain transects.

ECOLOGICAL SITES

3. Ecological Sites

As described in Section 2.3, few ecological sites have been described in District 8. However, Ecological site descriptions (ESDs) are continually being created and updated by NRCS field crews. Managers can use the following website to check for ESD updates and additions:

http://esis.sc.egov.usda.gov/Welcome/pgReportLocation.aspx?type=ESD.

The existing ESDs can be used as an additional management tool for specific locations. The following paragraphs provide more information regarding what is contained within an ESD.

Ecological sites are differentiated from each other based on significant variances 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 distinctions in topography, climate, and environmental factors or the response of vegetation to management. Each ESD describes the historic climax plant community (HCPC) that was present during European settlement of North America. Some ESDs go on to describe the plant communities that will likely result following various disturbance factors such as overgrazing or wildfire. These plant communities are called state and transistion models. Many rangelands have undergone significant transitions to the point that 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, differentiating them from an HCPC on the same site. Other information includes annual production of forbs, grasses, shrubs, and trees; plant growth curves; associated sites; recreational uses; and details pertaining to livestock grazing. Some ESDs are more complete than others.

A valuable application of an ESD is the employment of similarity indices. Calculating a similarity index involves comparing the plant community that currently exists on the ground to the HCPC or, when available, the PNC. The similarity index is expressed as a percentage. For example, if a current plant community contains the exact same species and proportions of species as the HCPC, the similarity index would be 100 percent, while a lower percentage would indicate that the current vegetation community is dissimilar in species weight and composition from the HCPC.

ESDs list two production values for each species found in an HCPC or PNC: one representing annual production if precipitation is high, and one if precipitation is low. If managers are using a reconstruction factor on field-collected data, the two values should be averaged because the reconstruction process adjusts plant weights to represent growth in an average year. The listed production value for each species is termed "allowable production." Production from every plant species encountered in the field is compared to the allowable production for the same species in the ESD and scored accordingly. For example, assume that a sampled area has 79 pounds per acre of alkali sacaton (*Sporobolus airoides*) and that the corresponding ESD lists 50 pounds per acre as the average allowable production for this same species. In this case, no more than 50 pounds are allowed to be counted toward the similarity index. If the ESD had listed alkali sacaton at 200 pounds per acre, then all 79 pounds (and no more) would be counted. If an individual species is not listed in the ESD, then no production is assigned or “allowed” for that species. At the end of this process, all allowable production is added up and divided by the total production for the HCPC or PNC found in the ESD. The resulting value is the similarity index.

Index values are meant to be used as a management tool and do not factor into stocking rate or carrying capacity. For example, a given ecological site may be producing over 2,000 pounds of galleta grass (*Pleuraphis jamesii*) and alkali sacaton. These two grasses are considered “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 carrying capacity would be relatively high. However, these grasses may comprise only a small percentage of the plant community in the ESD which would result in a low similarity index. In this case, it becomes a management decision whether it is more beneficial to manage for the current, high-producing plant community or whether to try establishing a plant assemblage more similar to the reference community. The benefit of managing toward t the reference community is that it’s comprised of the suite of species best adapted to the area which, in turn, leads to improved biological functioning such as water retention, soil building, and plant growth. The type of livestock grazed also should be taken into consideration. For example, if a given reference community is composed of primarily grass species but the producer is raising sheep, it would make more sense to manage for a plant community that contains a mix of grasses, forbs, and shrubs.

Rangeland managers should be aware that maps of ecological sites are available on the 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 component/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 is a basket of fruit containing 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 usually too coarse to use with rangeland management of pastures. In most cases of rangeland fieldwork, it is possible to provide field staff with descriptions of the dominant ecological site, as well as descriptions for non-dominant soil components and ecological sites. A decision regarding which ESD best fits a given transect can then be made based upon field examination of soils and the plant community.

METHODOLOGIES

4. METHODOLOGY

Methods used to collect these 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 to Ecosphere, described the study design and cited specific methodologies for data collection (Coulloudon et al. 1999, Habich 2001, and USDA NRCS 2003). The field methodology was based on the SOW and technical references, with modifications approved by the BIA.

4.1 Field Methodology

Data collection in the field occurred between September 7 and October 18, 2013. 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. A GPS unit was used in combination with topographic maps to navigate to the transect locations by vehicle and on foot. Transects were established within 1 to 10 meters of the GPS coordinates.

Transects consisted of a 200-foot line measured with an open reel tape placed flat and straight along the ground and stretched as taut 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 recorded from ten plots at 20-foot intervals along the open reel tape. The plots were measured with a square 9.6-square-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 from the left side of the tape. Aspect, slope, surface soil texture, and notes also were recorded. All plant species names were consistent with the NRCS Plants Database (USDA NRCS 2013).

4.1.1 Production Data Collection

Production is determined by measuring the weight of annual aboveground growth of vegetation because it has a direct relationship to feed units for grazing animals. 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. The 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 using the USDA double sampling methodology with a combination of estimating and harvesting. For this survey, Ecosphere followed the USDA's double sampling methodology, NRCS's modified standards outlined in the SOW, and modifications generated from the pre-work conference. The double sampling method is detailed in the following sections.

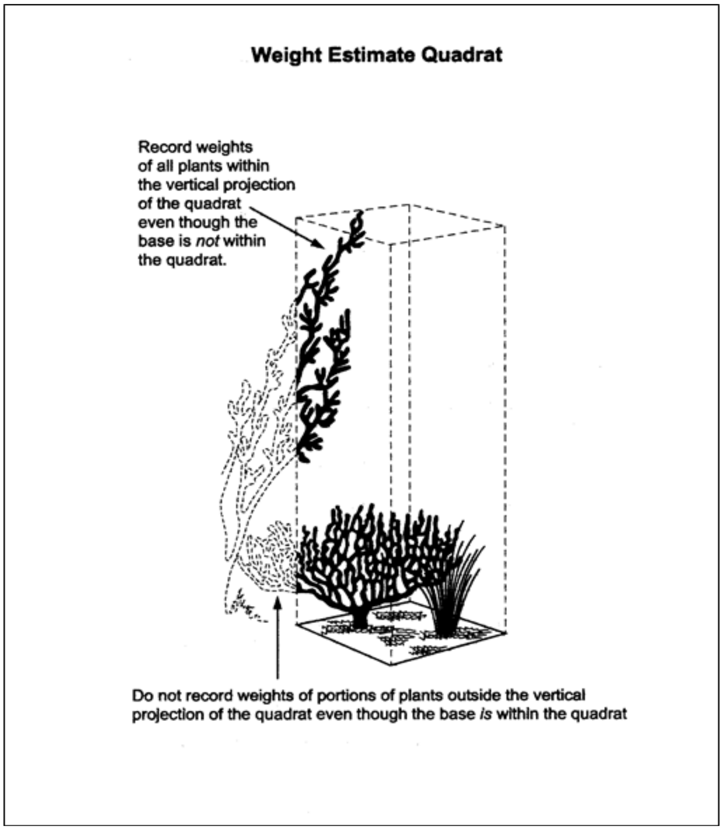
4.1.1.1 Establishing a Weight Unit

A weight unit is a part of a plant, an entire plant, or a group of plants of the same species used to assess production. 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, ungrazed Indian ricegrass (*Achnatherum hymenoides*) may be visually estimated to equal 10 grams. This clump of grass is then harvested and weighed with a hand scale to determine actual weight. This process is repeated until 10 grams of Indian ricegrass can be visually estimated with accuracy. After weight units are established, field teams can accurately estimate production. The field team maintained proficiency by regularly harvesting and weighing to check estimates of production.

4.1.1.2 Double Sampling Methodology (Estimating and Harvesting)

Production (measured in grams) was estimated by counting the weight units of each species in each plot. For example, four and a half weight units of Indian ricegrass would be 50 grams of production. All plants and parts of plants inside a quadrant outlined by the 9.6-ft^2 frame up to a height of 4 feet were estimated by the field team (Figure 4-1). Plants outside the quadrant were excluded from the weight estimate. Two fixed plots on each transect were harvested. On the harvested plots, all species were estimated *in situ* and then harvested at ground level (¼-inch stubble height).

Harvested biomass was weighed with a hand scale, and both estimated and harvested (green) weights were recorded. All harvested materials were collected and stored in paper bags labeled with tracking information including transect, date, species, and plot number. All of the harvested material was allowed to air dry for at least 10 days 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 data processing.



Source: Coulloudon et al. 1999

Figure 4-1. Weight Estimate Box

In many cases, vegetation in the transect was diverse and widespread so two plots could not effectively represent all species. Furthermore, Ecosphere has determined, through several years of data collection and analysis, that intermittently occurring species are under-represented in the harvested material. In an effort to include more species in the harvested material, a weight unit of any species that contributed 10 grams or more of estimated production on the transect, but did not occur in the two harvested plots, was estimated and harvested individually outside of the transect. This was called a calibration sample.

4.1.1.3 Large Shrub Plots

Extended plots were established when "large" shrubs were encountered in the area of a transect. Neither the SOW nor the National Range and Pasture Handbook (USDA NRCS 2003) adequately define the large shrub plot methodology. However, Ecosphere understands that the purpose of the large shrub plots is to capture the production of shrubs that are too wide to be adequately measured within the 9.6-ft^2 frame.

Large shrub plots were established if shrubs that were larger than the plot frame were present in the shrub belt area defined as the length of the transect (200 feet) and the width of a large shrub plot (20.8 feet) on the right side of the transect tape. Examples of areas with large shrub plots include shrublands with big sagebrush (*Artemisia tridentata*), black greasewood (*Sarcobatus vermiculatus*) flats, or on rolling hills with antelope bitterbrush (*Purshia tridentata*) and mountain mahogany (*Cercocarpus montanus*).

For transects with large shrubs, two 0.1-acre extended plots were established at fixed points along the transect (60 feet and 140 feet along the 200-foot tape). These extended plots formed the large shrub plots where only large shrub species were estimated. After a weight unit was established for each species of large shrub (see Section 4.1.1.1), the number of weight units occurring within the plot was counted. Annual production was estimated by multiplying the number of weight units by the value of the weight unit. Large shrubs were not measured inside the ten 9.6-ft^2 plots on the transect to avoid double counting them.

