District 14

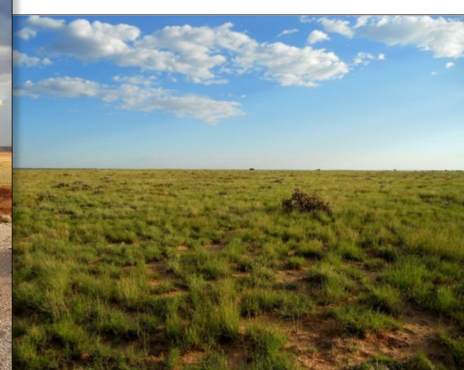
2013 Vegetation Inventory

Coyote Canyon, Naschitti, Mexican Springs, Tohatchi, and Twin Lakes Grazing Communities

Prepared for:

Bureau of Indian Affairs
Fort Defiance Navajo Agency
Natural Resources

2013



Ecosphere Environmental Services

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

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Acronyms and Abbreviations

2,4-D	2,4-dichlorophenoxyacetic acid
ADW	air-dry weight
AUM	animal unit month
BIA	Bureau of Indian Affairs
Ecosphere	Ecosphere Environmental Services
ESD	ecological site description
ft^2	square foot
GIS	geographic information system
GPS	Global Positioning System
HCPC	historic climax plant community
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

Ecosphere Environmental Services was contracted by the Bureau of Indian Affairs to collect and compile vegetation data on portions of District 14, of the Fort Defiance Agency. Data collection occurred during August and September of 2013. Measurements were taken for biomass production, ground cover, and species frequency. The data were analyzed to determine the carrying capacity of the range resource, as well as the similarity to the historic climax plant community.

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

1. Introduction

Ecosphere Environmental Services (Ecosphere) was contracted by the Bureau of Indian Affairs (BIA) to conduct understory rangeland vegetation inventories on a portion of District 14 of the Fort Defiance Agency, specifically in the Coyote Canyon, Mexican Springs, Naschitti, Tohatchi, and Twin Lakes grazing communities. Species-specific vegetation data measurements included biomass production and cover. These data also were used to calculate frequency, annual production, and carrying capacity based on available forage production. Information derived from these calculations can be used to guide management decisions, including stocking rates. This report provides the results of the vegetation inventory as well as the background, methodology, and discussion necessary for management planning.

1.1 Purpose and Need

It is essential to have baseline range condition data to properly establish quality range management practices. The purpose of this inventory was to provide baseline information about the existing range resource to enable resource managers and permittees to improve or maintain the condition of the range resource. The results of this inventory will facilitate determination of adjusted stocking rates in District 14, as well as more comprehensive range management plans that are crucial for future range productivity.

1.2 Regulatory Entities

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

1.2.1 BIA Agency Natural Resources Program

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 the American Indian Agricultural Resources Management Act of December 3, 1993, as amended.
- Comply with applicable environmental and cultural resources laws.

- Comply with applicable sections of the Indian Land Consolidation Act, as amended.
- Unless prohibited by federal law, recognize and comply with tribal laws regulating activities on Indian agricultural land including tribal laws relating to land use, environmental protection, and historic and/or cultural preservation.
- Manage Indian agricultural lands either directly or through contracts, compacts, cooperative agreements, or grants under the Indian Self-Determination and Education Assistance Act, as amended.
- Administer land use as set forth by 25 CFR 162 - Leases and Permits, 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 (SCS), (which became the Natural Resources Conservation Service [NRCS] in 1994) and adopted by the BIA.

Within each district are several chapters. Chapters 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 chapter who are responsible for monitoring livestock grazing within their respective chapters. District Grazing Committees approve the carrying capacities of their districts, as discussed in the 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 District Grazing Committee are responsible for enforcing range management and resolving grazing disputes.

1.3 Grazing 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; plant composition; and location of water, shelter, and minerals (Heitschmidt and Stuth 1991). The total forage production of a given analysis unit does not necessarily reflect the amount of forage available to livestock; therefore, it is important to recognize specific factors restricting 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.

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 on District 14's Coyote Canyon, Mexican Springs, Naschitti, Tohatchi, and Twin Lakes grazing communities. This information can be used to document future changes on the rangelands and assist with management decisions.

2.1 Geographic Setting

District 14 lies within the Colorado Plateau Major Land Resource Area. The project area is near the Arizona state line to the west and encompasses the southern portion of the Chuska Mountains. Highway 491 lies east of the Chuska Mountains and roughly divides the project area into a western and eastern half. The community of Twin Lakes occupies the southern part of the project area, and the community of Sheep Springs is at the northern end. East of Highway 491, the study area extends towards Highway 371 and includes Coyote Canyon to the southeast and follows the Chaco River to the northeast. A map of the project area is provided in Figure 2-1.

The Naschitti Community is the northernmost community, with Mexican Springs and Tohatchi in the middle of the project area. The southernmost communities are Twin Lakes to the southwest and Coyote Canyon to the southeast. Naschitti encompasses a portion of the Chuska Mountain foothills at its western side. The higher elevations consist of a mix of ponderosa pine (*Pinus ponderosa*), Rocky Mountain juniper (*Juniperus scopulorum*), twoneedle pinyon (*Pinus edulis*), Gambel oak (*Quercus gambelii*), and Douglas-fir (*Pseudotsuga menziesii*) growing on a volcanic substrate. As elevation decreases, this community transitions to pinyon-juniper woodland and includes shrubs such as antelope bitterbrush (*Purshia tridentata*), big sagebrush (*Artemisia tridentata*), Stansbury cliffrose (*Purshia* stansburiana), Utahserviceberry (*Amelanchier utahensis*), and various perennial forbs and grasses. Soils become gravelly, flaggy, and cobbly and are more representative of sedimentary rocks than volcanic. As the land continues to drop away to the west, the woodlands begin to thin out and Utah juniper (*Juniperus osteosperma*) becomes the dominant tree species. The landscape is marked by small canyons and numerous washes. Big sagebrush is a common shrub along with saltbush (*Atriplex* spp.), Bigelow sagebrush (*Artemisia bigelovii*), shadscale (*Atriplex confertifolia*), and broom snakeweed (*Gutierrezia sarothrae*). Grasses are a mix of cool- and warm-season species including Indian ricegrass (*Achnatherum hymenoides*), needle and thread (*Hesperostipa comata*), Fendler threeawn (*Aristida purpurea*), blue grama (*Bouteloua gracilis*), and galleta grass (*Pleuraphis jamesii*). Near Highway 491, slopes become gentler and most trees are replaced by grasslands mixed with shrubs. Annual and perennial forbs are abundant, and dominant shrubs include fourwing saltbush (*Atriplex canescens*), jointfir (*Ephedra* spp.), broom snakeweed, and rubber rabbitbrush (*Ericameria nauseosa*). East of the highway, the land continues to descend and soils become dominated by sand and sandy loams on the higher surfaces and clay loams in the wash bottoms. Salt-tolerant shrubs dominate the canopy; native and non-native annual species are prevalent in the understory.

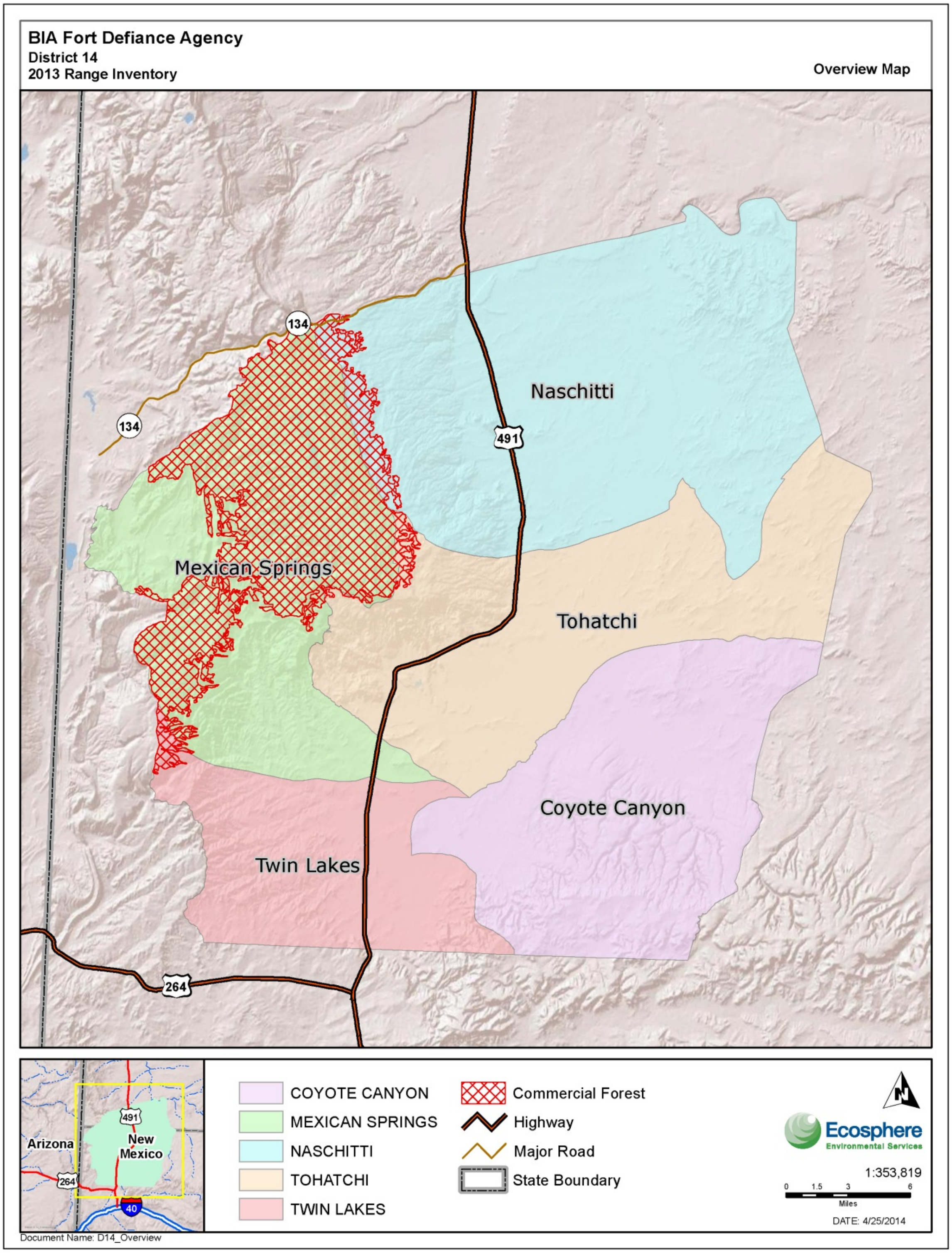


Figure 2-1. Overview of the Project Area

The Tohatchi Community is similar in topography and plant communities to the Naschitti Community. Both occupy a portion of the Chuska Mountain foothills and extend out to drier, flatter lands east of Highway 491; however, Tohatchi includes a slightly larger area of ponderosa pine forest and pinyon-juniper woodland. Most of the Mexican Springs Community is montane and borders the tribally managed Commercial Forest. Slopes are steep and cut by canyons and narrow drainages. Ponderosa pine and Douglas-fir are found throughout the higher regions, and dense pinyon-juniper woodlands are found in the middle elevations. Large, open meadows and small lakes are interspersed among the ponderosa pines near the summit of the Chuska Mountains. The meadows are bordered by Gambel oak and contain forbs such as fleabane (*Erigeron* spp.), groundsel (*Senecio* spp.), deervetch (*Lotus* spp.), and sagewort (*Artemisia* spp.) as well as grasses such as pine dropseed (*Blepharoneuron tricholepis*), blue grama, sedges (*Carex* spp.), and muttongrass (*Poa fendleriana*). Red sandstone cliffs and grassy meadows persist along the westernmost edge of the community and sagebrush shrublands occupy the lowest areas, primarily in the southeast corner near Highway 491.