4.1.1.4 Ocular Estimates of Utilization

Utilization 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 that has been consumed prior to the vegetation inventory. With the Ocular Estimation Method (Coulloudon et al. 1999), utilization is determined by visually inspecting forage species. This method is reasonably accurate, commonly applied, and suited for use with grasses and forbs. Field team personnel were thoroughly trained and practiced in making ocular estimates of plant utilization. An attempt was made to locate ungrazed plants near the transect. These ungrazed plants were assumed to approximate the species condition before grazing occurred. Ungrazed 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 ungrazed plant remaining was recorded for each species on each transect.

4.1.1.5 Sensitive Plants Protocol

Threatened, endangered, culturally important, or otherwise sensitive plants were estimated rather than harvested for the purposes of this inventory. Weights for cacti and yucca species were estimated using standard protocols as described in the Bureau of Land Management (BLM) Technical Reference 1734-7 (Habich 2001). The recommended values are as follows: 10 percent of total weight for prickly pear (*Opuntia* spp.), five percent for barrel-type cacti (*Ferocactus* spp., *Sclerocactus* spp., and *Echinocereus* spp.), 15 percent for cholla cacti (*Cylindropuntia* spp. and *Grusonia* spp.), and 15 percent for yuccas (*Yucca* spp.).

4.1.2 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.

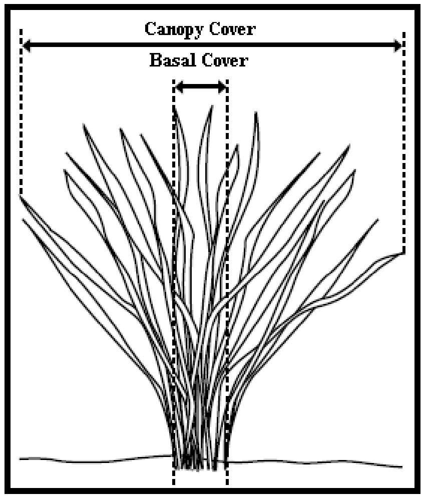
On rangeland, regeneration of desirable plants maintains good range conditions. Grazing by too many animals (livestock and wildlife), or heavy utilization by a few animals results in overuse, loss of vigor, and disappearance of the preferred and desirable plants. Deterioration of range vegetation begins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

4.1.3 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 also is important from a hydrologic perspective when examining basal vegetation and canopy (foliar) cover of perennial and annual species and litter cover. This study measured understory vegetation; no trees were included in the cover data measurements.

Ground cover data can assist in determining the soil stability, proper hydrologic function, and biotic integrity of a site. 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, which can make it difficult to compare results from different portions of a large area where sampling takes weeks or months. For this reason, future ground cover monitoring for each ecological site within each grazing unit should replicate the sampling period from this baseline inventory.

Measuring cover by points is considered one of the least biased and most objective cover measures (Bonham1989). Results of the ground cover data analysis are included in Section 5.



Source: Elzinga et al. 1998

Figure 4-2. Vegetative Cover

4.1.4 Soil Surface Texture Test

At each transect, the soil was sampled to determine or confirm the soil component of the site. The surface was cleared of debris to bare mineral soil. A small soil pit was dug to a determining layer of the soil profile and a soil sample from this layer was analyzed using the USDA Soil Texturing Field Flow Chart. The Flow Chart uses a systematic 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. The field crew assigned a texture class to the sample based on its tested content and ribbon characteristics. The results of the soil sample determined or confirmed the soil component using Map Unit Descriptions from the soil survey as the primary reference, supported by soil profiles described in ESDs.

4.2 Post-Field Data Processing Methodology

After all field data were collected, the data were downloaded into a database. Harvested biomass was air dried for 10 days and dry weights were entered into the database for each species on each transect. This initial field dataset was adjusted to compare the collected production data to the amount of vegetation that would occur in a “normal” year. These adjustments included factors for utilization, climate, growth curve, and ADW.

After the production estimates were “normalized” for every species on every transect, results were grouped by soil component within each analysis unit. Further analysis for each analysis unit included similarity indices, available forage based on forage value and harvest efficiency factors, stocking rates, and carrying capacity.

4.2.1 Reconstructed Annual Production

Pounds per acre were estimated from field data through a series of calculations derived from technical reference 1734-7 Ecological Site Inventory (Habich 2001) and the National Range and Pasture Handbook (USDA NRCS 2003). This methodology reconstructs the measured weight of biomass to a “normal” annual air-dry production weight that accounts for physical, physiological, and climatological factors. First, the field-estimated green weight of a species was multiplied by an estimation correction factor and then by a reconstruction factor. The reconstruction factor is the percent ADW of the species divided by the product of the utilization, normal precipitation for the current water year, and growth curve for that time of year, as shown in the formula below:

$$\textit{Corrected Green Weight} = \frac{(\%\ \textit{ADW})}{(\%\ \textit{Utilization})\ (\%\ \textit{Normal Precipitation})\ (\%\ \textit{Growth Curve})}$$

The result of multiplying the green weight of a species by the reconstruction factor is the “total reconstructed annual production.” Details of each of the elements in this equation are described in the following sections.

4.2.1.1 Corrected Green Weight (Estimation Correction Factor)

The harvested plots provide the data for correction factors of estimated species weights from the field. Measured (harvested) weights of species were divided by the estimated weights of the same species in the same plot to establish a correction factor. This correction factor was then applied to all estimations of that species for the entire transect. For example, if alkali sacaton (*Sporobolus airoides*) was estimated to weigh 10 grams but the harvested weight was measured as 9 grams, then all estimates of alkali sacaton for that transect were multiplied by a correction factor of 0.90 as presented below:

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

If the total estimated weight for alkali sacaton on all plots in this transect was 80 grams, the resulting corrected estimated green weight (grams) x correction factor = 80 grams x 0.90 = 72 grams. The corrected green weight is 72 grams.

4.2.1.2 Biomass ADW Conversion

The ADW percentage is part of the reconstruction factor and accounts for the amount of water contained in the plant. The purpose is to remove the weight of water from the weight of the actual plant forage. All biomass collected from harvested plots was placed in paper bags; tracking information (date, transect identification, plot number, and species) was recorded on the bags. Harvested, or green, weights were immediately obtained 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 10 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 percent ADW in grams to be used in the reconstruction factor. In the example in Section 4.2.1.1, the green weight of the harvested biomass was 9 grams. If the dry weight in the lab was measured at 8 grams, then the percent ADW would be 0.89.

$$\%\ ADW = \frac{\textit{Dry Weight (lab)}}{\textit{Green Weight (field)}} = \frac{\textit{8 grams}}{\textit{9 grams}} = 0.89$$

This value (0.89) represents the numerator of the reconstruction factor. The three values in the denominator are explained in the following sections. (Note: for species in a transect that were not harvested, an average percent ADW was used that was generated from the same species in the same analysis unit. In the case of remaining species, the percent ADW defaulted to 1.)

Cacti and yucca species were never clipped during fieldwork, but published %ADW values were used in the calculations (Habich 2001). Additionally, prickly Russian thistle (*Salsola tragus*) can be difficult to clip once it matures and begins to dry. A value of 80 percent was applied to individuals not clipped during the survey.

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 ungrazed. Grazed or utilized species were measured according to the average amount of plants that remained ungrazed near the transect. For example, if alkali sacaton was recorded at a utilization factor of 90 percent ungrazed, then the amount of alkali sacaton estimated would represent only 90 percent of the total.

$$Utilization = 0.90$$

The total weight of the species in the transect is divided by 0.90 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 weight measurement taken in June normally would be less than a measurement taken of the same plant 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 alkali sacaton was measured in a transect during August, that measurement may represent only 88 percent of the full growth of that species.

Growth curves typically are presented in an ESD; however, as ESD availability for the project area was limited, the growth curves associated with Common Resource Areas (CRAs) were used instead. A CRA is a subdivision of an MLRA and is defined by soils, climate, and landscape conditions. Three CRAs, 35.2, 35.3, and 35.6, were found within the project area. The charts below show the percent production by month for each CRA growth curve.

Percent production by month in AZ3521, 35.2, 6-10” p.z. (all sites) growth curve.

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

Percent production by month in AZ3531, 35.3, 10-14” p.z. (all sites) growth curve.

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	1	3	17	18	10	19	20	10	1	1	0

Percent production by month in AZ3561, 35.6, 13-17” p.z. (all sites) growth curve.

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	1	5	16	17	15	15	15	11	5	0	0

To illustrate, assume that a transect located in CRA 35.2 was sampled August 21. The first step in the growth curve analysis is to estimate, using growth curve AZ3521, the percentage of growth completed up to that date by adding up the preceding monthly categories as illustrated below:

Feb (1%) + Mar (9%) + Apr (20%) + May (27%) + June (14%) + July (10%) = 81%

Then, for the month of August, 21 days would need to be pro-rated 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 0.35 percent per day. The number of days that have occurred up to that date (21) is multiplied by the daily rate (0.35 percent) for 7.35 percent. This is added to the 81 percent that had occurred up to the end of July for a total of 88.35 percent of the growth curve completed. Therefore, the total weight of the species reported in that transect is divided by 0.88 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 in a sample area is directly affected by the relationship between growing conditions, especially precipitation amount, timing of precipitation, and temperature. Production varies each year depending on the favorability of these growing conditions. Biomass production measurements from year to year are not accurate without adjusting production to a "normal" year. The factors of precipitation, timing, and temperature are extremely difficult factors to quantify and apply to biomass production because the impacts vary by species. For this inventory, the variation in precipitation was used as the value for normal production percentage. Precipitation data gathered from 15 rain gauges located throughout the Western Navajo Agency were used to determine the percent of normal production for the 2013 water year up to the time of data collection. The 13 years prior to 2013 were averaged and used as an historic comparison. The 2013 water year was about 120 percent of the average.

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

Percent Normal Production = 1.02

The total weight of the species in the transect is divided by 1.02 to bring the measured wet year down to 100 percent. Normalizing the precipitation to an average year helps prevent over-allocating forage.

4.2.1.6 Reconstruction Equation

Using the example carried through the previous sections, Ecosphere began with an estimated green weight (in the field) of 80 grams of alkali sacaton, multiplied by the estimation correction factor for a corrected green weight of 72 grams. This corrected green weight of 72 grams was then multiplied by the reconstruction equation:

$$\textit{Reconstruction Equation} = \frac{0.89}{(0.90 \times 1.02 \times 0.8835)} = 1.10$$

The formula for the reconstruction equation, as explained in Section 4.2.1, is repeated here:

$$\textit{Corrected Green Weight} = \frac{(\%\ ADW)}{(\%\ Utilization)\ (\%\ Normal\ Precipitation)\ (\%\ Growth\ Curve)}$$

When actual values from the alkali sacaton example are inserted into the formula, the equation becomes:

$$72\ grams \times \frac{0.89}{0.90 \times 1.02 \times 0.8835} = 72\ grams \times 1.10 = 79.20\ grams$$

The corrected green weight from the example above (72 grams) multiplied by the reconstruction factor (1.10) results in a total reconstructed annual production of 79.20 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 also factored into production estimates. The plot size, 9.6 ft^2, was repeated ten times in each transect, thereby creating 96 ft^2 of sampling area. The sampling area size accounts for the conversion from grams to pounds (453.59 grams per pound) and square feet to acres (43,560 ft^2 per acre), which calculates into a 1:1 conversion (Coulloudon et al. 1999). Therefore, in this case the conversion factor equals one and is not explicitly included into the total reconstruction annual production equation. Hence, in the example, there were 79.20 pounds per acre of alkali sacaton. The value 79.20 represents the total reconstructed annual production of the species in pounds per acre.

4.2.2 Calculating Ground Cover

Ground cover calculation categories were measured in terms of top canopy, basal cover, and bare soil surface. Forty ground cover point intercepts were measured in each transect. Ground cover categories were calculated by a percentage of the total. For example, if 30 hits were recorded for bare ground, the percent of bare ground on that transect would be 75 percent:

$$\frac{30\ \text{“bare ground” hits}}{40\ \text{total hits}} = 75\%\ \text{bare ground}$$

Ground cover calculation categories included canopy vegetation, basal vegetation, litter, rocks or gravel, biological soil crust, and bare ground. 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 bare ground. This is because true bare soil has less soil stability than duff, litter, rock, or bedrock. Cover data were averaged by analysis unit.

4.2.3 Frequency Calculations

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 alkali sacaton occurred in six of the ten plots on a given transect, the frequency would be 60 percent. Frequency of species by plot on each transect is included in the database of production data with this report in digital format. Frequency of the most common species (including large shrubs) to occur on transects within each analysis unit is presented in Section 5.

4.2.4 Similarity Index Calculations

A discussion of similarity index values can be found in Section 3. No similarity indices were calculated for transects in the project area because ESDs for most of the project area were not described and published at the time of our field data collection and analysis.

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, the Utah NRCS developed a list of species from the Colorado Plateau area. This list was the primary source used to assign forage values to species encountered in the survey. Forage values for plants not included in the NRCS records were obtained from other professional sources. A master comprehensive list of all plant species, their forage values, and additional resources for plant information, is included with the digital Excel data submitted with this report. Species are grouped into five categories; each category is weighted by preference by grazing animals. The five groups recognized by the National Range and Pasture Handbook (USDA NRCS 2003), plus a sixth category representing species injurious to livestock, 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 generally are 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 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.

Undesirable (or emergency) plants—These plants are relatively unpalatable to grazing animals, or they are available only for a very short period. They generally occur in insignificant amounts, but may become abundant if more highly preferred species are removed.

Non-consumed 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 (denoted in tables and in the database with a superscript t)—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.

Injurious plants (denoted in tables and in the database with a superscript i)—These plants are physically harmful to grazing animals. Specifically, these plants usually have spines or thorns that irritate the mouths or lower legs of domestic livestock. They may be utilized during seasons when they don't present serious harm so these plants also have a palatability rating.

Many species have more than one forage value according to the season of use. For example, muttongrass (*Poa fendleriana*) is considered preferred by sheep in the spring, but only desirable during the remainder of the year. Grazing in District 8 is permitted throughout the year so a single forage value is needed. The lowest seasonal forage value was chosen for each plant species as a conservative estimate of the forage available and to avoid overgrazing during times of the year when forage palatability is lowest. Ecosphere used forage values during the least palatable season (usually fall or winter) to calculate available forage for sheep.

Each forage group is assigned a harvest efficiency factor. The harvest efficiency factor accounts for production that is actually consumed by grazers. 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. The harvest efficiency factor is applied to the amount of production within a management area; its purpose is to ensure watershed protection and sustainability of the range resource by limiting allocation of the available forage.

The harvest efficiency factor generally averages 25 percent on rangelands with continuous grazing (USDA NRCS 2003). Using NRCS guidelines, the harvest efficiency factors applied for this project were 35 percent for preferred plants, 25 percent for desirable species, and 15 percent for undesirable/emergency plants. Non-consumed, toxic, and injurious species, regardless of their forage value, were excluded from the calculations.

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 this estimate of available forage.

4.2.6 Grazing Area Adjustments

The amount of actual land available for grazing was quantified using geographic information system (GIS) files from the BIA. Home sites and farmland were removed from the total acreage available for livestock grazing. Roads were buffered 1.5 to 15 meters from their center line. Washes and streams were also given a ten foot buffer.

Based on livestock behavior, carrying capacity was adjusted to account for distance to water and the steepness of slopes. Distance to water and slope percent were adjusted incrementally (Table 4-1). Slopes up to 10 percent had no reduction in carrying capacity; moderate slopes had a 30 percent reduced carrying capacity, while steep slopes had a 60 percent reduction in carrying capacity. Slopes greater than 60 percent are generally inaccessible to livestock and were excluded from the available grazing acres.

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

Distance to Water	Stocking Rate Reduction	Slope	Stocking Rate Reduction
0-1 mile	0%	0-10%	0%
1-2 miles	50%	11-30%	30%
>2 miles	100%	31-60%	60%
		>60%	100%

Livestock will rarely range more than 2 miles from a water source (Holecheck 1999). Areas farther than 2 miles from a water source can be considered ungrazeable 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 adjusting carrying capacity.

The BIA recommendations include 100-percent stocking rates and carrying capacity between 0 and 1 mile from a water source, 50 percent stocking rates 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.

4.2.7 Initial Stocking Rates and Carrying Capacity

The initial stocking rate and carrying capacities were calculated by the percentage of soil components within each analysis unit. Carrying capacity for rangeland management purposes is defined as the number of grazing animals that a specified area can support without depleting the forage resources. Carrying capacity may vary annually in response to forage production.

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 had no transects were not included in the GIS analysis. Carrying capacity numbers are derived by dividing the stocking rate by the total acreage of a given soil component within an analysis unit.

Stocking rates represent the number of acres needed to support one animal unit for 1 year. For this project, yearlong numbers are derived from a BIA-approved animal unit month (AUM) of 790 pounds per acre. The AUM is multiplied by 12 months and the result is divided by the animal unit equivalent in order to derive the amount of forage necessary to support one animal for a year. The stocking rate is determined by dividing this number by the average amount of available forage in each soil component within an analysis unit. Table 4-2 is an example calculation for sheep using an available forage amount of 100 pounds per acre.

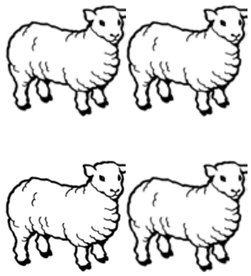
Table 4-2. Example Stocking Rate Calculation

Description	Calculation
AUM multiplied by 12 months = Amount of forage needed to support one animal unit for a year.	(790 x 12) = 9,480 lbs per acre
Amount of forage needed to support one animal unit for a year divided by sheep forage equivalent of AUM (5) = Amount of forage to support one sheep for a year.	9,480/5 = 1,896 lbs per acre
Amount of forage needed to support one sheep for a year/available forage = Number of acres necessary to provide the yearly forage amount for one sheep (stocking rate).	1,896/100 lbs per acre = 18.96 acres per year

Notes: AUM = animal unit month; lbs = pounds.

By law (25 CFR §167), the sheep forage equivalent of one animal unit in District 8 is four sheep. In other words, 790 pounds of forage can support one animal unit per month, or four sheep for a month.

4 Sheep = 1 animal unit (AU)



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Range Forage

Hay and Grains

790 lbs of feed

1 animal unit per month (AUM)

RESULTS

5. RESULTS

During this inventory, 729 transects were read on the District 8 project area and included five analysis units. 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 soil components within each analysis unit. Soil components with the same name within different soil map units were combined for analysis. Refer to Table 2-1 for a list of soil map units for each soil component. Carrying capacity was calculated by GIS analysis of the potential acres of each soil component within each analysis unit. Carrying capacity and acreage numbers have been rounded to the nearest whole number in all tables. The electronic database that accompanies this report contains numbers in decimal form.

Table 5-1 displays the carrying capacity of the range resource in District 8. The total size of the project area is 827,868 acres. Areas that were considered non-range were removed from the analysis; these included 18,897 acres of roads, home sites, and water. There were 28,830 acres that could not be analyzed due to a lack of transects within the soil components in each analysis unit.

The study results show an unadjusted carrying capacity of 3,286 sheep units in the entire District 8 project area. The carrying capacity is not evenly dispersed across a grazing analysis unit; therefore, it is important to examine the stocking rates of each soil component to determine which areas may tolerate more livestock and which areas may be exceeding the carrying capacity. The discussion in Section 6 identifies ways that carrying capacity could be improved.

Table 5-1. Carrying Capacity Results Summary

Analysis Unit	Number of Transects	Acres (Non-Range Excluded)	Initial Carrying Capacity (SUYL)	Adjusted Carrying Capacity (SUYL)
1	94	114,686	284	114
2	219	230,498	1,102	302
3	164	171,42	1,120	237
4	34	42,444	134	64
5	218	249,930	646	206
Total	**729**	**808,971**	**3,286**	**923**

Note: SUYL = sheep unit year long.

5.1 Description of Results by Analysis Unit

The results of this study have been broken down into the following categories: carrying capacity, initial stocking rates, available forage, ground cover, and species frequency. An initial description of each category is presented below, followed by a more detailed analysis of each analysis unit.

5.1.1 Initial Stocking Rates and Carrying Capacity

In general, the derived stocking rates reflect an accurate depiction of available forage. In some cases, however, only one transect was located in a soil component. 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 soil component within the analysis unit. In these situations, it may be necessary to gather additional data prior to adjusting animal numbers.

Results include the number of transects in each soil component in each grazing analysis unit. Sites without transects, and therefore no carrying capacity, can be identified and range managers can collect site-specific data in those areas in order to assess the available forage and calculate carrying capacity. The areas also are visible on the accompanying maps.