Sagebrush shrublands and grassy flats continue in the eastern half of the Twin Lakes Community and rise up to rough, pinyon-juniper covered slopes in the west. A small section rises above the woodlands to the upper ponderosa pine forest. An additional area of low washes and floodplains dominated by fourwing saltbush can be found just east of the highway. The final community, Coyote Canyon, backs up against the northern slopes of the highlands just north of Interstate 40. At the highest elevations, woodlands are dominated by pinyon, Utah juniper, big sagebrush, cliffrose, Mormon tea (*Ephedra viridis*), muttongrass, western wheatgrass (*Pascopyrum smithii*), and blue grama. Many rock outcrops are present, slopes are steep, and there are some badland areas. From this point, the land continues to drop to the north to a region of numerous, deeply incised, sandstone canyons. Vegetation is scarce among the rocky areas, but within the canyons are fans and accumulations of deep soils. Much of these areas contain a mix of juniper, rabbitbrush, saltbush, broom snakeweed, Mormon tea, blue grama, and various native and non-native annual plants. As the topography begins to moderate, the canyons persist but become shallower where level grasslands and floodplains appear to the north. This landscape persists throughout the northern end of the community.

2.2 Precipitation

An accurate precipitation monitoring system is essential to range management programs. Biomass production estimates are directly affected by precipitation measurements when reconstructing the plant community 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 and the Navajo Nation Division of Water Resources manages the corresponding data. Thirty-two precipitation gauges with complete data sets located throughout the Fort Defiance Agency were averaged to provide a measurement for the 2013 water year up until the time of data collection.

2.3 Soils

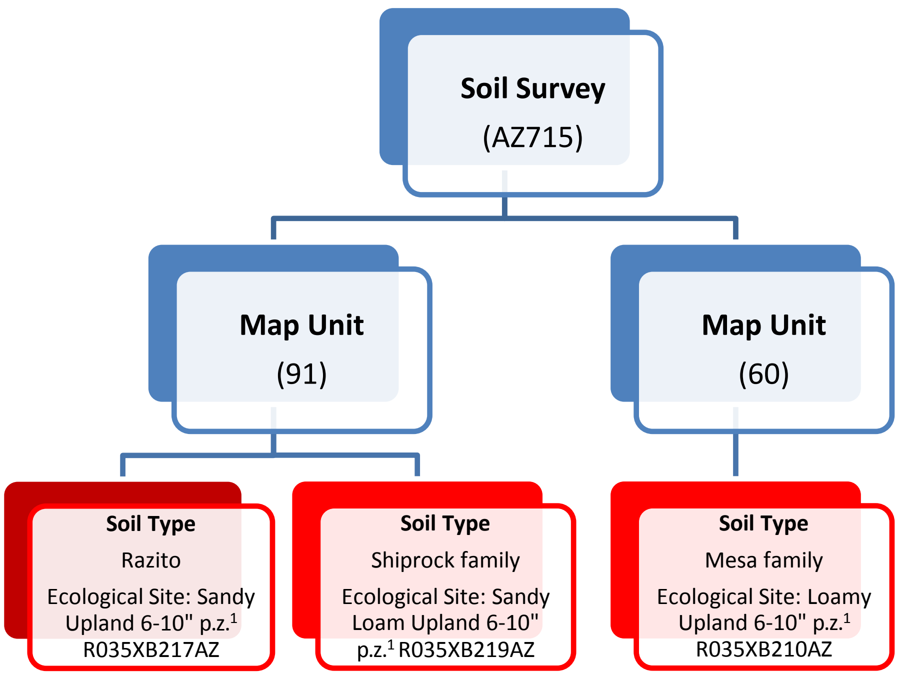
Knowledge of the soil properties in a particular area can help predict forage production. Soil properties such as texture, depth, moisture content, and capacity can dictate the type and amount of vegetation that will grow in that soil. The application of soil survey information enables rangeland managers 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), NRCS: Fort Defiance Area, Parts of Apache and Navajo Counties, Arizona, and McKinley and San Juan Counties, New Mexico (AZ715) (USDOI BIA 2008).

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.

Some of the associated ecological site descriptions that correspond to soils in these soil surveys are in draft form and have not yet been finalized, or have changed. Soil surveys and ecological site descriptions are valuable for rangeland managers, as long as their limitations are understood. 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.



[1]p.z.—precipitation zone.

Figure 2-2. Soil Survey Hierarchy

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

3. Ecological Sites

Ecological sites are differentiated from each other based on significant 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 ecological site description (ESD) describes the historic climax plant community (HCPC) that was present during European settlement of North America. Many rangelands have undergone significant transitions to 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.

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

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 might use 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.

For this inventory, the soil component and ecological site for each transect was determined primarily using soil profile and texture test results and the map unit descriptions from the soil survey, supplemented with interpretation of the current vegetative community compared to the expected HCPC. In cases where the ESD was not developed, no ESD was assigned. Generally, the ESDs represent the most up-to-date information available at the time of this study. It should be noted that they also are continually updated as new information is brought forth from field studies. The ESDs in this report should not be relied upon for future studies; instead the most recent information should be collected from the NRCS. Approved and published ESDs are available on the internet at http://esis.sc.egov.usda.gov/.

The ecological sites from the District 14 analysis area in the Coyote Canyon, Naschitti, Mexican Springs, Tohatchi, and Twin Lakes grazing communities are listed in Table 3-1, followed by representative photographs of ecological sites containing transects, with transect locations identified. Some sites had only one transect located within the ecological site. Many ecological sites contain no transects, especially those with few acres; those ecological sites have no representative photographs.

Table 3-1. Ecological Sites in the Analysis Area

Ecological Site Number	Ecological Site Name	Number of Transects	Acres	% of Project Area
F035XC321AZ	*Juniperus osteosperma/Purshia stansburiana-Artemisia bigelovii/Pleuraphis jamesii-Achnatherum hymenoides*	4	342.76	0.06
F035XC322AZ	*Juniperus osteosperma/Artemisia bigelovii-Purshia stansburiana/Achnatherum hymenoides-Hesperostipa neomexicana*	28	14,591.82	2.75
F035XF622AZ	*Juniperus monosperma-Pinus edulis/Artemisia tridentata* ssp. *wyomingensis/Achnatherum hymenoides-Hesperostipa comata* ssp. *comata*	0	4.80	0.00
F035XF627AZ	*Juniperus osteosperma-Pinus edulis/Artemisia tridentata* ssp. *wyomingensis-Ephedra viridis/Poa fendleriana*	45	18,701.41	3.52
F035XF628AZ	*Juniperus osteosperma-Pinus edulis/Artemisia tridentata* ssp. *wyomingensis-Purshia tridentata/Poa fendleriana-Achnatherum hymenoides*	21	7,762.38	1.46
F035XF629AZ	*Pinus edulis/Cercocarpus montanus-Purshia tridentata/Poa fendleriana-Achnatherum hymenoides*	7	792.18	0.15
F035XF630AZ	*Pinus edulis-Juniperus osteosperma/Artemisia nova-Quercus gambelii/Poa fendleriana-Bouteloua gracilis*	2	1,773.19	0.33
F035XF632AZ	*Pinus edulis-Juniperus osteosperma/Artemisia tridentata* ssp. *wyomingensis-Artemisia nova/Poa fendleriana-Bouteloua gracilis*	11	6,749.12	1.27
F035XF633AZ	*Pinus edulis/Cercocarpus montanus-Amelanchier utahensis/Poa fendleriana*	31	12,929.02	2.43
F035XG134NM	*Pinus edulis-Juniperus monosperma/Quercus gambelii/Bouteloua gracilis*	0	40.46	0.01

Ecological Site Number	Ecological Site Name	Number of Transects	Acres	% of Project Area
F035XH811AZ	*Pinus ponderosa/Quercus gambelii-Artemisia tridentata* ssp. *vaseyana/Bouteloua gracilis-Carex geophila*	2	3,528.57	0.66
F035XH812AZ	*Pinus ponderosa-Pseudotsuga menziesii/Quercus gambelii-Ceanothus fendleri/Carex geophila-Lupinus argenteus*	3	623.18	0.12
F035XH817AZ	*Pinus ponderosa-Pseudotsuga menziesii* var. *glauca/Quercus gambelii-Purshia tridentata/Poa fendleriana-Carex geophila*	0	182.23	0.03
F035XH818AZ	*Pinus ponderosa-Populus tremuloides/Symphoricarpos oreophilus/Carex geophila-Elymus elymoides*	2	357.24	0.07
F035XH826AZ	*Pinus ponderosa-Pinus edulis/Artemisia tridentata* ssp. *wyomingensis-Mahonia repens/Bouteloua gracilis-Muhlenbergia montana*	1	509.88	0.10
F035XH827AZ	*Pinus ponderosa-Quercus gambelii/Artemisia tridentata* var. *vaseyana-Artemisia tridentata* var. *wyomingensis/Muhlenbergia montana-Bouteloua gracilis*	4	1,846.98	0.35
R035XA104AZ	Clayey Bottom 10-14" p.z.	3	2,365.11	0.45
R035XA112AZ	Loamy Bottom 10-14" p.z.	5	2,069.47	0.39
R035XA113AZ	Loamy Upland 10-14" p.z.	0	25.79	0.01
R035XA117AZ	Sandy Loam Upland 10-14" p.z.	1	1,342.39	0.25
R035XA119AZ	Shallow Loamy 10-14" p.z.	0	17.76	< 1
R035XB016NM	Clay Loam Terrace (sodic) 7-10"	1	409.57	0.08
R035XB022NM	Loamy Upland sodic	0	24.46	0.01
R035XB028NM	Sandy Bottom 6-10"	2	273.05	0.05
R035XB030NM	Sandy Loam Upland 6-10"	0	3.71	< 1
R035XB035NM	Sandy Upland 6-10"	0	2.89	< 1
R035XB204AZ	Sandstone Upland 6-10" p.z. Very Shallow	0	14.36	< 1
R035XB210AZ	Loamy Upland 6-10" p.z.	56	30,810.23	5.80
R035XB211AZ	Loamy Wash 6-10" p.z. Saline	86	47,875.73	9.02
R035XB215AZ	Sandstone/Shale Upland 6-10" p.z.	19	9,063.85	1.71
R035XB216AZ	Sandy Wash 6-10" p.z.	1	333.57	0.06
R035XB217AZ	Sandy Upland 6-10" p.z.	17	7,052.97	1.33

Ecological Site Number	Ecological Site Name	Number of Transects	Acres	% of Project Area
R035XB219AZ	Sandy Loam Upland 6-10" p.z.	86	34,335.43	6.47
R035XB222AZ	Sandy Terrace 6-10" p.z.	37	20,892.97	3.93
R035XB228AZ	Loamy Upland 6-10" p.z. Sodic	75	37,221.66	7.01
R035XB237AZ	Clay Loam Terrace 6-10" p.z. Sodic	114	68,567.13	12.91
R035XB268AZ	Shale Hills 6-10" p.z. Sodic	70	22,111.57	4.16
R035XB270AZ	Porcelanite Hills 6-10" p.z.	5	828.03	0.16
R035XB274AZ	Sandy Loam Upland 6-10" p.z. Saline	3	715.69	0.13
R035XC302AZ	Sedimentary Cliffs 10-14" p.z.	33	17,892.11	3.37
R035XC306AZ	Clayey Upland 10-14" p.z.	14	5,120.33	0.96
R035XC307AZ	Clay Loam Upland 10-14" p.z.	0	9.18	< 1
R035XC309AZ	Clay Loam Flat 10-14" p.z. Saline	3	260.06	0.05
R035XC313AZ	Loamy Upland 10-14" p.z.	48	28,564.05	5.38
R035XC317AZ	Sandy Loam Upland 10-14" p.z.	36	13,196.25	2.48
R035XC319AZ	Shallow Loamy 10-14" p.z.	12	4,349.70	0.82
R035XC320AZ	Shale Hills 10-14" p.z.	43	13,695.85	2.58
R035XC328AZ	Cobbly Slopes 10-14" p.z.	45	16,319.19	3.07
R035XF605AZ	Loamy Upland 13-17" p.z.	6	4,226.46	0.80
R035XH807AZ	Loamy Upland 17-25" p.z.	3	131.26	0.02
R035XH821AZ	Meadow 17-25" p.z.	1	1,105.33	0.21
R036XB006NM	Gravelly Loamy	0	8.09	< 1
	Badland	11	22,014.53	4.15
	Coal Mine Lands	0	15.63	< 1
	Dune Land	10	3,410.69	0.64
	Riverwash	0	414.50	0.08
	Rock Outcrop	10	43,220.03	8.14
Total		**1017**	**531,045.85**	**100**

Notes: " = inches, p.z. = precipitation zone.