5.1.2 Available Forage Production

Available forage is the portion of the total reconstructed production classified as preferred, desirable, or undesirable (emergency) forage. This quantity is used to calculate stocking rates. Forage production is low throughout the project area. The highest average production of available forage is in analysis unit 3 (19 pounds per acre), followed by analysis unit 2 (12 pounds per acre). The remaining units all average about 7 pounds per acre. The highest producing soil components are Lindrith and Vessilla in analysis unit 3, Santrick in analysis unit 2, and Gotho in analysis unit 4.

A table in the results section for each analysis unit presents available forage values and the number of transects for each soil component, as well as the total grazeable acres, stocking rate, and carrying capacity.

5.1.3 Ground Cover

Ground cover values provide a baseline for determining the trend in future studies. An average of all ground cover data for the District 8 project area is included for comparison (Figure 5-1). The most represented ground cover category across the project area is bare ground. The highest percentage of bare ground was found in the northeast corner of the 5 analysis unit and in the flatlands in the eastern portion of the 1 analysis unit. Bare ground is of particular concern in District 8, as much of the area is composed of sandy soils that are highly susceptible to erosion.

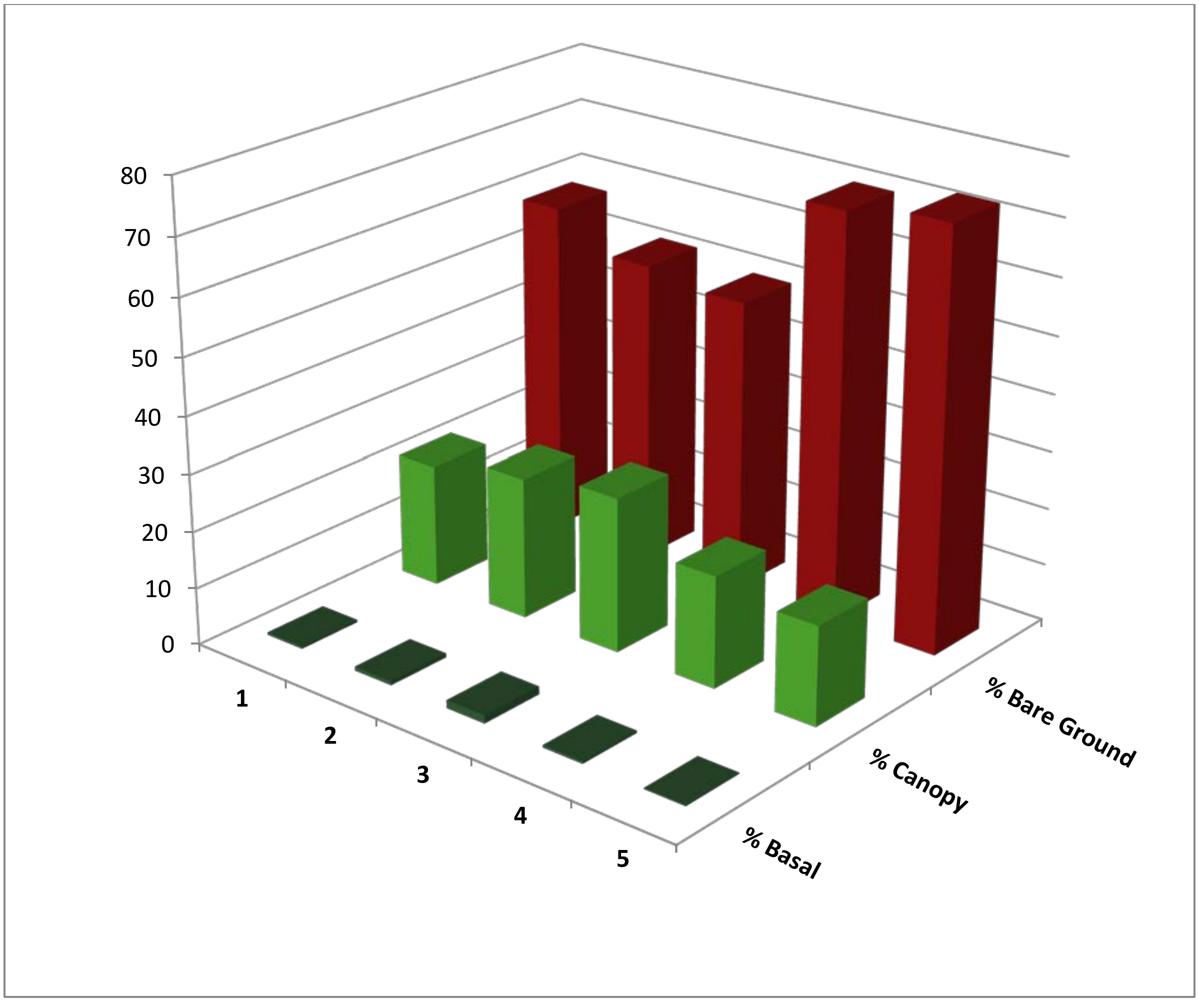

Figure 5-1. Ground Cover in District 8 by Analysis Unit

5.1.4 Frequency and Composition

The most commonly encountered species by transect are listed in the second to last table in the results section of each analysis unit along with forage value information (an explanation of forage values is found in Section 4.2.5). The individual species frequency data (by the ten plots within each transect) are included in the electronic data with this report. The species composition table presents the top contributors of biomass production. Several species are repeatedly found in these two tables for most of the analysis units; these include Russian thistle, galleta grass, broom snakeweed (*Gutierrezia sarothrae*), sand dropseed (*Sporobolus cryptandrus*), and blue grama (*Bouteloua gracilis*).

5.2 Analysis Unit 1

 

Sample Transects from Unit 1

There are 94 transects in analysis unit 1. Table 5-2 presents the total acreage for the unit, total analyzed acreage, number of analyzed soil components, and carrying capacity. Adjusted carrying capacity represents the carrying capacity after adjusting for slope and distance to water. There are 30 soil components in this unit, but only 20 contain transects. The remaining 10 unanalyzed components make up 8 percent of the total unit area.

Table 5-2. 1 Carrying Capacity

Total Acres (Non-Range Excluded)	Total Analyzed Acres	# of Analyzed Soil Components	Initial Carrying Capacity (SUYL)	Adjusted Carrying Capacity (SUYL)
114,686	105,141	20	284	114

Note: SUYL = sheep unit year long.

Table 5-3 shows the minimum and maximum stocking rates, and associated soil components. The Mido soil component has virtually no available forage and would require nearly 50,000 acres to support one sheep unit for one year. This is one of the smallest components in analysis unit 1 and contains one transect. Vegetation is scarce and composed of mostly Russian thistle (*Salsola tragus*) and blackbrush (*Coleogyne ramosissima*). The Mespun soil component is moderately sized and has the best stocking rate. Primary contributors to available forage are big sagebrush (*Artemisia tridentata*), blue grama (*blue grama*), and jointfir (*Ephedra* spp.).

Table 5-3. 1 Stocking Rate

Stocking Rate Minimum (acres/SUYL)	Soil Component with Minimum Stocking Rate	Stocking Rate Maximum (acres/SUYL)	Soil Component with Maximum Stocking Rate
47,400	Mido	142	Mespun

Note: SUYL = sheep unit year long.

Table 5-4 displays each soil component found within the unit and the number of transects, acreage, available forage, stocking rate, and annual carrying capacity within each component. Most transects are located within the Sheppard component. Soils here are sandy and these sites often are expansive stabilized dune sheets. Available forage from the better-producing sites is mostly contributed by Indian ricegrass (*Achnatherum hymenoides*), fourwing saltbush (*Atriplex canescens*), and Cutler's jointfir (*Ephedra cutleri*). The general plant community present in this analysis unit is dominated by shrubs like rubber rabbitbrush (*Ericameria nauseosa*), big sagebrush, Greene's rabbitbrush (*Chrysothamnus greenei*), and Cutler's jointfir. Other plants commonly encountered include Russian thistle, broom snakeweed, and galleta grass (*Pleuraphis jamesii*).

Table 5-4. 1 Results by Soil Component

Component	# of Transects	Total Acres (Non-Range Excluded)	Average Available Forage (lbs/acre)	Stocking Rate (acres/ SUYL)	Initial Annual Carrying Capacity (SUYL)
Aneth	2	1,075	5	488	2
Aneth Family	0	475	N/A	N/A	N/A
Arches	3	3,279	5	492	7
Bispen	0	873	N/A	N/A	N/A
Counselor	4	3,855	10	247	16
Gish	0	374	N/A	N/A	N/A
Gotho	2	1,329	3	729	2
Hawaikuh	2	964	7	330	3
Marcou	6	12,101	5	475	25
Massadona	0	5,729	N/A	N/A	N/A
Mathis	2	1,507	6	419	4
Mespun	4	3,845	17	142	27
Mido	1	323	0	47,400	0.01
Moclom	1	3,373	1	2,236	2
Monue	14	9,142	12	204	45
Nalcase	7	3,256	10	248	13
Parkwash	0	564	N/A	N/A	N/A
Pensom	0	757	N/A	N/A	N/A
Pinepoint	1	790	15	157	5
Radnik	0	69	N/A	N/A	N/A
Reef	0	374	N/A	N/A	N/A
Riverwash	0	46	N/A	N/A	N/A
Rizno	0	284	N/A	N/A	N/A
Rock Outcrop	4	16,727	4	554	30
Sheppard	17	12,718	8	307	41
Torriorthents	3	2,949	3	743	4
Typic	1	1,075	14	173	6
Typic	2	4,037	5	512	8
Ustic	15	22,575	5	510	44
Wayneco	3	221	2	1,102	0.2

Notes: lbs = pounds, SUYL = sheep unit year long.

Table 5-5 contains ground cover information. Canopy and bare ground cover are a little below average for the project area. About half of the transects show moderate signs of erosion, while an additional 14 percent exhibit more advanced erosion. These latter transects are located in the western half of the unit with slopes ranging from 1 to 28 degrees. Soils are mostly sandy, vegetation is composed primarily of shrubs and trees, and much of the soil surface is exposed.

Table 5-5. 1 Ground Cover

Canopy (%)	Bare ground (%)	Basal (%)
21.0	58.0	0.4

The final two tables (Table 5-6 and Table 5-7) show the most frequently occurring species and the species contributing the most biomass, respectively. The percent frequency of occurrence is an important number as it gives mangers an idea of the distribution of species across a given area.