F035XC321AZ *Juniperus osteosperma/Purshia stansburiana-Artemisia bigelovii/Pleuraphis jamesii-Achnatherum hymenoides* (Transects 1008_TL and 1004_TL)

F035XC322AZ *Juniperus osteosperma/Artemisia bigelovii-Purshia stansburiana/Achnatherum hymenoides-Hesperostipa neomexicana* (Transects 00147_CC and 0095_CC)

F035XF627AZ *Juniperus osteosperma-Pinus edulis/Artemisia tridentata* ssp. *wyomingensis-Ephedra viridis/Poa fendleriana* (Transects 0024_TL and 0562_MS)

F035XF628AZ ***Juniperus osteosperma-Pinus edulis/Artemisia tridentata*** **ssp.** ***wyomingensis-Purshia tridentata/Poa fendleriana-Achnatherum hymenoides*** (Transects 0777_N and 0541_T)

F035XF629AZ ***Pinus edulis/Cercocarpus montanus-Purshia tridentata/Poa fendleriana-Achnatherum hymenoides*** (Transects 0389_MS and 0613_MS)

F035XF630AZ ***Pinus edulis-Juniperus osteosperma/Artemisia nova-Quercus gambelii/Poa fendleriana-Bouteloua gracilis*** (Transects 0526_MS and 0551_MS)

F035XF632AZ *Pinus edulis-Juniperus osteosperma/Artemisia tridentata* ssp. *wyomingensis-Artemisia nova/Poa fendleriana-Bouteloua gracilis* (Transects 0521_T and 0559_T)

F035XF633AZ *Pinus edulis/Cercocarpus montanus-Amelanchier utahensis/Poa fendleriana* (Transects 0086_CC and 0367_MS)

F035XH811AZ *Pinus ponderosa/Quercus gambelii-Artemisia tridentata* ssp. *vaseyana/Bouteloua gracilis-Carex geophila* (Transects 0546_MS and 0664_MS)

F035XH812AZ *Pinus ponderosa-Pseudotsuga menziesii/Quercus gambelii-Ceanothus fendleri/Carex geophila-Lupinus argenteus* (Transects 1010_MS and 1011_MS)

F035XH818AZ *Pinus ponderosa-Populus tremuloides/Symphoricarpos oreophilus/Carex geophila-Elymus elymoides* (Transects 1013_MS and 1014_MS)

F035XH826AZ *Pinus ponderosa-Pinus edulis/Artemisia tridentata* ssp. *wyomingensis-Mahonia repens/Bouteloua gracilis-Muhlenbergia montana* (Transect 0597_MS)

F035XH827AZ *Pinus ponderosa-Quercus gambelii/Artemisia tridentata* var. *vaseyana-Artemisia tridentata* var. *wyomingensis/Muhlenbergia montana-Bouteloua gracilis* (Transects 0333_MS and 646_MS)

R035XA104AZ Clayey Bottom 10-14" p.z. (Transects 0121_CC and 0611_MS)

R035XA112AZ Loamy Bottom 10-14" p.z. (Transects 0107_TL and 0600_MS)

R035XA117AZ Sandy Loam Upland 10-14" p.z. (Transect 0241_TL)

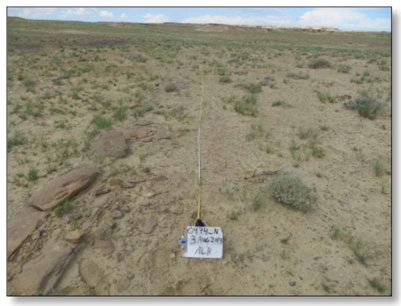
R035XB016NM Clay Loam Terrace (sodic) 7-10" (Transect 1003_N)

R035XB028NM Sandy Bottom 6-10" (Transects 1001_N and 1002_N)

R035XB210AZ Loamy Upland 6-10" p.z. (Transects 0452_CC and 0604_T)

R035XB211AZ Loamy Wash 6-10" p.z. Saline (Transects 0727_N and 0423_T)

R035XB215AZ Sandstone/Shale Upland 6-10" p.z. (Transects 0696_N and 0974_N)



R035XB216AZ Sandy Wash 6-10" p.z. (Transects 0690_N)

R035XB217AZ Sandy Upland 6-10" p.z. (Transects 0458 and 0694_T)

R035XB219AZ Sandy Loam Upland 6-10" p.z. (Transects 0292_CC and 0800_N)


R035XB222AZ Sandy Terrace 6-10" p.z. (Transects 0668_N and 0573_T)

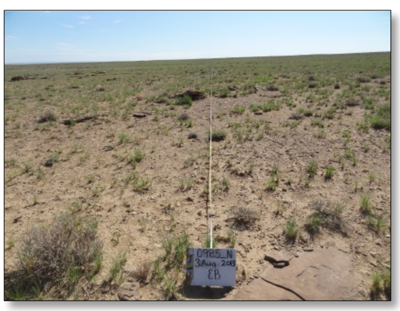
R035XB228AZ Loamy Upland 6-10" p.z. Sodic (Transects 0772_T and 0981_N)

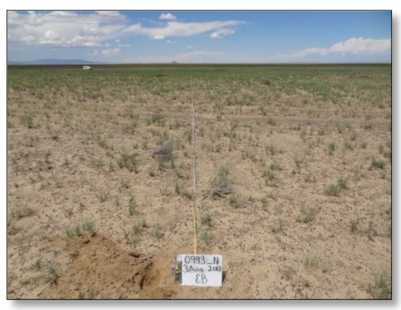

R035XB237AZ Clay Loam Terrace 6-10" p.z. Sodic (Transects 0495_N and 0647_T)


R035XB268AZ Shale Hills 6-10" p.z. Sodic (Transects 0587_T and 0995_N)

R035XB270AZ Porcelanite Hills 6-10" p.z. (Transects 0008_N and 0987_N)

R035XB274AZ Sandy Loam Upland 6-10" p.z. Saline (Transects 0985_N and 0993_N)

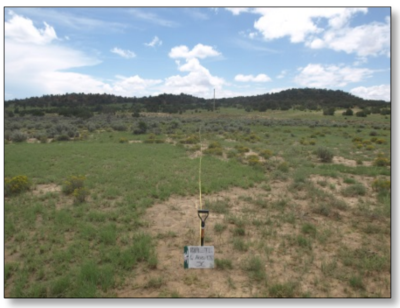
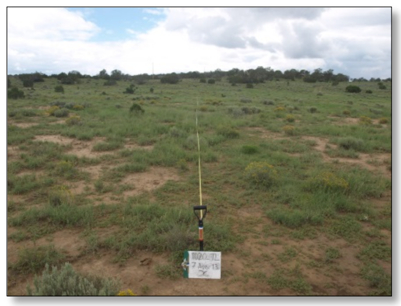




R035XC302AZ Sedimentary Cliffs 10-14" p.z. (Transects 0365_MS and 0484_T)

R035XC306AZ Clayey Upland 10-14" p.z. (Transects 0210_TL and 0345_MS)


R035XC309AZ Clay Loam Flat 10-14" p.z. Saline (Transects 1019_TL and 1020_TL)

R035XC313AZ Loamy Upland 10-14" p.z. (Transects 0160_CC and 0636_MS)


R035XC317AZ Sandy Loam Upland 10-14" p.z. (Transects 0168_CC and 0649_MS)


R035XC319AZ Shallow Loamy 10-14" p.z. (Transects 0152_CC and 0199_CC)

R035XC320AZ Shale Hills 10-14" p.z. (Transects 0043_TCC and 0434_T)

R035XC328AZ Cobbly Slopes 10-14" p.z. (Transects 0395_T and 0784N)

R035XF605AZ Loamy Upland 13-17" p.z. (Transects 0548_TL and 0233_TL)

R035XH807AZ Loamy Upland 17-25" p.z. (Transects 1016_N and 1017_N)

R035XH821AZ Meadow 17-25" p.z. (Transect 0866_N)

Badland (Transects 0903_NA and 0956_NA)

Dune Land (Transects 0324_T and 0577_T)

Rock Outcrop (Transects 0666_MS and0133_CC)

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 August 2 and September 7, 2013. The Universal Transverse Mercator (UTM) coordinates of 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, starting at the 20-foot mark, not at zero. 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.

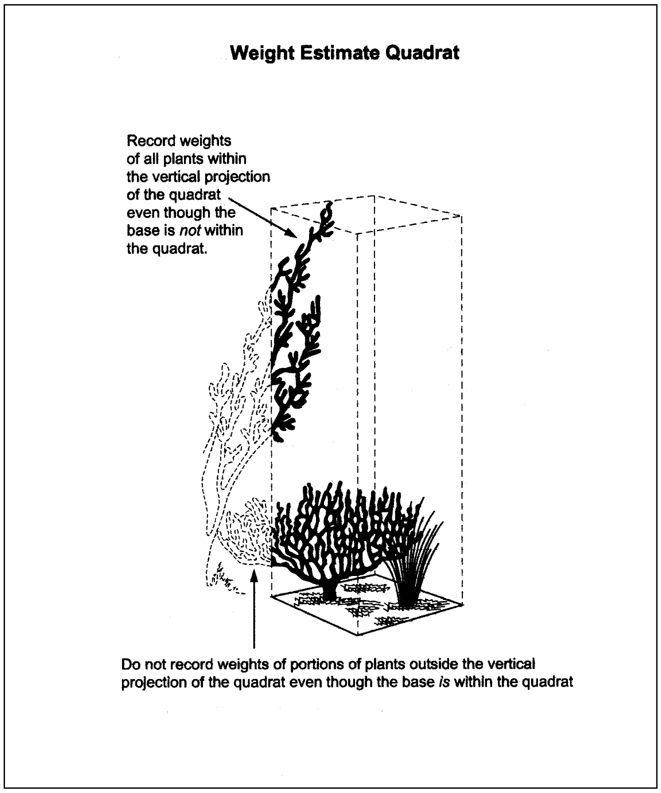
Production and composition of the plant communities were determined using the USDA double sampling methodology with a combination of estimating and harvesting. For this survey, Ecosphere followed the USDA's double sampling methodology, NRCS's modified standards outlined in the SOW, and modifications 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, un-grazed Indian ricegrass 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. 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 plots on each transect were chosen for harvesting. On the harvested plots, all species were estimated *in situ* and then harvested at ground level (¼-inch stubble height).



Source: Coulloudon et al. 1999

Figure 4-1. Weight Estimate Box

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.

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 selected 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, black greasewood (*Sarcobatus vermiculatus*) flats, or on rolling hills with antelope bitterbrush 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 un-grazed plants near the transect. These un-grazed plants were assumed to approximate the species condition before grazing occurred. Un-grazed plants were used as a comparison to estimate grazed plants. Some re-growth may have occurred before the inventory period; however, if grazing patterns are undetectable on the plant, it is impossible to determine what re-growth, if any, may have occurred. The percentage of un-grazed plant remaining was recorded for each species on each transect.

4.1.1.5 Sensitive Plants Protocol

Threatened, endangered, culturally important, or otherwise sensitive plants were never intentionally harvested for the purposes of this inventory. The weight of such plants was estimated, but the plants were not harvested. Cacti and yucca species were not harvested; instead, their annual production was estimated using standard protocols as described in USDA NRCS Technical Reference 1734-7.

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.

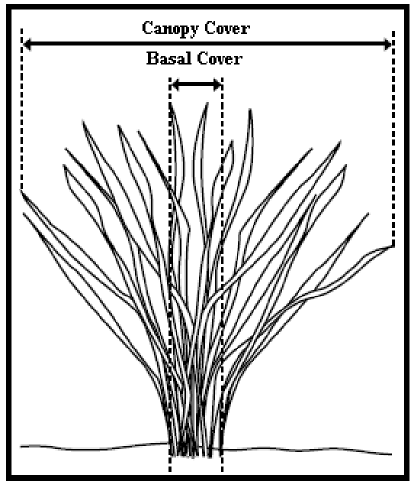
The line-point intercept method employed on this study is described in *Monitoring Manual for Grassland, Shrubland and Savanna Ecosystems* (Herrick et al. 2005). There are 50 point measurements spaced every 4 feet along a 200-foot measuring tape anchored securely at each end. At each point along the transect, a sighting device (pin flag) was placed perpendicular to the ground along the measuring tape. Three layers of point intercept were recorded as the pin flag was dropped into place: Top Canopy, Lower Canopy, and Soil Surface.

The first cover category is determined by the first plant interception of the pin flag. The species of plant that the pin flag hits is recorded as the “Top Canopy.” If no plants are intercepted, “None” is recorded.

Up to three additional species intercepted by the pin flag below the top canopy are recorded as “Lower Canopy” layers. If herbaceous or woody litter is intercepted, this is recorded as a lower canopy layer.

The final point intercept, “Soil Surface,” is recorded either as the base of a plant species (Figure 4-2) or one of the following categories: Rock, Bedrock, Embedded Litter, Duff, Moss, Lichen Crust, or Soil. Bare ground occurs only when the Top Canopy is "None," there are no Lower Canopy layers, and the Soil Surface is "Soil."

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



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 ecological sites 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:

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

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:

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

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 were never clipped during fieldwork, but published %ADW values were used in the calculations. USDA NRCS Technical Reference 1734-7 presents the values used: 10 percent for prickly pear (*Opuntia* spp.), 5 percent for barrel-type cacti (*Ferocactus* spp.) and 15 percent for cholla cactus (*Cylindropuntia* and *Grusonia* spp.).

4.2.1.3 Utilization

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

$$\textit{Utilization} = 0.90$$

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 would normally be less than a measurement of the same plant taken in September, when the plant is nearing full growth. A growth curve calculates the average growth, by month, of plant species throughout the year within a specific region. For example, if alkali sacaton was measured in a transect during August, that measurement may represent only 88 percent of the full growth of that species.

Each growth curve entry was a pro-rated value according to the day of the month. For example, using the growth curve AZ3521 and a transect that was sampled August 21, the first step in the growth curve analysis would be to estimate the percentage of growth completed up to that date by adding up the 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 prorated and added to the total. The value is determined by dividing the percent of growth occurring in August (11 percent) by the 31 days that occur during the month of August. This calculation yields a rate of 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.

Growth curves typically are presented in an ecological site description. However, many of the ESDs in the survey area did not have growth curves, or had incorrect growth curves. If the growth curve in the ESD was determined to be incorrect, then the ESD was replaced with the most suitable growth curve in the same common resource area, if possible. The growth curve used for many sites was AZ3521, 35.2, 6-10” p.z. (all sites). In this growth curve, plant growth begins in the spring and continues through the summer with most growth occurring in spring. The percent production by month using this growth curve is shown in the chart below.

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%

The growth curve value for the example sample collected on August 21 is 0.8835.

Growth Curve = 0.88

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. The precipitation measurements from 27 rain gauges throughout the Eastern Navajo Agency were used in the calculations to determine the percent of normal production. The 13 years prior to 2013 were averaged and used as an historic comparison. The 2013 water year was 85 percent of the average.

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

$$\textit{Percent Normal Production} = 1.02$$

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:

$$\textit{Reconstruction Equation} = \frac{0.89}{(0.90 \times 1.02 \times 0.88)} = 1.10$$

The formula for the reconstruction equation, as explained earlier 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:

$$72 \textit{ grams} \times \frac{0.89}{0.90 \times 1.02 \times 0.88} = 72 \textit{ grams} \times 1.10 = 79.20 \textit{ grams}$$

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. Fifty ground cover point intercepts were measured, so ground cover categories were divided by 50 and the result was multiplied by 100 to estimate a percentage of ground cover for each transect. For example, if 30 hits were recorded for bare ground, the percent bare ground on that transect would be 60 percent.

$$\frac{30 \text{ “bare ground” hits}}{50 \text{ total hits}} \; X\ 100 = 60\% \text{ bare ground}$$

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

Each ecological site has a unique HCPC described in the ESD. The similarity index is a process of comparing the plant community that currently exists on the ground to the HCPC. The similarity index is expressed as a percentage. 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. A similarity index was calculated for all transects assigned to ecological sites with available ESDs.

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

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

The similarity index for this survey was calculated by comparing the estimated production value for each plant species to the ESD. The ESD has an assigned production value for each species (or group of species) expected to occur in the HCPC. Production that is expected to occur in the ecological site (up to the maximum percent listed) is termed "allowable production." If an individual species (or group of species) is not listed in the ESD, no production is assigned or "allowed" from that species. For example, a transect had 79.20 pounds per acre of alkali sacaton. Based on the information in the ESD, the allowable production for alkali sacaton is 50 pounds per acre. No more than 50 pounds may be allowed to be counted toward the similarity index for the transect. If the ESD had listed the allowable percentage of alkali sacaton at 200 pounds per acre, then all 79.20 pounds (and no more) would have been allowed to be counted toward the similarity index for the transect.

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

4.2.5 Calculating Available Forage

The forage value of a species is defined in terms of palatability and availability, as they apply to a particular type of livestock. Ecological site descriptions list only the values for common plant species; however, 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 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) 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.

Emergency (or undesirable) 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 or Injurious—Species that can be toxic or injurious to livestock, regardless of their palatability, were also noted with the forage value. Injurious species are noted with a superscript letter "i" (i) next to the forage value, and toxic species are noted with a superscript letter "t" (t) next to the forage value. Toxic and injurious species never were included in the available forage because of the year-round grazing scheme on the Navajo Nation. However, managers should be aware of their forage values because some are palatable and not toxic or injurious during certain seasons.

Many species have more than one forage value according to the season of use. For example, muttongrass is considered preferred by sheep in the spring, but only desirable during the remainder of the year. District 19 currently allows for year-round grazing Grazing in District 14 is permitted throughout the year so a single forage value is needed. The lowest seasonal forage value was chosen for each 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 species as well as any 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, farmland, and roads were buffered and removed from the total acreage available for livestock grazing.

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

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

Livestock will rarely range more than 2 miles from a water source (Holechek 1988). Areas farther than 2 miles from a water source can be considered un-grazeable and that acreage should be removed from stocking rate calculations. Permitting in areas beyond 2 miles will lead to overgrazing and deterioration. However, if permittees are hauling water to their stock, this should be considered when 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 ecological site within each grazing community. 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 or ecological sites 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 ecological site within an analysis unit.

Stocking rates represent the number of acres needed to support one animal unit for 1 year. In the Eastern Navajo Agency, 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 figured by dividing this number by the average amount of available forage in each ecological site 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 14 is four sheep. In other words, 790 pounds of forage can support one animal unit per month, or four sheep for a month.

5. RESULTS

During this inventory, 1,116 transects were read on the District 14 analysis area and included five grazing communities: Coyote Canyon, Mexican Springs, Naschitti, Tohatchi, and Twin Lakes. The attributes collected at each transect were biomass production, ground cover, and species frequency. From the production data, annual forage production and initial stocking rates were calculated by ecological sites in soil map units within each analysis unit. Carrying capacity was calculated by GIS analysis of the potential acres of ecological sites within each analysis unit.

Table 5-1 displays the carrying capacity of the range resource in the project area. The total size of the project area is 553,011 acres. Areas considered non-range were removed from the analysis; these include 24,230 acres of roads, home sites, and water. There were 16,440 acres that could not be analyzed due to a lack of transects within the ecological sites in each grazing community.

The study results show an unadjusted carrying capacity of 3,684 sheep units in the entire District 14 project area. The carrying capacity is not consistent across analysis units; therefore, it is important to examine the stocking rates of each ecological site to determine which areas within the analysis unit 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)
Coyote Canyon	213	113,631.20	856.16	508.82
Mexican Springs	107	54,669.70	516.03	140.79
Naschitti	334	176,548.30	984.41	318.07
Tohatchi	227	122,032.10	843.28	344.38
Twin Lakes	135	64,176.30	483.64	289.99

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, similarity indices, 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 are an accurate depiction of available forage. In some cases, however, only one transect was located in an ecological site. If the single transect happened to have extra high or extra low production, the resulting high or low stocking rate was applied to all acres of the ecological site within the 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 ecological site in each grazing community. 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 Similarity Indices

Similarity indices were calculated for all transects associated with a given, described ecological site. Index values are meant to be used as a management tool and do not factor into stocking rate and carrying capacity. For example, a given ecological site may be producing over 2,000 pounds of galleta grass and alkali sacaton. These two grasses are considered to be “available forage” and all of this weight would be factored into the stocking rate and carrying capacity calculations. As a result, both the stocking rate and carrying capacity would be relatively high. However, the reference plant community in the ecological site description may be comprised of a small percentage of the two aforementioned grass species. This would likely result in a low similarity index. In this case, it becomes a management decision as to whether it is more beneficial to manage for the current, high producing plant community or try to establish a plant assemblage more similar to the reference community. The benefit of managing toward this community is that the reference community is typically 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 being grazed also should be taken into consideration. For example, if a given reference community is composed primarily of grass species, but the producer is raising sheep, then it would make more sense to manage for a community containing a mix of grasses, forbs, and shrubs.

5.1.3 Available Forage Production

Available forage is the portion of the total reconstructed production classified as preferred, desirable, or 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 the Mexican Springs unit (28 pounds per acre), followed by the Twin Lakes unit (24 pounds per acre). The lowest average available forage is in the Tohatchi unit (15 pounds per acre). The highest producing ecological sites are F035XF628AZ in the Coyote Canyon unit, R035XA104AZ in the Mexican Springs, R035XH821AZ in Naschitti, R035XC313AZ in Tohatchi, and R035XC309AZ in Twin Lakes.

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

5.1.4 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 14 project area is included for comparison (Figure 5-1). It is possible to have total ground cover values over 100 percent due to overlapping layers. The most represented ground cover category across the project area is bare ground. The highest percentage of bare ground was found in areas near Tohatchi, New Mexico. The least amount of bare ground was found in the Mexican Springs Community. Bare ground is of particular concern in District 14, as much of the area is composed of soils and slopes that are highly susceptible to erosion