It also is useful to know how much biomass or weight is being produced by a given plant species. For example, a desirable grass may occur frequently, but may produce only a small amount of forage. In analysis unit 1t, the invasive annual Russian thistle was found to be the most frequently occurring species and was the top producer of biomass. The perennial grass galleta grass, and broom snakeweed also occur frequently and are top producers of biomass, but produce far less than Russian thistle. The prevalence of shrubs and Russian thistle indicate that much of this unit is in a deteriorated state.

Table 5-6. 1 Frequently Encountered Species

Species		Percentage of Total Transects	Growth Form	Duration	Native (N) or Introduced (I)	Sheep Forage Value
Common Name	Scientific Name					
Russian thistle	*Salsola tragus*	56	Forb	Annual	I	Emergency[i]
Sandmat	*Chamaesyce* spp.	55	Forb	Annual	N	Not Consumed
Indian ricegrass	*Achnatherum hymenoides*	55	Graminoid	Perennial	N	Desirable
Galleta grass	*Pleuraphis jamesii*	52	Graminoid	Perennial	N	Emergency
Broom snakeweed	*Gutierrezia sarothrae*	51	Shrub	Perennial	N	Emergency[t]

Note: [i] = Injurious, [t] = Toxic

Table 5-7. 1 Composition by Weight

Species		Percentage of Total Weight	Growth Form	Duration	Native (N) or Introduced (I)	Sheep Forage Value
Common Name	Scientific Name					
Russian thistle	*Salsola tragus*	54	Forb	Annual	I	Emergency[i]
Broom snakeweed	*Gutierrezia sarothrae*	6	Shrub	Perennial	N	Emergency[t]
Rubber rabbitbrush	*Ericameria nauseosa*	4	Shrub	Perennial	N	Emergency
Galleta grass	*Pleuraphis jamesii*	3	Graminoid	Perennial	N	Emergency
Big sagebrush	*Artemisia tridentata*	3	Shrub	Perennial	N	Emergency
Plains pricklypear	*Opuntia polyacantha*	3	Cactus	Perennial	N	Emergency[i]

Note: [i] = Injurious, [t] = Toxic

5.3 Analysis Unit 2

Sample Transects from Unit 2

There are 222 transects in t analysis unit 2. Table 5-8 presents the total acreage for the unit, total analyzed acreage, number of analyzed soil components, and carrying capacity. Adjusted carrying capacity represents the carrying capacity after adjusting for slope and distance to water. There are 39 soil components in this unit, but only 29 contain transects. The remaining 10 unanalyzed components make up 4 percent of the total unit area.

Table 5-8. 2 West Carrying Capacity

Total Acres (Non-Range Excluded	Total Analyzed Acres	# of Analyzed Soil Components	Initial Carrying Capacity (SUYL)	Adjusted Carrying Capacity (SUYL)
230,498	221,867	29	1,102	302

Note: SUYL = sheep unit year long.

Table 5-9 shows the minimum and maximum stocking rates, and associated soil components. The Berryhill Family soil component currently has no available forage and is considered to be non-stockable. Data for this component come from six transects located immediately west of Kayenta, Arizona. This is a floodplain that, in addition to livestock, is heavily disturbed from human-related activities such as trash dumping and foot traffic. Managing rangeland immediately adjacent to large population centers is not recommended unless steps are taken to minimize human impacts. The Santrick soil component occupies roughly 2,000 acres, but contains only one transect. Therefore, although it has the best stocking rate, this may be an inaccurate portrayal of the overall component and more data should be collected to enhance accuracy. At this time, the primary contributors of available forage are galleta grass (*Pleuraphis jamesii*) and sand dropseed (*Sporobolus cryptandrus*).

Table 5-9. 2 Stocking Rate

Stocking Rate Minimum (acres/SUYL)	Soil Component with Minimum Stocking Rate	Stocking Rate Maximum (acres/SUYL)	Soil Component with Maximum Stocking Rate
Not Stockable	Berryhill Family	62	Santrick

Note: SUYL = sheep unit year long.

Table 5-10 displays each soil component found within the unit and the number of transects, acreage, available forage, stocking rate, and annual carrying capacity within each component. A large portion of analysis unit 2 is comprised of rocky slopes and areas of exposed bedrock; in fact, the largest soil component is Rock Outcrop. Available forage is low in this component, but it has one of the highest carrying capacities due to its large size. Forage is being provided by primarily Indian ricegrass (*Achnatherum hymenoides*), muttongrass (*Poa fendleriana*), and blue grama (*Bouteloua gracilis*). The highest stocking rate is from the Santrick soil component. This is a moderately sized component with a plant community composed of shrubs like fourwing saltbush (*Atriplex canescens*) and black greasewood (*Sarcobatus vermiculatus*) mixed with dropseed (*Sporobolus* spp.), Indian ricegrass, galleta grass, and various annual grasses and forbs. This particular assemblage of plants is common throughout the analysis unit, although the density of shrubs and annual species tends to be higher in the drainages and floodplains.

Table 5-10. 2 Results by Soil Component

Component	# of Transects	Total Acres (Non-Range Excluded)	Average Available Forage (lbs/acre)	Stocking Rate (acres/ SUYL)	Initial Annual Carrying Capacity (SUYL)
Aneth Family	19	9,377	9	261	36
Arabrab	0	3	N/A	N/A	N/A
Arches	3	1,815	6	384	5
Berryhill Family	6	173	0	Not Stockable	Not Stockable
Councelor	2	4,388	10	245	18
Denazar	21	13,922	18	130	107
Eslendo Family	0	759	N/A	N/A	N/A
Gish, Moderately Deep	2	2,490	6	388	6
Gotho	10	26,261	20	119	221
Hawaikuh	5	1,097	16	144	8
Lindrith	0	1	N/A	N/A	N/A
Lithic Torriorthents	7	6,249	23	103	61
Lybrook	3	1,367	5	480	3
Massadona	0	2,689	N/A	N/A	N/A
Mathis	10	5,325	4	574	9
Mespun	11	10,298	6	374	28

Component	# of Transects	Total Acres (Non-Range Excluded)	Average Available Forage (lbs/acre)	Stocking Rate (acres/ SUYL)	Initial Annual Carrying Capacity (SUYL)
Mido	1	951	5	473	2
Moclom	0	3,840	N/A	N/A	N/A
Monue	6	2,241	18	132	17
Nakai	4	10	20	121	0
Nalcase	26	13,686	14	166	82
Needle	5	4,824	6	373	13
Parkwash	15	6,625	14	167	40
Pensom	0	647	N/A	N/A	N/A
Pinepoint	4	9,275	23	102	91
Radnik	1	204	4	567	0
Reef	3	2,490	17	137	18
Riverwash	0	136	N/A	N/A	N/A
Rock Outcrop	8	51,455	4	587	88
Sanfeco	2	9	14	174	0
Santrick	1	2,011	38	62	33
Sheppard	11	18,124	12	202	90
Simel	3	456	10	233	2
Tewa	2	4	11	225	0
Tsosie	0	456	N/A	N/A	N/A
Typic Haplargids	7	5,050	15	163	31
Urban Land	0	97	N/A	N/A	N/A
Ustic Torriorthents	21	21,690	10	231	94
Vessilla	0	3	N/A	N/A	N/A

Notes: lbs = pounds, SUYL = sheep unit year long.

Table 5-11 contains ground cover information. The percentage of bare ground is fairly low for the project area and canopy cover is above average. Signs of erosion are light to moderate at most of the transects. More advanced erosion is occurring on 7 percent of the transects, mostly on the northern slopes of Black Mesa and in the hills east of Kayenta, Arizona.

Table 5-11. 2 Ground Cover

Canopy (%)	Bare ground (%)	Basal (%)
25	53	1

The final two tables (Table 5-12 and Table 5-13) show the most frequently occurring species and the species contributing the most biomass, respectively. Broom snakeweed (*Gutierrezia sarothrae*), sand dropseed, and Russian thistle (*Salsola tragus*) have both high frequency and high biomass on the landscape. Many of the top producers of biomass are perennial forage species, but their weights are far less than the total biomass produced by Russian thistle.

Table 5-12. 2 Frequently Encountered Species

Species		Percentage of Total Transects	Growth Form	Duration	Native (N) or Introduced (I)	Sheep Forage Value
Common Name	Scientific Name					
Broom snakeweed	*Gutierrezia sarothrae*	58	Shrub	Perennial	N	Emergency[t]
False buffalograss	*Monroa squarrosa*	58	Graminoid	Annual	N	Not Consumed
Sand dropseed	*Sporobolus cryptandrus*	58	Graminoid	Perennial	N	Not Consumed
Russian thistle	*Salsola tragus*	52	Forb	Annual	I	Emergency[i]
Sandmat	*Chamaesyce* spp.	52	Forb	Annual	N	Not Consumed

Note: [i] = Injurious; [t] = Toxic

Table 5-13. 2 Composition by Weight

Species		Percentage of Total Weight	Growth Form	Duration	Native (N) or Introduced (I)	Sheep Forage Value
Common Name	Scientific Name					
Russian thistle	*Salsola tragus*	40	Forb	Annual	I	Emergency[i]
Galleta grass	*Pleuraphis jamesii*	9	Graminoid	Perennial	N	Emergency
Big sagebrush	*Artemisia tridentata*	4	Shrub	Perennial	N	Emergency
Plains pricklypear	*Opuntia polyacantha*	4	Forb	Perennial	N	Emergency[i]
Broom snakeweed	*Gutierrezia sarothrae*	3	Shrub	Perennial	N	Emergency[t]
Sand dropseed	*Sporobolus cryptandrus*	3	Graminoid	Perennial	N	Not consumed
Fourwing saltbush	*Atriplex canescens*	3	Shrub	Perennial	N	Desirable
Blue grama	*Bouteloua gracilis*	3	Graminoid	Perennial	N	Emergency
Roundleaf buffaloberry	*Shepherdia rotundifolia*	3	Shrub	Perennial	N	Not consumed

Note: [i] = Injurious; [t] = Toxic

5.4 Analysis Unit 3


Sample Transects from Unit 3

There are 161 transects in analysis unit 3. Table 5-14 presents the total acreage for the unit, total analyzed acreage, number of analyzed soil components, and carrying capacity. Adjusted carrying capacity represents the carrying capacity after adjusting for slope and distance to water. There are 19 soil components in this unit, but only 12 contain transects. The remaining seven unanalyzed components make up 5 percent of the total unit area.