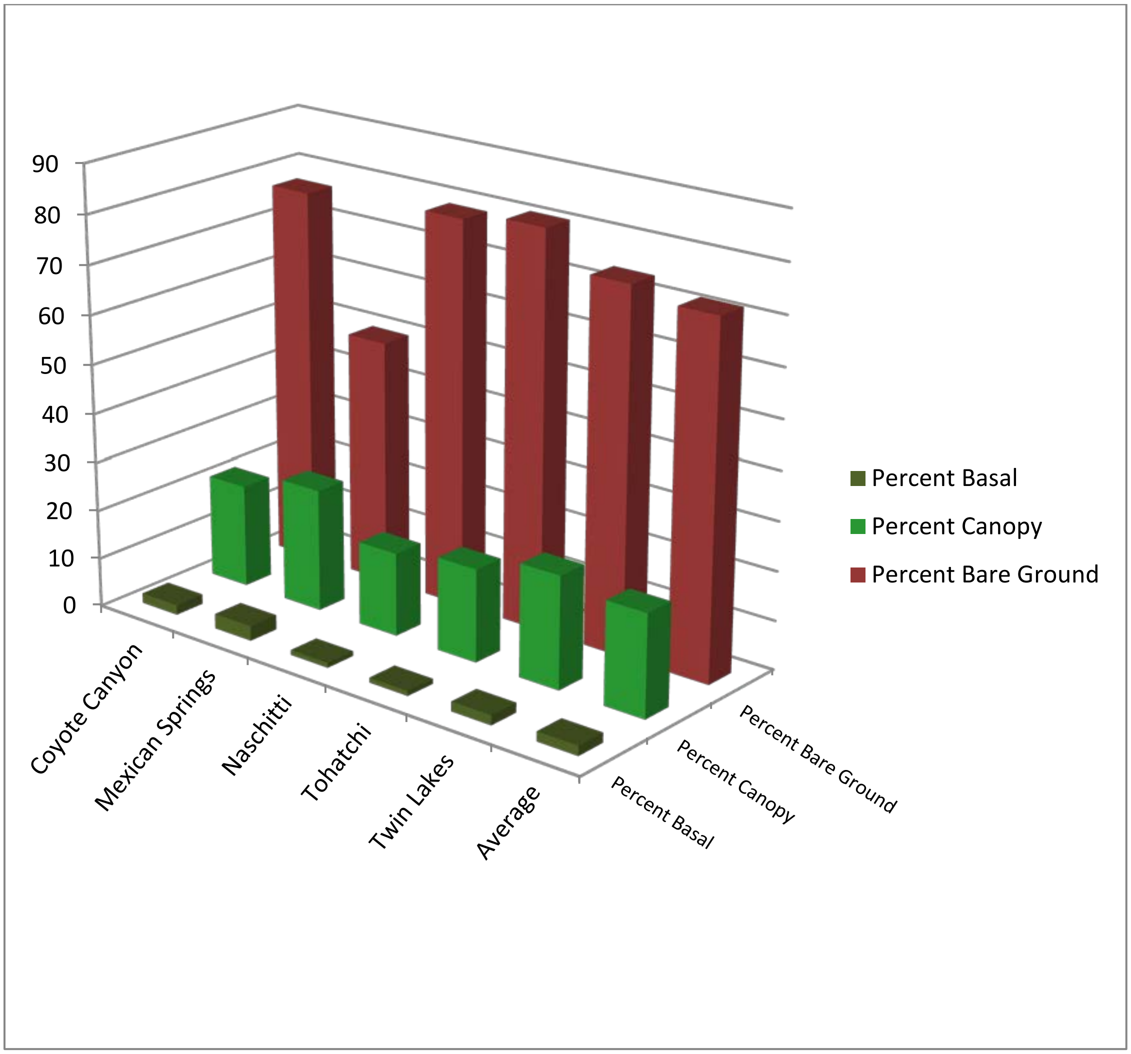


Figure 5-1. Ground Cover in District 14

5.1.5 Frequency and Composition

The five 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 (*Salsola tragus*), galleta grass, blue grama, and alkali sacaton.

5.2 Coyote Canyon

The Coyote Canyon analysis unit contains 213 transects. Table 5-2 presents the total acreage for the unit, total analyzed acreage, number of analyzed ecological sites, and carrying capacity. Adjusted carrying capacity represents the carrying capacity after adjusting for slope and distance to water. Five ecological sites, contributing less than 1 percent of the total unit acreage, were excluded from analysis as they do not contain any transects. There are no ecological site correlations for areas identified as Badland, Dune Land, or Rock Outcrop, but as they do have transects, the resulting data were analyzed and included in this report.

Table 5-2. Coyote Canyon Carrying Capacity

Total Acres (non-range excluded)	Total Analyzed Acres	# of Analyzed Ecological Sites	Initial Carrying Capacity (SUYL)	Adjusted Carrying Capacity (SUYL)
113,631.20	112,749.67	24	856.16	508.82

Note: SUYL – sheep unit year long.

Table 5-3 shows the minimum and maximum stocking rates, and the associated ecological sites. The lowest stocking rate is associated with the R035XB268AZ site; however, this is one of the smaller sites in the analysis unit and contains only two transects. The site with the best stocking rate, F035XF628AZ, also is fairly small and contains six transects.

Table 5-3. Coyote Canyon Stocking Rate

Stocking Rate Minimum (Acres/SUYL)	Ecological Site with Minimum Stocking Rate	Stocking Rate Maximum (Acres/SUYL)	Ecological Site with Maximum Stocking Rate
752.38	R035XB268AZ	39.37	F035XF628AZ

Note: SUYL – sheep unit year long.

Table 5-4 displays the ecological sites found within the unit and the number of transects, acreage, available forage, stocking rate, and annual carrying capacity within each ecological site. The Coyote Canyon unit occupies an area of deep, sandstone canyons, so it is not surprising that the largest ecological site is Rock Outcrop. The carrying capacity for this site is above average, but the highest carrying capacity is associated with the second largest site, F035XC322AZ.

Table 5-4. Coyote Canyon Results by Ecological Site

Ecological Site	# of Transects	Total Acres	Average Available Forage (Pounds)	Stocking Rate (Acres/SUYL)	Initial Annual Carrying Capacity (SUYL)
Badland	0	258.17	N/A	N/A	N/A
Dune land	2	301.06	3.20	740.62	0.41
F035XC322AZ	27	13,910.80	19.83	119.52	116.39
F035XF622AZ	0	4.80	N/A	N/A	N/A
F035XF627AZ	7	4,038.62	33.90	69.91	57.77
F035XF628AZ	6	1,808.10	60.20	39.37	45.93
F035XF630AZ	0	199.05	N/A	N/A	N/A
F035XF633AZ	8	2,814.68	15.09	157.06	17.92
R035XA104AZ	1	752.17	25.46	93.09	8.08
R035XA112AZ	2	658.15	33.32	71.13	9.25
R035XA113AZ	0	25.79	N/A	N/A	N/A
R035XA117AZ	0	392.50	N/A	N/A	N/A
R035XB210AZ	17	9,077.77	13.40	176.87	51.32
R035XB211AZ	9	7,956.62	4.82	491.70	16.18
R035XB215AZ	7	3,105.90	13.63	173.88	17.86
R035XB217AZ	4	1,461.72	11.74	201.87	7.24
R035XB219AZ	26	12,788.14	20.08	118.03	108.35
R035XB222AZ	3	2,021.91	9.63	246.11	8.22
R035XB228AZ	8	3,071.19	10.86	218.23	14.07
R035XB237AZ	20	10,791.10	15.42	153.70	70.21
R035XB268AZ	2	587.72	3.15	752.38	0.78
R035XB270AZ	1	34.86	5.35	442.99	0.08
R035XC302AZ	4	1,989.96	13.57	174.65	11.39
R035XC313AZ	10	4,585.74	34.10	69.50	65.98
R035XC317AZ	22	6,770.07	28.84	82.18	82.38
R035XC319AZ	10	3,441.72	33.45	70.85	48.58
R035XC320AZ	8	2,984.95	8.85	267.80	11.15
R035XF605AZ	3	527.59	34.65	68.40	7.71
Rock Outcrop	6	17,269.13	10.83	218.84	78.91

Note: SUYL – sheep unit year long.

Table 5-5 shows the maximum, minimum, and median similarity indices. The highest similarity value came from the R035XF605AZ site, followed by the R035XB237AZ and R035XC317AZ sites. The HCPC for the R035XF605AZ site consists of big sagebrush (*Artemisia tridentata*) shrubland with a grassy understory. Primary grasses include blue grama (*Bouteloua gracilis*), western wheatgrass (*Pascopyrum smithii*), bottlebrush squirreltail (*Elymus elymoides*), and galleta grass (*Pleuraphis jamesii*). Disturbance can lead to reductions in perennial grass species and increases in shrubs and annual plants. The current plant community is largely dominated by big sagebrush and blue grama.

The R035XB237AZ site is characterized by warm-season, perennial grasses with scattered shrubs and a small component of forbs. Common species include alkali sacaton (*Sporobolus airoides*), galleta grass, common purslane (*Portulaca oleracea*), mound saltbush (*Atriplex obovata*), and black greasewood (*Sarcobatus vermiculatus*). This is a resilient site, but continued disturbance will eventually lead to an increase in shrubs and annual species like Russian thistle (*Salsola tragus*) and cocklebur (*Xanthium strumarium*). Precipitation was very high at the time of the survey; consequently, annual species such as matted grama (*Bouteloua simplex*), common purslane, Russian thistle, and prostrate pigweed (*Amaranthus albus*) are especially abundant. The main perennial species are alkali sacaton and black greasewood.

Cool- and warm-season grasses represent the main component of the HCPC for the R035XC317AZ site. Dominant species include galleta grass, blue grama, sand dropseed (*Sporobolus cryptandrus*), and purple threeawn (*Aristida purpurea*). Annuals, broom snakeweed (*Gutierrezia sarothrae*), and rabbitbrush (*Chrysothamnus* spp.) are likely to increase following disturbance. Frequently encountered species at the transects are blue grama, galleta grass, and Russian thistle.

Table 5-5. Coyote Canyon Similarity Index

Maximum Similarity Index	Minimum Similarity Index	Median Similarity Index
72.32	0.17	12.92

Table 5-6 contains ground cover information. Canopy cover and bare ground are average for the project area. Erosion is light to moderate at most transects. A little over 10 percent of transects showed signs of more advanced erosion; most of of these transects are clustered at the southern end of the analysis unit, particularly in the highlands above Coyote Canyon.

Table 5-6. Coyote Canyon Ground Cover

Canopy (%)	Bare Ground (%)	Basal (%)
21.1	65.1	0.1

The final two tables (Table 5-7 and Table 5-8) 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. Common species in the Coyote Canyon analysis unit are mix of perennial grasses and annual forbs.

In addition to species frequency, 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. The three most frequently occurring species, galleta grass, Russian thistle, and blue grama, also are the top producers of biomass.

Table 5-7. Coyote Canyon Frequently Encountered Species

Species		Percentage of Total Transects	Growth Form	Duration	I=Introduced, N=Native	Sheep Forage Value
Common Name	Scientific Name					
Galleta grass	*Pleuraphis jamesii*	70	Graminoid	Perennial	N	Emergency
Russian thistle	*Salsola tragus*	57	Forb	Annual	I	Emergency[i]
Blue grama	*Bouteloua gracilis*	55	Graminoid	Perennial	N	Emergency
Sandmat	*Chamaesyce spp.*	52	Forb	Annual	N	Unknown
Common purslane	*Portulaca oleracea*	51	Forb	Annual	I	Not Consumed

Note: [i] = Injurious

Table 5-8. Coyote Canyon Composition by Weight

Species		Percentage of Total Weight	Growth Form	Duration	I=Introduced, N=Native	Sheep Forage Value
Common Name	Scientific Name					
Russian thistle	*Salsola tragus*	44	Forb	Annual	I	Emergency[i]
Blue grama	*Bouteloua gracilis*	10	Graminoid	Perennial	N	Emergency
Galleta grass	*Pleuraphis jamesii*	9	Graminoid	Perennial	N	Emergency
Big sagebrush	*Artemisia tridentata*	8	Shrub	Perennial	N	Emergency
Alkali sacaton	*Sporobolus airoides*	4	Graminoid	Perennial	N	Emergency

Note: [i] = Injurious

5.3 Mexican Springs

The Mexican Springs analysis unit contains 107 transects. Table 5-9 presents the total acreage for the unit, total analyzed acreage, number of analyzed ecological sites, and carrying capacity. Adjusted carrying capacity represents the carrying capacity after adjusting for slope and distance to water. There are 34 ecological sites in this unit, but only 26 contain transects. The remaining eight unanalyzed ecological sites make up 4 percent of the total unit acreage; these were excluded from analysis as they do not contain any transects.

Table 5-9. Mexican Springs Carrying Capacity

Total Acres	Total Analyzed Acres	# of Analyzed Ecological Sites	Initial Carrying Capacity (SUYL)	Adjusted Carrying Capacity (SUYL)
54,669.70	52,257.37	26	516.03	140.79

Note: SUYL = sheep unit year long.

Table 5-10 shows the minimum and maximum stocking rates, and the associated ecological sites. The highest stocking rate was found in the R035XA104AZ site, which has far more available forage than any other site in the unit. The lowest stocking rate is in the F035XH827AZ site which is of average size and contains four transects. These transects are located at mid-elevation zones where the pinyon-juniper woodlands transition into ponderosa pine (*Pinus ponderosa*) forests. These areas normally receive up to 25 inches of precipitation per year, but at this time, herbaceous understory species are scarce and the shrub/tree overstory is typically dense.

Table 5-10. Mexican Springs Stocking Rate

Stocking Rate Minimum (Acres/SUYL)	Ecological Site with Minimum Stocking Rate	Stocking Rate Maximum (Acres/SUYL)	Ecological Site with Maximum Stocking Rate
532.58	F035XH827AZ	26.46	R035XA104AZ

Note: SUYL = sheep unit year long.