Table 5-14. 3 Carrying Capacity

Total Acres (Non-Range Excluded)	Total Analyzed Acres	# of Analyzed Soil Components	Initial Carrying Capacity (SUYL)	Adjusted Carrying Capacity (SUYL)
171,423	162,909	12	1,120	237

Note: SUYL = sheep unit year long.

Table 5-15 shows the minimum and maximum stocking rates, and associated soil components. The Moclom soil component contains over 8,000 acres, but the transects are clustered around the community of Chilchinbeto, Arizona. Vegetation is currently scarce in this highly disturbed area and consists of primarily Russian thistle (*Salsola tragus*), broom snakeweed (*Gutierrezia sarothrae*), sandhill muhly (*Muhlenbergia pungens*), Indian ricegrass (*Achnatherum hymenoides*), fineleaf hymenopappus (*Hymenopappus filifolius*), and sandmat (*Chamaesyce* spp.). Additional transects should be placed in this component in order to assess the amount of available forage in areas located farther away from population centers. The Lindrith component has the highest stocking rate in analysis unit 3. The main contributors to available forage are fourwing saltbush (*Atriplex canescens*), sand sagebrush (*Artemisia filifolia*), and western wheatgrass (*Pascopyrum smithii*). This component is located along the upper slopes of Black Mesa, just east of the Peabody coal mine.

Table 5-15. 3 Stocking Rate

Stocking Rate Minimum (acres/SUYL)	Soil Component with Minimum Stocking Rate	Stocking Rate Maximum (acres/SUYL)	Soil Component with Maximum Stocking Rate
570	Moclom	48	Lindrith

Note: SUYL = sheep unit year long.

Table 5-16 displays each soil component found within the unit and the number of transects, acreage, available forage, stocking rate, and annual carrying capacity within each component. The Denazar soil component is the largest in the unit, has the most transects, and has the second highest carrying capacity. This is a grass-dominated component and common species include galleta grass (*Pleuraphis jamesii*), blue grama (*Bouteloua gracilis*), Indian ricegrass, and tall dropseed (*Sporobolus airoides*). The highest carrying capacity was recorded for the Vessilla soil component, which occupies the upper slopes of Black Mesa. The main contributors of available forage are fourwing saltbush (*Atriplex canescens*), big sagebrush (*Artemisia tridentata*), Indian ricegrass, blue grama, galleta grass, and bottlebrush squirreltail (*Elymus elymoides*).

Table 5-16. 3 Results by Soil Component

Component	# of Transects	Total Acres (Non-Range Excluded)	Average Available Forage (lbs/acre)	Stocking Rate (acres/ SUYL)	Initial Annual Carrying Capacity (SUYL)
Aneth Family	4	2,110	10	226	9
Arabrab	30	27,795	16	149	187
Councelor	9	9,678	13	183	53
Denazar	57	32,108	18	129	248
Gotho	0	5,908	N/A	N/A	N/A
Hawaikuh	6	2,420	18	135	18
Lindrith	14	6,949	49	48	145
Lithic	3	10,703	10	242	44
Massadona	0	30	N/A	N/A	N/A
Mido	0	18	N/A	N/A	N/A
Moclom	4	8,469	4	570	15
Monue	0	25	N/A	N/A	N/A
Pits	0	4	N/A	N/A	N/A
Reef	2	46	8	309	0
Rock Outcrop	0	2,511	N/A	N/A	N/A
Sheppard	8	21,440	7	331	65
Ustic	17	13,396	10	232	58
Vessilla	10	27,795	24	100	278
Zukan	0	18	N/A	N/A	N/A

Notes: lbs = pounds, SUYL = sheep unit year long.

Table 5-17 contains ground cover information. Analysis unit 3 has the lowest percentage of bare ground and the highest percentage of canopy cover. This ratio of bare ground to ground cover is due in part to the higher amounts of litter and gravel associated with the piñon-juniper woodlands in the western half of the unit. Four percent of the transects are currently experiencing severe erosion, but the majority of transects exhibit only minimal signs of erosion.

Table 5-17. 3 Ground Cover

Canopy (%)	Bare ground (%)	Basal (%)
27	51	1

The final two tables (Table 5-18 and Table 5-19) show the most frequently occurring species and the species contributing the most biomass, respectively. Broom snakeweed is the most commonly encountered species in this analysis unit; the primary producers consist of galleta grass, Russian thistle, blue grama, sand dropseed (*Sporobolus cryptandrus*), and big sagebrush. Broom snakeweed and warm-season, sod-forming grasses like blue grama and galleta grass have increased in this unit and more desirable forage species have decreased.

Table 5-18. 3 Frequently Encountered Species

Species		Percentage of Total Transects	Growth Form	Duration	Native (N) or Introduced (I)	Sheep Forage Value
Common Name	Scientific Name					
Broom snakeweed	*Gutierrezia sarothrae*	63	Shrub	Perennial	N	Emergency[t]
Galleta grass	*Pleuraphis jamesii*	57	Graminoid	Perennial	N	Emergency
Blue grama	*Bouteloua gracilis*	55	Graminoid	Perennial	N	Emergency
Sand dropseed	*Sporobolus cryptandrus*	55	Graminoid	Perennial	N	Not consumed
Indian ricegrass	*Achnatherum hymenoides*	53	Graminoid	Perennial	N	Desirable

Note: [t] = Toxic

Table 5-19. 3 Composition by Weight

Species		Percentage of Total Weight	Growth Form	Duration	Native (N) or Introduced (I)	Sheep Forage Value
Common Name	Scientific Name					
Galleta grass	*Pleuraphis jamesii*	16	Graminoid	Perennial	N	Emergency
Russian thistle	*Salsola tragus*	8	Forb	Annual	I	Emergency[i]
Blue grama	*Bouteloua gracilis*	7	Graminoid	Perennial	N	Emergency
Sand dropseed	*Sporobolus cryptandrus*	7	Graminoid	Perennial	N	Not consumed
Big sagebrush	*Artemisia tridentata*	7	Shrub	Perennial	N	Emergency

Note: [i] = Injurious

5.5 Analysis Unit 4

Sample Transects from Unit 4

Analysis unit 4 is the smallest in the District 8 project area and contains 34 transects. Table 5-20 presents the total acreage for the unit, total analyzed acreage, number of analyzed soil components, and carrying capacity. Adjusted carrying capacity represents the carrying capacity after adjusting for slope and distance to water. Only one of the 13 soil components did not contain transects. This component was excluded from analysis and makes up 2 percent of the total unit area.

Table 5-20. 4 Carrying Capacity

Total Acres (Non-Range Excluded)	Total Analyzed Acres	# of Analyzed Soil Components	Initial Carrying Capacity (SUYL)	Adjusted Carrying Capacity (SUYL)
42,444	41,595	12	134	64

Note: SUYL = sheep unit year long.

Table 5-21 shows the minimum and maximum stocking rates, and associated soil components. The Aneth Family soil component is currently not stockable. Vegetation on the transects is composed of primarily Russian thistle (*Salsola tragus*), black greasewood (*Sarcobatus vermiculatus*), and sixweeks grama (*Bouteloua barbata*). The best stocking rate was reported for the Gotho soil component. Shrub species, especially fourwing saltbush (*Atriplex canescens*), are the main contributors of available forage.

Table 5-21. 4 Stocking Rate

Stocking Rate Minimum (acres/SUYL)	Soil Component with Minimum Stocking Rate	Stocking Rate Maximum (acres/SUYL)	Soil Component with Maximum Stocking Rate
Not Stockable	Aneth Family	75	Gotho

Note: SUYL = sheep unit year long.

Table 5-22 displays each soil component found within the unit and the number of transects, acreage, available forage, stocking rate, and annual carrying capacity within each component.

This analysis unit straddles Comb Ridge and contains areas of exposed sandstone, deep sand, and several large, shallow washes. Available forage is low throughout but two components, Gotho and Typic Calcigypsids, have numbers well above the other components. Russian thistle is a very common forb, followed by various shrubs including fourwing saltbush, Cutler's jointfir (*Ephedra cutleri*), Torrey's jointfir (*Ephedra torreyana*), rubber rabbitbrush (*Ericameria nauseosa*), and Greene's rabbitbrush (*Chrysothamnus greenei*). The highest carrying capacity is associated with the Gotho component, followed by Sheppard, the largest component in the unit.

Table 5-22. 4 Results by Soil Component

Component	# of Transects	Total Acres (Non-Range Excluded)	Average Available Forage (lbs/acre)	Stocking Rate (acres/ SUYL)	Initial Annual Carrying Capacity (SUYL)
Aneth	0	849	N/A	N/A	N/A
Aneth Family	2	1,514	0	0	0
Gotho	3	4,239	32	75	57
Lithic Haplogypsids	2	4,557	3	849	5
Lithic Torriorthents	2	1,102	1	1,730	1
Marcou	1	849	4	578	1
Moenkopie Family	1	1,820	1	2,043	1
Needle	6	6,098	2	979	6
Rock Outcrop	1	6,118	3	699	9
Sheppard	9	9,624	8	285	34
Typic Calcigypsids	1	849	21	115	7
Typic Haplogypsids	4	2,278	4	539	4
Typic Torriorthents	2	2,547	8	292	9

Notes: lbs = pounds, SUYL = sheep unit year long.

Table 5-23 contains ground cover information. The percent canopy cover is average for the project area, but bare ground is very high. However, at the time of the survey, erosion on all but two transects was only light to moderate. Large areas of bare ground are most susceptible to wind erosion as so much of this unit is composed of loose, sandy soil.

Table 5-23. 4 Ground Cover

Canopy (%)	Bare ground (%)	Basal (%)
20	71	0

The final two tables (Table 5-24 and Table 5-25) show the most frequently occurring species and the species contributing the most biomass, respectively. Grazing disturbances have led to a huge increase in the invasive annual forb, Russian thistle. This species was found on almost every transect and contributes nearly 80 percent of the biomass for the entire unit. Forage species including galleta grass (*Pleuraphis jamesii*), Torrey's jointfir, and Indian ricegrass are widespread but do not contribute significantly to the overall biomass.