Table 5-11 displays the ecological sites found within the unit and the number of transects, acreage, available forage, stocking rate, and annual carrying capacity within each ecological site. The largest ecological site is Rock Outcrop; however, its carrying capacity is currently low, which is not surprising as production is naturally limited within this site. The best carrying capacity is in the R035XC313AZ site is the second largest in the Mexican Springs analysis unit. It is distributed primarily in the northwest corner and southeast corner of the unit. Warm-season grasses and fourwing saltbush (*Atriplex canescens*) are the primary forage species at this site.

Table 5-11. Mexican Springs Results by Ecological Site

Ecological Site	# of Transects	Total Acres	Average Available Forage (Pounds)	Stocking Rate (Acres/SUYL)	Initial Annual Carrying Capacity (SUYL)
F035XC322AZ	0	210.70	N/A	N/A	N/A
F035XF627AZ	19	6,328.26	22.49	105.38	60.05
F035XF628AZ	1	539.16	41.35	57.32	9.41
F035XF629AZ	7	769.73	35.71	66.37	11.6
F035XF630AZ	2	1,306.55	8.12	291.87	4.48
F035XF632AZ	1	560.42	31.02	76.40	7.34
F035XF633AZ	2	942.46	31.02	76.40	12.34
F035XH811AZ	2	2,708.49	29.38	80.67	33.57
F035XH812AZ	2	273.21	41.26	57.44	4.76
F035XH817AZ	0	173.36	N/A	N/A	N/A
F035XH818AZ	2	357.24	8.62	274.94	1.30
F035XH826AZ	1	440.82	26.71	88.73	4.97
F035XH827AZ	4	1,590.82	4.45	532.58	2.99
R035XA104AZ	2	1,192.94	89.56	26.46	45.08
R035XA112AZ	2	1,043.82	59.70	39.70	26.29
R035XA117AZ	0	626.06	N/A	N/A	N/A
R035XA119AZ	0	17.76	N/A	N/A	N/A
R035XB210AZ	3	1,303.84	19.93	118.92	10.96
R035XB211AZ	1	723.99	6.81	348.02	2.08
R035XB215AZ	1	41.24	4.63	511.88	0.08
R035XB219AZ	2	1,197.53	25.34	93.53	12.80
R035XB222AZ	0	229.93	N/A	N/A	N/A
R035XB237AZ	2	904.99	32.74	72.39	12.50
R035XC302AZ	13	3,578.65	18.10	130.94	27.33
R035XC306AZ	3	1,361.24	18.70	126.74	10.74
R035XC313AZ	13	6,533.77	40.40	58.66	111.38
R035XC317AZ	5	3,588.23	26.13	90.70	39.56
R035XC319AZ	1	252.84	45.69	51.87	4.87

Ecological Site	# of Transects	Total Acres	Average Available Forage (Pounds)	Stocking Rate (Acres/SUYL)	Initial Annual Carrying Capacity (SUYL)
R035XC320AZ	11	4,702.42	13.53	175.17	26.84
R035XC328AZ	2	798.67	29.56	80.18	9.96
R035XF605AZ	0	260.44	N/A	N/A	N/A
R035XH807AZ	0	0.61	N/A	N/A	N/A
R035XH821AZ	0	893.53	N/A	N/A	N/A
Rock Outcrop	3	9,216.04	5.85	405.13	22.75

Note: SUYL = sheep unit year long.

Table 5-12 shows the maximum, minimum, and median similarity indices. The highest similarity values primarily come from the R035XC313AZ site. The HCPC is grassland with a moderate amount of shrubs. Common species include blue grama (*Bouteloua gracilis*), western wheatgrass (*Pascopyrum smithii*), Indian ricegrass (*Achnatherum hymenoides*), galleta grass (*Pleuraphis jamesii*), big sagebrush (*Artemisia tridentata*), and fourwing saltbush. Broom snakeweed (*Gutierrezia sarothrae*), big sagebrush (*Artemisia tridentata*), rabbitbrush (*Chrysothamnus* spp.), and junipers (*Juniperus* spp.) often increase or invade following prolonged disturbance. Currently, the plant community is dominated by blue grama, galleta grass, fourwing saltbush, and Russian thistle (*Salsola tragus*).

The F035XF627AZ site has the lowest similarity index value and all 19 transects are less than 10 percent similar to the HCPC. This is a pinyon-juniper woodland site; in its undisturbed state, the understory tends to be fairly productive. Blue grama, muttongrass (*Poa fendleriana*), various forbs, Bigelow's sagebrush (*Artemisia bigelovii*), and big sagebrush are common, and annual production averages around 700 pounds per acre. At this time, forage production is very low. Many forage species are present including mountain mahogany (*Cercocarpus montanus*), Utah serviceberry (*Amelanchier utahensis*), and blue grama, but in a limited capacity.

Table 5-12. Mexican Springs Similarity Index

Maximum Similarity Index	Minimum Similarity Index	Median Similarity Index
56.98	0.7	10.85

Table 5-13 contains ground cover information. The Mexican Springs analysis unit has the lowest percentage of bare ground and the highest percentage of canopy in the project area. Erosion is most pronounced in the dissected hills found in the southern third of the unit.

Table 5-13. Mexican Springs Ground Cover

Canopy (%)	Bare Ground (%)	Basal (%)
25.0	42.9	0.3

The final two tables (Table 5-14 and Table 5-15) show the most frequently occurring species and the species contributing the most biomass, respectively. Blue grama contributes the most biomass and is the most frequently occurring species; however, this grass is not especially abundant as it only contributes 19 percent of the total biomass for the unit. This is due in part because a large proportion of the Mexican Springs unit is in either pinyon-juniper woodland or ponderosa pine (*Pinus ponderosa*) forest. These ecosystems tend to foster a variable understory, creating a situation where annual production is more dispersed rather than concentrated among just a few species. Grazing pressure has also reduced the amount of perennial forage species, freeing up space for more annual plants like common purslane (*Portulaca oleracea*) and golden crownbeard (*Verbesina encelioides*).

Table 5-14 Mexican Springs Frequently Encountered Species

Species		Percentage of total Transects	Growth Form	Duration	I=Introduced, N=Native	Sheep Forage Value
Common Name	Scientific Name					
Blue grama	*Bouteloua gracilis*	75	Graminoid	Perennial	N	Emergency
Broom snakeweed	*Gutierrezia sarothrae*	57	Shrub	Perennial	N	Emergency[t]
Galleta grass	*Pleuraphis jamesii*	45	Graminoid	Perennial	N	Emergency
Sandmat	*Chamaesyce spp.*	44	Forb	Annual	N	Unknown
Common purslane	*Portulaca oleracea*	31	Forb	Annual	I	Not Consumed

Note: [t] = Toxic

Table 5-14. Mexican Springs Composition by Weight

Species		Percentage of Total Weight	Growth Form	Duration	I=Introduced, N=Native	Sheep Forage Value
Common Name	Scientific Name					
Blue grama	*Bouteloua gracilis*	19	Graminoid	Perennial	N	Emergency
Russian thistle	*Salsola tragus*	18	Forb	Annual	I	Emergency[i]
Galleta grass	*Pleuraphis jamesii*	8	Graminoid	Perennial	N	Emergency
Mountain mahogany	*Cercocarpus montanus*	5	Shrub	Perennial	N	Desirable
Golden crownbeard	*Verbesina encelioides*	4	Forb	Annual	N	Not Consumed[t]

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

5.4 Naschitti

The Naschitti analysis unit is the largest analysis unit and contains 334 transects. Table 5-16 presents the total acreage for the unit, total analyzed acreage, number of analyzed ecological sites, and carrying capacity. Adjusted carrying capacity represents the carrying capacity after adjusting for slope and distance to water. There are 39 ecological sites in this unit, but only 24 contain transects. The remaining 15 unanalyzed ecological sites make up 3 percent of the total unit acreage; these were excluded from analysis as they do not contain any transects.

Table 5-15. Naschitti Carrying Capacity

Total Acres	Total Analyzed Acres	# of Analyzed Ecological Sites	Initial Carrying Capacity (SUYL)	Adjusted Carrying Capacity (SUYL)
176,537.82	170,787.66	24	984.41	318.07

Note: SUYL = sheep unit year long.

Table 5-17 shows the minimum and maximum stocking rates, and the associated ecological sites. The Dune Land site is currently considered non-stockable; only annual forbs, particularly Russian thistle (*Salsola tragus*), were found during the survey. However, more data should be collected as there is only one transect in this site. The best stocking rate was found in the R035XH821AZ site, which is another small site also containing one transect.

Table 5-16. Naschitti Stocking Rate

Stocking Rate Minimum (Acres/SUYL)	Ecological Site with Minimum Stocking Rate	Stocking Rate Maximum (Acres/SUYL)	Ecological Site with Maximum Stocking Rate
Not stockable	Dune Land	28.04	R035XH821AZ

Note: SUYL = sheep unit year long.

Table 5-18 displays each ecological site found within the unit and the number of transects, acreage, available forage, stocking rate, and annual carrying capacity within each ecological site. The largest sites, R035XB237AZ and R035XB228AZ, have the highest carrying capacities. These sites occupy much of the grasslands in the eastern half of the analysis unit. The lowest carrying capacities are found in sites located in the very northeast corner of the unit (Dune Land, R035XB216AZ, and R035XB270AZ) and the southwest corner (R035XH807AZ).

Table 5-17. Naschitti Results by Ecological Site

Ecological Site	# of Transects	Total Acres	Average Available Forage (Pounds)	Stocking Rate (Acres/SUYL)	Initial Annual Carrying Capacity (SUYL)
Badland	10	20,234.27	3.17	747.63	27.06
Dune Land	1	331.65	0	0	0
F035XC322AZ	0	25.83	N/A	N/A	N/A
F035XF628AZ	10	3,568.53	12.46	190.21	18.76
F035XF632AZ	4	4,078.32	7.30	324.66	12.56
F035XG134NM	0	40.46	N/A	N/A	N/A
F035XH811AZ	0	319.31	N/A	N/A	N/A
F035XH812AZ	0	260.70	N/A	N/A	N/A
F035XH817AZ	0	6.56	N/A	N/A	N/A
R035XB016NM	1	401.80	45.28	52.34	7.68
R035XB022NM	0	24.46	N/A	N/A	N/A
R035XB028NM	2	267.87	45.03	52.63	5.09
R035XB030NM	0	3.71	N/A	N/A	N/A
R035XB035NM	0	2.89	N/A	N/A	N/A
R035XB204AZ	0	14.36	N/A	N/A	N/A
R035XB210AZ	18	9,466.60	31.61	74.98	126.26
R035XB211AZ	34	18,589.75	16.65	142.34	130.6
R035XB215AZ	8	2,369.62	8.51	278.50	8.51
R035XB216AZ	1	333.57	5.77	410.75	0.81
R035XB217AZ	4	1,443.31	7.26	326.45	4.42
R035XB219AZ	17	5,732.83	16.38	144.69	39.62
R035XB222AZ	7	5,906.29	19.55	121.23	48.72
R035XB228AZ	51	25,672.89	13.66	173.50	147.97
R035XB237AZ	49	27,207.58	12.30	192.68	141.21
R035XB268AZ	63	19,615.84	7.82	303.07	64.72
R035XB270AZ	4	793.17	2.86	828.67	0.96
R035XB274AZ	3	693.34	19.82	119.58	5.80
R035XC302AZ	5	6,726.58	23.06	102.78	65.45
R035XC313AZ	6	5,082.73	19.43	121.98	41.67

Ecological Site	# of Transects	Total Acres	Average Available Forage (Pounds)	Stocking Rate (Acres/SUYL)	Initial Annual Carrying Capacity (SUYL)
R035XC317AZ	0	166.02	N/A	N/A	N/A
R035XC319AZ	0	31.00	N/A	N/A	N/A
R035XC320AZ	7	872.76	9.67	245.09	3.56
R035XC328AZ	25	11,060.52	15.58	152.12	72.71
R035XF605AZ	0	1,698.08	N/A	N/A	N/A
R035XH807AZ	3	127.94	51.48	46.04	2.78
R035XH821AZ	1	209.90	84.51	28.04	7.49
R036XB006NM	0	8.09	N/A	N/A	N/A
Riverwash	0	411.91	N/A	N/A	N/A
Rock Outcrop	0	2,736.78	N/A	N/A	N/A

Note: SUYL = sheep unit year long.

Table 5-19 shows the maximum, minimum, and median similarity indices. The majority of the highest values are associated with the R035XB228AZ site. The HCPC for this site is primarily made up of grassland with a moderate shrub overstory. Dominant species include alkali sacaton (*Sporobolus airoides*), galleta grass (*Pleuraphis jamesii*), shadscale (*Atriplex confertifolia*), and mound saltbush (*Atriplex obovata*). This site is most vulnerable to grazing that occurs in the winter and spring, which reduces cool-season grasses and causes increases in cheatgrass (*Bromus tectorum*), broom snakeweed (*Gutierrezia sarothrae*), annual forbs, and shadscale. The main species found on the transects are alkali sacaton, galleta grass, and Russian thistle (*Salsola tragus*).

Table 5-18. Naschitti Similarity Index

Maximum Similarity Index	Minimum Similarity Index	Median Similarity Index
59.13	0.0	12.7

Table 5-20 contains ground cover information. The Naschitti analysis unit encompasses much of the lower elevation grasslands found in the project area. This region has experienced prolonged disturbance as evidenced by the proliferation of annual forbs and the high percentage of bare ground. About 13 percent of the transects are experiencing advanced erosion. These are scattered around the periphery of the unit.

Table 5-19. Naschitti Ground Cover

Canopy (%)	Bare Ground (%)	Basal (%)
17.0	70.3	0.1

The final two tables (Table 5-14 and Table 5-15) show the most frequently occurring species and the species contributing the most biomass, respectively. All but the western edge of the Naschitti analysis unit is located in the rolling grasslands extending east from the Chuska Mountains. This is reflected in the tables below, as the most common species are consistent with moderately deteriorated grassland. Annual forbs, especially Russian thistle, are common as are perennial forage grasses such as alkali sacaton and galleta grass.

Table 5-20. Naschitti Frequently Encountered Species

Species		Percentage of total Transects	Growth Form	Duration	I=Introduced, N=Native	Sheep Forage Value
Common Name	Scientific Name					
Russian thistle	*Salsola tragus*	61	Forb	Annual	I	Emergency[i]
Alkali sacaton	*Sporobolus airoides*	54	Graminoid	Perennial	N	Emergency
Galleta grass	*Pleuraphis jamesii*	54	Graminoid	Perennial	N	Emergency
False buffalograss	*Monroa squarrosa*	45	Graminoid	Annual	N	Not Consumed
Sandmat	*Chamaesyce sp.*	44	Forb	Annual	N	Unknown

Note: [i] = Injurious

Table 5-21. Naschitti Composition by Weight

Species		Percentage of Total Weight	Growth Form	Duration	I=Introduced, N=Native	Sheep Forage Value
Common Name	Scientific Name					
Russian thistle	*Salsola tragus*	42	Forb	Annual	I	Emergency[i]
Alkali sacaton	*Sporobolus airoides*	13	Graminoid	Perennial	N	Emergency
Galleta grass	*Pleuraphis jamesii*	10	Graminoid	Perennial	N	Emergency
False buffalograss	*Monroa squarrosa*	3	Graminoid	Annual	N	Not Consumed
Puncturevine	*Tribulus terrestris*	2	Forb	Annual	I	Not Consumed

Note: [i] = Injurious

5.5 Tohatchi

The Tohatchi analysis unit contains 227 transects. Table 5-23 presents the total acreage for the unit, total analyzed acreage, number of analyzed ecological sites, and carrying capacity. Adjusted carrying capacity represents the carrying capacity after adjusting for slope and distance to water. There are 30 ecological sites in this unit, but only 22 contain transects. The remaining eight unanalyzed ecological sites make up less than one percent of the total unit acreage; these were excluded from analysis as they do not contain any transects.

Table 5-22. Tohatchi Carrying Capacity

Total Acres	Total Analyzed Acres	# of Analyzed Ecological Sites	Initial Carrying Capacity (SUYL)	Adjusted Carrying Capacity (SUYL)
122,032.10	121,877.99	22	843.28	344.38

Note: SUYL = sheep unit year long.

Table 5-24 shows the minimum and maximum stocking rates, and the associated ecological sites. The Badland site is small and tends to have low annual production even when left undisturbed. The one transect found within this site contained low amounts of annuals and alkali sacaton (*Sporobolus airoides*). The site with the best rate, R035XC313AZ, is found in the semi-wooded foothills in the western portion of the unit. Galleta grass (*Pleuraphis jamesii*) and blue grama (*Bouteloua gracilis*) are fairly prevalent.

Table 5-23. Tohatchi Stocking Rate

Stocking Rate Minimum (Acres/SUYL)	Ecological Site with Minimum Stocking Rate	Stocking Rate Maximum (Acres/SUYL)	Ecological Site with Maximum Stocking Rate
3118	Badland	75.91	R035XC313AZ

Note: SUYL = sheep unit year long.

Table 5-25 displays each ecological site found within the unit and the number of transects, acreage, available forage, stocking rate, and annual carrying capacity within each ecological site. The largest ecological site, R035XB237AZ, has the highest carrying capacity, followed by the second largest site, R035XB211AZ. Both sites occupy the grassland area east of the Chuska Mountain foothills.

Table 5-24. Tohatchi Results by Ecological Site

Ecological Site	# of Transects	Total Acres	Average Available Forage (Pounds)	Stocking Rate (Acres/SUYL)	Initial Annual Carrying Capacity (SUYL)
Badland	1	1,499.36	0.76	3,118.42	0.48
Duneland	7	2,713.12	17.94	132.11	20.54
F035XF628AZ	4	1,846.59	8.53	277.84	6.65
F035XF632AZ	6	2,110.38	16.76	141.41	14.92
F035XH811AZ	0	109.27	N/A	N/A	N/A
F035XH812AZ	1	89.27	11.50	206.09	0.43
F035XH817AZ	0	2.31	N/A	N/A	N/A
R035XB016NM	0	7.77	N/A	N/A	N/A
R035XB028NM	0	5.18	N/A	N/A	N/A
R035XB210AZ	14	9,675.17	20.68	114.60	84.43
R035XB211AZ	30	16,383.63	14.77	160.46	102.10
R035XB215AZ	2	3,411.91	11.27	210.29	16.22
R035XB217AZ	9	4,147.94	8.50	278.82	14.88
R035XB219AZ	38	13,292.82	12.93	183.29	72.52
R035XB222AZ	21	8,219.72	20.68	114.60	71.73
R035XB228AZ	15	8,477.58	3.71	638.81	13.27
R035XB237AZ	32	24,386.29	21.22	111.69	218.34
R035XB268AZ	5	1,887.81	9.43	251.33	7.51
R035XB274AZ	0	22.35	N/A	N/A	N/A
R035XC302AZ	6	4,434.56	19.36	122.42	36.22
R035XC306AZ	1	558.12	14.06	168.56	3.31
R035XC313AZ	4	3,291.09	31.22	75.91	43.36
R035XC317AZ	1	397.88	19.93	118.92	3.35
R035XC320AZ	9	2,935.17	20.52	115.50	25.41

Ecological Site	# of Transects	Total Acres	Average Available Forage (Pounds)	Stocking Rate (Acres/SUYL)	Initial Annual Carrying Capacity (SUYL)
R035XC328AZ	18	4,460.00	18.18	130.36	34.21
R035XF605AZ	2	1,608.77	10.66	222.33	7.24
R035XH807AZ	0	2.71	N/A	N/A	N/A
R035XH821AZ	0	1.90	N/A	N/A	N/A
Riverwash	0	2.59	N/A	N/A	N/A
Rock Outcrop	1	6,050.81	18.08	131.08	46.16

Note: SUYL = sheep unit year long.

Table 5-26 shows the maximum, minimum, and median similarity indices. The two highest similarity values were recorded for transects in the R035XB237AZ site. This site is primarily comprised of alkali sacaton (*Sporobolus airoides*), galleta grass (*Pleuraphis jamesii*), and mound saltbush (*Atriplex obovata*). The current plant community is similar to the HCPC, but the dominant shrub is fourwing saltbush (*Atriplex canescens*) and most of the transects have become invaded by Russian thistle (*Salsola tragus*).

Many of the lowest scores came from the R035XB211AZ site. Without undue disturbance, this site is a shrub/grassland dominated by blue grama (*Bouteloua gracilis*), alkali sacaton, vine mesquite (*Panicum obtusum*), fourwing saltbush, shadscale (*Atriplex confertifolia*), and mound saltbush. Most of the current plant community is composed of perennial forage species, but production is low and many annual species are present as well.

Table 5-25. Tohatchi Similarity Index

Maximum Similarity Index	Minimum Similarity Index	Median Similarity Index
66.3	0.0	9.54

Table 5-27 contains ground cover information. The geography and proportions of ground cover in the Tohatchi analysis unit are virtually identical as those found in the Naschitti unit. Continuous grazing pressure and past droughts have reduced perennial grass species and increased the amount of bare ground. Erosion is a little less prevalent however, with only 6 percent of all transects showing more advanced signs of erosion. These are located mostly in the western third of the unit.

Table 5-26. Tohatchi Ground Cover

Canopy (%)	Bare Ground (%)	Basal (%)
18.8	70.1	0.2

The final two tables (Table 5-14 and Table 5-15) show the most frequently occurring species and the species contributing the most biomass, respectively. The prevalent species in the Tohatchi analysis unit are similar to those found in the Naschitti unit. Russian thistle is abundant and other annual species were frequently encountered on the transects; however, most of the top producing species are perennial forage species.

Table 5-27. Tohatchi Frequently Encountered Species

Species		Percentage of total Transects	Growth Form	Duration	I=Introduced, N=Native	Sheep Forage Value
Common Name	Scientific Name					
Russian thistle	*Salsola tragus*	70	Forb	Annual	I	Emergency[i]
Galleta grass	*Pleuraphis jamesii*	64	Graminoid	Perennial	N	Emergency
Sandmat	*Chamaesyce sp.*	47	Forb	Annual	N	Unknown
False buffalograss	*Monroa squarrosa*	41	Graminoid	Annual	N	Not Consumed
Common purslane	*Portulaca oleracea*	39	Forb	Annual	I	Unknown

Note: [i] = Injurious

Table 5-28. Tohatchi Composition by Weight

Species		Percentage of Total Weight	Growth Form	Duration	I=Introduced, N=Native	Sheep Forage Value
Common Name	Scientific Name					
Russian thistle	*Salsola tragus*	53	Forb	Annual	I	Emergency[i]
Galleta grass	*Pleuraphis jamesii*	11	Graminoid	Perennial	N	Emergency
Alkali sacaton	*Sporobolus airoides*	7	Graminoid	Perennial	N	Emergency
Fourwing saltbush	*Atriplex canescens*	5	Shrub	Perennial	N	Desirable
Blue grama	*Bouteloua gracilis*	3	Graminoid	Perennial	N	Emergency

Note: [i] = Injurious

5.6 Twin Lakes

The Twin Lakes analysis unit contains 135 transects. Table 5-30 presents the total acreage for the unit, the total analyzed acreage, the number of analyzed ecological sites, and carrying capacity. Adjusted carrying capacity represents the carrying capacity after adjusting for slope and distance to water. There are 32 ecological sites in this unit, 20 of which had transects. The remaining 12, unanalyzed ecological sites make up 15 percent of the total analysis unit area.

Table 5-29. Twin Lakes Carrying Capacity

Total Acres	Total Analyzed Acres	# of Analyzed Ecological Sites	Initial Carrying Capacity (SUYL)	Adjusted Carrying Capacity (SUYL)
64,176.22	54,669.59	20	483.64	289.99

Table 5-31 shows the minimum and maximum stocking rates, and the associated ecological sites. The lowest stocking rate is associated with the R035XB222AZ site, which is located in the northeast corner of the Twin Lakes analysis unit. This is a grasslands area currently dominated by various annual grasses and forbs. The R035XC309AZ site has the highest stocking rate and is located mostly in the grassy hills in the southwest corner of the Twin Lakes analysis unit. Common forage plants encountered at the transects include blue grama (*Bouteloua gracilis*), galleta grass (*Pleuraphis jamesii*), western wheatgrass (*Pascopyrum smithii*), and bottlebrush squirreltail (*Elymus elymoides*).