Table 5-24. 4 Frequently Encountered Species

Species		Percentage of Total Transects	Growth Form	Duration	Native (N) or Introduced (I)	Sheep Forage Value
Common Name	Scientific Name					
Russian thistle	*Salsola tragus*	94	Forb	Perennial	I	Emergency[i]
Galleta grass	*Pleuraphis jamesii*	62	Graminoid	Perennial	N	Emergency
Torrey's jointfir	*Ephedra torreyana*	47	Shrub	Perennial	N	Desirable
Indian ricegrass	*Achnatherum hymenoides*	47	Graminoid	Perennial	N	Desirable
Blackbrush	*Coleogyne ramosissima*	41	Shrub	Perennial	N	Not consumed

Note: [i] = Injurious

Table 5-25. 4 Composition by Weight

Species		Percentage of Total Weight	Growth Form	Duration	Native (N) or Introduced (I)	Sheep Forage Value
Common Name	Scientific Name					
Russian thistle	*Salsola tragus*	79	Forb	Annual	I	Emergency[i]
Fourwing saltbush	*Atriplex canescens*	3	Shrub	Perennial	N	Desirable
Blackbrush	*Coleogyne ramosissima*	2	Shrub	Perennial	N	Not consumed
Mojave seablite	*Suaeda moquinii*	2	Shrub	Perennial	N	Not consumed
Rubber rabbitbrush	*Ericameria nauseosa*	2	Shrub	Perennial	N	Emergency
Black greasewood	*Sarcobatus vermiculatus*	2	Shrub	Perennial	N	Not consumed

Note: [i] = Injurious

5.6 Analysis Unit 5


Sample Transects from Unit 5

There are 218 transects in analysis unit 5. Table 5-26 presents the total acreage for the unit, total analyzed acreage, number of analyzed soil components, and carrying capacity. Adjusted carrying capacity represents the carrying capacity after adjusting for slope and distance to water. There are 11 soil components in this unit, but only 9 contain transects. The remaining two unanalyzed components make up less than 1 percent of the total unit area.

Table 5-26. 5 Carrying Capacity

Total Acres (Non-Range Excluded)	Total Analyzed Acres	# of Analyzed Soil Components	Initial Carrying Capacity (SUYL)	Adjusted Carrying Capacity (SUYL)
249,930	248,636	9	646	206

Note: SUYL – sheep unit year long.

Table 5-27 shows the minimum and maximum stocking rates, and associated soil components. The stocking rate is lowest in the Rock Outcrop soil component. Vegetation is scarce and consists of mostly Russian thistle (*Salsola tragus*), threadleaf snakeweed (*Gutierrezia microcephala*), and Indian ricegrass (*Achnatherum hymenoides*). The Denazar component has the best stocking rate. Available forage is currently being provided by galleta grass (*Pleuraphis jamesii*), tall dropseed (*Sporobolus contractus*), blue grama (*Bouteloua gracilis*), Torrey's jointfir (*Ephedra torreyana*), and Cutler's jointfir (*Ephedra cutleri*). This component is located primarily along the western edge of analysis unit 5.

Table 5-27. 5 Stocking Rate

Stocking Rate Minimum (acres/SUYL)	Soil Component with Minimum Stocking Rate	Stocking Rate Maximum (acres/SUYL)	Soil Component with Maximum Stocking Rate
1,354	Rock Outcrop	168	Denazar

Note: SUYL – sheep unit year long.

Table 5-28 displays each soil component found within the unit and the number of transects, acreage, available forage, stocking rate, and annual carrying capacity within each component. The component with the highest carrying capacity, Sheppard, has one of the lower amounts of available forage, but its large size increases the overall carrying capacity. Top producers of available forage in this component are rubber rabbitbrush (*Ericameria nauseosa*), sand buckwheat (*Eriogonum leptocladon*), galleta grass, and Indian ricegrass. Across the entire analysis unit, shrubs constitute the primary sources of available forage including Gardner's saltbush (*Atriplex gardneri*), fourwing saltbush, mound saltbush (*Atriplex obovata*), rubber rabbitbrush, Torrey's jointfir (*Ephedra torreyana*), and Cutler's jointfir (*Ephedra cutleri*).

Table 5-28. 5 Results by Soil Component

Component	# of Transects	Total Acres (Non-Range Excluded)	Average Available Forage (lbs/acre)	Stocking Rate (acres/ SUYL)	Initial Annual Carrying Capacity (SUYL)
Aneth Family	15	8,680	13	182	48
Denazar	42	28,291	14	168	169
Gotho	16	24,305	6	397	61
Lithic	8	13,934	5	516	27
Massadona	5	17,188	5	482	36
Monue	28	14,323	7	360	40
Needle	33	25,547	5	516	49
Riverwash	0	81	N/A	N/A	N/A
Rock Outcrop	3	33,425	2	1,354	25
Sheppard	68	82,943	5	432	192
Tsaya Family	0	1,213	N/A	N/A	N/A

Notes: lbs = pounds, SUYL = sheep unit year long.

Table 5-29 contains ground cover information. Analysis unit 5 has the highest percentage of bare ground and the lowest percentage of canopy cover. Currently, signs of erosion were only slight to moderate on most of the transects. However, this region experiences high winds that funnel up the Chinle Valley and evidence of numerous sand dunes indicate that much of the soil tends to be unstable. Efforts to re-establish native perennials would help stabilize this area.

Table 5-29. 5 Ground Cover

Canopy (%)	Bare ground (%)	Basal (%)
17	74	0

The final two tables (Table 5-30 and Table 5-31) show the most frequently occurring species and the species contributing the most biomass, respectively. As with all units in the District 8 project area, Russian thistle is a dominant component of the plant community. Other annual species like sandmat (*Chamaesyce* spp.) and false buffalograss (*Monroa squarrosa*) also are widespread. False buffalograss is an early successional annual grass that thrives in disturbed areas. Forage species are fairly limited, but include the desirable grass Indian ricegrass, mound saltbush, and galleta grass.

Table 5-30. 5 Species Frequency

Species		Percentage of Total Transects	Growth Form	Duration	Native (N) or Introduced (I)	Sheep Forage Value
Common Name	**Scientific Name**					
Russian thistle	*Salsola tragus*	85	Forb	Annual	I	Emergency[i]
Galleta grass	*Pleuraphis jamesii*	66	Graminoid	Perennial	N	Emergency
Sandmat	*Chamaesyce* spp.	65	Forb	Annual	N	Not consumed
Indian ricegrass	*Achnatherum hymenoides*	62	Graminoid	Perennial	N	Desirable
False buffalograss	*Monroa squarrosa*	53	Graminoid	Annual	N	Not consumed

Note: [i] = Injurious

Table 5-31. 5 Composition by Weight

Species		Percentage of Total Weight	Growth Form	Duration	Native (N) or Introduced (I)	Sheep Forage Value
Common Name	**Scientific Name**					
Russian thistle	*Salsola tragus*	60	Forb	Annual	I	Emergency[i]
Black greasewood	*Sarcobatus vermiculatus*	9	Shrub	Perennial	N	Not consumed
Galleta grass	*Pleuraphis jamesii*	5	Graminoid	Perennial	N	Emergency
Rubber rabbitbrush	*Ericameria nauseosa*	4	Shrub	Perennial	N	Emergency
Mound saltbush	*Atriplex obovata*	2	Shrub	Perennial	N	Emergency

Note: [i] = Injurious

CONCLUSIONS AND RECOMMENDATIONS

6. Conclusions and Recommendations

District 8 is divided into several distinct ecosystems. Piñon-juniper woodlands dominate the northern extension of Black Mesa in the southwest corner. Common understory species include shrubs like fourwing saltbush (*Atriplex canescens*), shadscale (*Atriplex confertifolia*), big sagebrush (*Artemisia tridentata*), sand sagebrush (*Artemisia filifolia*), and roundleaf buffaloberry (*Shepherdia rotundifolia*). The most abundant grass species are western wheatgrass (*Pascopyrum smithii*), needle and thread (*Hesperostipa comata*), crested wheatgrass (*Agropyron smithii*), and blue grama (*Bouteloua gracilis*).

Desert grasslands occupy the Chinle Valley region, forming much of the eastern half of the project area. Russian thistle (*Salsola tragus*) is prevalent throughout this region. Dominant grasses include dropseed (*Sporobolus* spp.), galleta grass (*Pleuraphis jamesii*), and blue grama. Black greasewood (*Sarcobatus vermiculatus*) and saltbush (*Atriplex* spp.) occur regularly in the clay soils found in floodplains and along washes, while rubber rabbitbrush (*Ericameria nauseosa*) and jointfir (*Ephedra* spp.) are associated more with sandier soils.

Slickrock canyons and sandstone outcrops can be found in the northwest corner and along Comb Ridge, which extends northeast from Kayenta, Arizona. Vegetation is dispersed where soils are rocky and thin, but pockets of denser vegetation occur in coves and along canyon bottoms. Frequently encountered species include plains pricklypear (*Opuntia polyacantha*), broom snakeweed (*Gutierrezia sarothrae*), blackbrush (*Coleogyne ramosissima*), roundleaf buffaloberry, big sagebrush, blue grama, galleta grass, Indian ricegrass (*Achnatherum hymenoides*), and pillar false gumweed (*Vanclevea stylosa*). A few transects also contain the highly desirable forage grass, black grama (*Bouteloua eriopoda*).

Analysis of the five units revealed that moderate to severe deterioration has occurred in many areas of District 8. The decline in plant communities is largely a result of continuous grazing pressure and past drought conditions. Extensive colonization by the exotic species Russian thistle has occurred in every analysis unit except unit 3. The most intact plant communities are found in the grassland communities just below the slopes of Black Mesa in unit 3 and the more remote portions of analysis unit 2.

6.1 Drought

Precipitation is one of the greatest obstacles to overcome when managing and restoring rangeland. Local precipitation monitoring stations recorded higher than average precipitation in September and October. Despite this, precipitation levels throughout the southwest indicate ongoing long-term drought conditions (National Drought Mitigation Center [NDMC] 2013). Therefore, it is extremely important to maintain healthy plant communities, not only for forage purposes, but to reduce soil exposure and loss. To complicate matters, moisture arriving during the monsoon season often is in the form of severe thunderstorms that can produce several inches of rain in a short time. As the percentage of bare ground is fairly high in much of the project area, many areas are at risk of accelerated water erosion during this type of storm event. This increases soil loss while decreasing water retention. The potential for soil loss due to wind erosion is also very high as much of the project area contains unstable sandy soils. Sandy soils require a lot of plant cover to become stable. It may be necessary to encourage growth of less palatable species initially. Grasses such as sandhill muhly (*Muhlenbergia pungens*) and galleta grass are excellent cover plants that do well in loose soils.

It also is very important to collect accurate precipitation data. Calculations for annual production (and resulting stocking rates) incorporate average precipitation for a given water year. Location-specific precipitation gauges allow managers to more closely monitor precipitation, giving them the opportunity to proactively implement drought management plans. Plants demonstrate rapid growth during a certain portion of the growing season; cool-season plants tend to experience this between March and the beginning of June, with a smaller growth surge in the fall, while warm-season plants grow more quickly during mid-summer. These are critical time periods for forage species and a lack of adequate moisture will compromise growth for the duration of the growing season. Moisture that arrives outside of these windows of rapid growth will help plants, but will be much less effective. Semiarid regions generally are considered to be experiencing drought conditions when the cumulative growing season precipitation is 20 to 25 percent below average during these periods of rapid growth (NDMC 2013). Closely monitoring precipitation would alert managers to impending drought toward the beginning of the growing season and allow for drought mitigation plans to be put into place in a more timely fashion. This is particularly important for the lower-elevation sites in District 8 as the majority of forage plants are warm-season grasses like galleta grass and alkali sacaton (*Sporobolus airoides*). Monsoonal moisture arriving in mid to late July corresponds well with the period of rapid growth for these grasses. However, in years where the monsoons are delayed or largely absent, it will be necessary to adjust the grazing plan. Ultimately, it is up to the individual livestock owner to gain the most thorough knowledge possible of the area being grazed. The best way to mitigate the effects of drought is to keep or restore rangeland to a good condition with a healthy diversity of plants species.

6.2 Soil and Grazing Management

Soils are an extremely important component of rangeland ecosystems. Well-developed soils retain water and provide the substrate and nutrients necessary to produce vibrant plant communities. In areas with large patches of bare ground and/or active erosion, the best way to recover forage production is to build up the soils so they are capable of supporting viable plant populations. Rebuilding soils requires a combination of erosion control, revegetation, and periodic disturbance of the soil surface. Deeply eroded gullies and arroyos are the most difficult and cost-prohibitive features to restore. In their immature form, the sides of channels usually are 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 (Valentin et al. 2005). Unfortunately, the cost and logistics involved with getting equipment into more remote locations can make this option prohibitive. Another alternative 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 include simple hand-constructed rock check dams. In addition to capturing soil and preventing further loss, check dams redistribute water, especially during the monsoon season. Spreading runoff across the landscape and retaining water for longer periods leads to more plant growth and 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 erosion is a potential problem for most of the project area, especially in regions containing moderate to steep slopes and high clay content in the soils.

Revegetation may require reseeding programs, particularly in areas experiencing channelization and in sandy regions with active dunes; however, elements of the native plant community are still present within portions of the project area. Especially visible are perennial grass species such as blue grama, galleta grass, and dropseed (*Sporobolus* spp.). Important forb and shrub species such as globemallow (*Sphaeralcea* spp.), fourwing saltbush, Torrey’s jointfir (*Ephedra torreyana*), and Cutler’s jointfir (*Ephedra cutleri*) also are abundant. This indicates that with careful and proactive management, native species production and frequency should increase naturally without much intervention. In areas that are more deteriorated, seeding with local, drought-tolerant species that can germinate early, such as scarlet globemallow (*Sphaeralcea coccinea*) and sand dropseed (*Sporobolus cryptandrus*), may speed up revegetation and increase the likelihood of success.

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 spring and early summer production also are expected to be low and livestock numbers should be adjusted accordingly.

The final part of rebuilding soil is to make sure 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 key to reaping these benefits. Many of the ecological site descriptions available for the project area recommend deferring grazing from late winter through early spring. This practice alone would help increase available forage. Other areas are better suited for winter/spring grazing and can be utilized to provide forage while less suitable areas are rested. 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 also are valuable tools for excluding stray livestock, especially horses. NRCS programs such as the Environmental Quality Incentives Program can aid in providing the technical and financial support needed for this to occur.

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 parts of the project area. Populations of big sagebrush are fairly dense along the base of Black Mesa in portions of analysis units 2 and 3. Large populations of broom snakeweed can be found in the grassland areas in most units, and blackbrush (*Coleogyne ramosissima*) monocultures are present in the northern sections of analysis units 1, 4 and 5. In some cases, employing proper grazing management may be sufficient to encourage the re-establishment 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. However, it may become 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 and the cost of operating the equipment can be expensive, which limits their practicality in the project area. There also is the danger of encouraging the spread of invasive species by removing large swaths of vegetation at one time (DiTomaso 2000). However, it should be noted that the BIA is currently developing an integrated weed management plan for the entire Navajo Indian Reservation.

Chemical control is less expensive 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 also is much reduced, which decreases opportunities for exotic plants to invade the project area (Olsen et al. 1994; DiTomaso 2000). The use of the herbicide tebuthiuron (Spike®, Scrubmaster®, Perflan®), which inhibits photosynthetic activity, has been quite successful in thinning dense stands of big sagebrush. Low rates of this chemical effectively thin the stand, while still leaving adequate cover and browse for wildlife. Application rates ranging from 0.3 to 0.5 pound 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 effective in controlling broom snakeweed, as well. However, most studies have found that at least 90 percent of the plants need to be killed to see significant increases in perennial forage species (Schmutz and Little 1970; Gesink et al. 1973; Sosebee et al. 1979; McDaniel and Duncan 1987). Greene's rabbitbrush (*Chrysothamnus greenei*) is a common shrub species associated with broom snakeweed and big sagebrush. Aerial applications of Picloram often are successfully used to control this shrub and mixing Picloram with 2,4-dichlorophenoxyacetic acid (2,4-D) can effectively reduce brush stands containing both Greene's rabbitbrush and big sagebrush (Cook et al. 1965; Tueller and Evans 1969; Evans and Young 1978). Before implementing shrub control measures, consultation with experts is recommended to determine the best rates and timing for herbicide applications, minimize impacts to non-target plant and wildlife species, and explore alternate control methods.

Blackbrush is seldom used by livestock, but can provide a marginal amount of forage when other alternatives are unavailable, especially in the spring (Humphrey 1955; Bowns 1973). The forage value of this shrub has been improved by employing mechanical brush-beating techniques and subjecting stands to heavy browsing by goats. Both methods remove the spinescent growths and stimulate growth of new shoots (Bowns 1973; Provenza and Bowns 1985; Urness and Austin 1989). The use of fire to reduce blackbrush stands has had unpredictable results and it is not recommended. The likelihood of encouraging exotic annual brome (*Bromus* spp.) is high and the cryptogamic crusts usually found in these areas often are damaged beyond repair (Bowns 1973; Callison et al. 1985).

6.4 Russian thistle

Russian thistle is a drought tolerant, disturbance-loving species that does well in sandy soils (Whitson et al. 2002). Although this plant is an invasive species, it does provide forage for sheep and cattle in its immature form and when softened by snow or rain (USDA USFS 1937). Consumption of large quantities of this plant has been known to cause diarrhea, especially in lambs, which can compromise the heath of animals already in a weakened condition (Cook et al. 1954). This can be an issue in areas where little else is growing and consumption is likely to be high.

Russian thistle also can accelerate revegetation of disturbed areas by supporting the growth of soil mycorrhiza. Soil mycorrhizae are fungi that form associations with many native plant species. The fungi help the plants absorb more water and nutrients and, in return, receive carbohydrates from the plant roots. Certain mycorrhiza invade the roots of Russian thistle and do not form an association with this plant, but rather kill the infected roots and move on to the roots of neighboring plants. In this manner, the fungi population increases while Russian thistle populations begin to die (Allen and Allen 1988; Allen et al. 1989). The dead plants provide cover for seedlings of other species that are capable of forming associations with the newly established mycorrhiza colonies (Allen and Allen 1988; Grilz et al. 1988). Typically, Russian thistle will persist on a site for about 2 years and then will be replaced by annual and biennial mustards like tall tumblemustard (*Sisymbrium altissimum*) and various tansymustard (*Descurainia* spp.) (Chapman et al. 1969). The mustard species continue to build up the soil substrate by maintaining soil mycorrhiza populations and adding organic matter to the soil as the plants die.

Russian thistle also helps prepare a site by releasing oxalates into the soil. These chemicals work to change inorganic phosphorous into a soluble form that can be taken up by plants (Cannon et al. 1995). Phosphorus often is a limiting nutrient in the soil and by increasing its availability, favorable forage plants can become established more quickly. Russian thistle can be controlled or even eradicated through various mechanical and chemical treatments (Young and Whitesides 1987; Burrill et al. 1989); however, this process is time consuming and expensive. Given the potential benefits of the plant, it is generally better to leave it and focus on encouraging the establishment of desirable, perennial species through proper grazing management and seeding treatments.

6.5 Data Analysis and Monitoring

Data analysis revealed several patterns including areas with large populations of invasive species, areas lacking in ground cover, and other sites that are maintaining good populations of key forage species such as Indian ricegrass, galleta grass, tall dropseed (*Sporobolus contractus*), blue grama, and fourwing saltbush. The next step is to use this data to identify specific locations that would benefit most from improvement measures and then 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 locations are rested. Visits to these areas would allow managers to determine the feasibility of adding water sources if none are present. If data from certain transects show that native forage species are not present, it may be necessary to implement reseeding programs. Agriculture extension offices and the NRCS are good resources to help determine appropriate seed mixes and find seed sources.

Grazing programs should make use of available tools. When it is possible to erect fences, they should be designed to ease 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, also would 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 areas or to encourage them to use underutilized locations. In addition, the initial stocking rates and carrying capacities provided in this report should be used as a guide to be adjusted appropriately with consideration of forage value, seasonal palatability of forage, and 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, placement of the previously discussed check dams and other water catchment systems such as 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 have 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 also would be valuable to assess soil stability and hydrologic function. Numerous references can be utilized to develop monitoring programs and help interpret the results, such as the Monitoring Manual for Grassland, Shrubland, and Savanna Ecosystems published by the Arid Lands Research Program (Herrick et al. 2005) and the Bureau of Land Management’s Technical Reference 1734-6: Interpreting Indicators of Rangeland Health (Pellant et al. 2005).

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