Table 5-30. Twin Lakes Stocking Rate

Stocking Rate Minimum (Acres/SUYL)	Ecological Site with Minimum Stocking Rate	Stocking Rate Maximum (Acres/SUYL)	Ecological Site with Maximum Stocking Rate
634	R035XB222AZ	43	R035XC309AZ

Note: SUYL = sheep unit year long.

Table 5-32 displays each ecological site found within the unit and the number of transects, acreage, available forage, stocking rate, and annual carrying capacity within each ecological site. The ecological site with the most transects and acreage is the F035XF633AZ site. The F035XF627AZ and R035XC313AZ sites have the highest carrying capacities in the unit. The majority of moderately sized ecological sites have carrying capacities well below average.

Table 5-31. Twin Lakes Results by Ecological Site

Ecological Site	# of Transects	Total Acres	Average Available Forage (Pounds)	Stocking Rate (Acres/SUYL)	Initial Annual Carrying Capacity (SUYL)
Badland	0	22.73	N/A	N/A	N/A
Coal Mine Lands	0	15.63	N/A	N/A	N/A
Dune Land	0	64.86	N/A	N/A	N/A
F035XC321AZ	4	342.76	43.44	54.56	6.28
F035XC322AZ	1	444.49	37.78	62.73	7.09
F035XF627AZ	19	8,334.53	25.74	92.07	90.52
F035XF629AZ	0	22.45	N/A	N/A	N/A
F035XF630AZ	0	267.59	N/A	N/A	N/A
F035XF633AZ	21	9,171.88	19.15	123.76	74.11
F035XH811AZ	0	391.5	N/A	N/A	N/A
F035XH826AZ	0	69.06	N/A	N/A	N/A
F035XH827AZ	0	256.16	N/A	N/A	N/A
R035XA104AZ	0	420	N/A	N/A	N/A
R035XA112AZ	1	367.50	45.41	52.19	7.04
R035XA117AZ	1	323.83	36.65	64.67	5.01
R035XB210AZ	4	1,286.85	14.75	160.68	8.01
R035XB211AZ	12	4,221.74	9.34	253.75	16.64
R035XB215AZ	1	135.18	4.37	542.33	0.25
R035XB219AZ	5	1,324.11	13.59	174.39	7.59
R035XB222AZ	6	4,515.12	3.74	633.69	7.13
R035XB237AZ	10	5,277.17	14.45	164.01	32.18
R035XB268AZ	0	20.20	N/A	N/A	N/A
R035XC302AZ	5	1,162.36	18.60	127.42	9.12
R035XC306AZ	10	3,200.97	32.89	72.06	44.42

R035XC307AZ	0	9.18	N/A	N/A	N/A
R035XC309AZ	3	260.06	55.53	42.68	6.09
R035XC313AZ	15	9,070.72	33.06	71.69	126.53
R035XC317AZ	8	2,274.05	17.64	134.35	16.93
R035XC319AZ	1	624.14	18.50	128.11	4.87
R035XC320AZ	7	2,200.55	13.17	179.95	12.23
R035XF605AZ	1	131.58	28.84	82.18	1.60
Rock Outcrop	0	7,947.27	N/A	N/A	N/A

Note: SUYL = sheep unit year long.

Table 5-33 shows the maximum, minimum, and median similarity indices. Similarity values are highest in the R035XC313AZ ecological site. The HCPC for this site contains a mix of cool- and warm-season grasses and small shrubs. Common species include blue grama (*Bouteloua gracilis*), western wheatgrass (*Pascopyrum smithii*), Indian ricegrass (*Achnatherum hymenoides*), globemallow (*Sphaeralcea* spp.), big sagebrush (*Artemisia tridentata*), and fourwing saltbush (*Atriplex canescens*). The plant community found at the transects contains many of these species, but cool-season grasses are largely absent and annual species have increased.

Table 5-32. Twin Lakes Similarity Index

Maximum Similarity Index	Minimum Similarity Index	Median Similarity Index
40.11	0.37	13.6

Table 5-34 contains ground cover information. Ground cover percentages are average for the project area. Approximately 20 percent of the transects in this unit are actively losing soil to erosion. All but two of these are located in the hill country west of Highway 491.

Table 5-33. Twin Lakes Ground Cover

Canopy (%)	Bare Ground (%)	Basal (%)
23.5	63.9	0.4

The final two tables (Table 5-14 and Table 5-15) show the most frequently occurring species and the species contributing the most biomass, respectively. Plant communities in the Twin Lakes analysis unit are in a partially degraded condition as evidenced by an abundance of warm-season, perennial grasses and annual forbs. Although annual forbs are not considered forage plants, certain species like sandmat (*Chamaesyce* spp.) and common purslane (*Portulaca oleracea*) do help stabilize the soil and will not persist if more desirable perennial species become more established.

Table 5-34. Twin Lakes Frequently Encountered Species

Species		Percentage of total Transects	Growth Form	Duration	I=Introduced, N=Native	Sheep Forage Value
Common Name	Scientific Name					
Galleta grass	*Pleuraphis jamesii*	80	Graminoid	Perennial	N	Emergency
Russian thistle	*Salsola tragus*	59	Forb	Annual	I	Emergency[i]
Sandmat	*Chamaesyce sp.*	56	Forb	Annual	N	Unknown
Blue grama	*Bouteloua gracilis*	53	Graminoid	Perennial	N	Emergency
Common purslane	*Portulaca oleracea*	50	Forb	Annual	I	Not Consumed

Note: [i] = Injurious

Table 5-35. Twin Lakes Composition by Weight

Species		Percentage of Total Weight	Growth Form	Duration	I=Introduced, N=Native	Sheep Forage Value
Common Name	Scientific Name					
Russian thistle	*Salsola tragus*	38	Forb	Annual	I	Emergency[i]
Galleta grass	*Pleuraphis jamesii*	15	Graminoid	Perennial	N	Emergency
Common purslane	*Portulaca oleracea*	7	Forb	Annual	I	Unknown
Big sagebrush	*Artemisia tridentata*	5	Shrub	Perennial	N	Emergency
Blue grama	*Bouteloua gracilis*	5	Graminoid	Perennial	N	Emergency

Note: [i] = Injurious

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6. Conclusions and Recommendations

District 14 is comprised of a varied topography that essentially starts with high elevation pine forests in the west, transitions down through pinyon-juniper woodlands, and ends in desert grassland to the east. The higher elevations receive much more moisture than the adjacent grasslands, which tends to yield sizable amounts of forage production. However, at the time of the survey, production was not especially high. Desirable forage species including blue grama (*Bouteloua gracilis*), mountain muhly (*Muhlenbergia montana*), needle and thread (*Hesperostipa comata*), muttongrass (*Poa fendleriana*), and white mountain sedge (*Carex geophila*), were among the most productive species found, but overall production was low. Bare ground was high or the understory was crowded out by dense shrubs. One region of the Mexican Springs unit sits at a high elevation on the west side of Chuska Mountains, but is unique in that it contains large, grassy valleys flanked by pine-clad slopes. The valley bottoms appear to have been extensively cultivated in the past, but the fields have since been allowed to go fallow. This transition has allowed numerous species to colonize these areas, resulting in a diverse system containing a variety of forbs and grasses. In some cases, undesirable species such as broom snakeweed (*Gutierrezia sarothrae*) and Russian thistle (*Salsola tragus*) have become dominant; but other areas have a large component of grasses such as blue grama and mountain muhly.

The midrange elevations occupy the foothills of the Chuska Mountains and the hill country found just south of the Coyote Canyon network. The foothills region is covered in pinyon-juniper woodlands with twoneedle pinyon (*Pinus edulis*) and Rocky Mountain juniper (*Juniperus scopulorum*) more prevalent on the upper slopes, and Utah juniper (*Juniperus osteosperma*) dominating the lower slopes. Shrub species are abundant, especially big sagebrush (*Artemisia tridentata*), mountain mahogany (*Cercocarpus montanus*), Stansbury cliffrose (*Purshia stansburiana*), and Utah serviceberry (*Amelanchier utahensis*). Herbaceous understory is generally sparse with the most commonly encountered forage species being blue grama and galleta grass (*Pleuraphis jamesii*). The hills south of Coyote Canyon are largely dominated by big sagebrush on the slopes. The hill crests and upper draws contain Gambel oak (*Quercus gambelli*) and Douglas fir (*Pseudotsuga menziesii*), with a sparse understory. Soils are clayey and shale outcrops are common.

The desert grasslands make up the majority of the project area. Warm-season grasses, especially alkali sacaton (*Sporobolus airoides*) and galleta grass, are the prevailing forage species. At the time of the survey, annual plants also were abundant; the most common being Russian thistle, common purslane (*Portulaca oleracea*), Madagascar dropseed (*Sporobolus pyramidatus*), matted grama (*Bouteloua simplex*), sixweeks grama (*Bouteloua barbata*), and various species of sandmat (*Chamaesyce* spp.). Numerous clay playas are scattered throughout the area; these tend to collect much of the water running off the Chuska Mountains and southern hills. This is important because many of these clay bottomlands are overgrazed and have become dominated by cocklebur (*Xanthium strumarium*). This species does well in moist areas and, once established, tends to exclude other species. This forb is toxic to livestock; transects in these areas often contained cocklebur monocultures several acres in size. Some of the rockier areas in the grassland region have small, remnant populations of highly desirable forage grasses including black grama (*Bouteloua eriopoda*), sideoats grama (*Bouteloua curtipendula*), and little bluestem (*Schizachyrium scoparium*).

The following sections provide some recommendations pertaining to fencing, seasonal grazing, forage availability, distribution of water sources, increasing water retention, and monitoring.

6.1 Drought

Precipitation is one of the greatest obstacles to overcome when managing and restoring rangeland. In July 2013 (the month before fieldwork), local precipitation monitoring stations recorded slightly lower than normal precipitation (95 percent of 13-year average). During field sampling in August, the precipitation record improved to normal (100 percent of 13-year average). 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. This was particularly true this season in the Mexican Springs analysis unit. The potential for soil loss due to wind erosion is a concern in lower elevation sites, especially where sand dunes are common. 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 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 14 as the majority of forage plants are warm-season grasses like galleta grass and alkali sacaton. 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, mountain muhly and dropseed species (*Sporobolus* spp.). Important forb and shrub species such as globemallow (*Sphaeralcea* spp.), fourwing saltbush (*Atriplex canescens*), and Stansbury cliffrose 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 most difficult areas to restore will be the low-lying playa areas found in the Tohatchi and Naschitti analysis units, particularly in the areas dominated by cocklebur. Chemical or mechanical control of this species can be followed up with planting more desirable species that do well in moist, clay soils such as Bonneville saltbush (*Atriplex bonnevillensis*) and black greasewood (*Sarcobatus vermiculatus*). Winterfat (*Krascheninnikovia lanata*) is a good restoration option for the drier soils found adjacent to the playas. It is adapted to alkaline soils, is drought tolerant, helps control erosion, and provides excellent forage for livestock and wildlife (Uncompahgre Plateau Project 2007). It is important to use fresh seed as viability is quickly lost. Planting in the winter or early spring tends to produce the best stands (Ogle et al. 2012).

Higher-elevation areas with dense shrubs may require thinning to release the native herbaceous component. Although shrub production is high throughout the study area, shrub populations are not always dense. The lack of native herbaceous diversity is due, in large part, to unmanaged continuous grazing systems. Determining forage production based upon a normal precipitation year allows managers to establish a “ceiling” or carrying capacity for their land. These determinations should not be used to generate stocking rates when precipitation is below normal, especially during drought conditions. In a continuous grazing system, it is difficult to prepare for times of scarce moisture; however, this situation can be partially mitigated by allowing managers to reduce and increase stock numbers based on current resource conditions. Ideally, permits would require an estimate of the current climate and production of the range resource at periodic intervals. Expected precipitation generally falls during late summer and through the winter. If precipitation is low during the winter, then 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 study area. Populations of big sagebrush are fairly dense along the southern edge of the Coyote Canyon analysis unit and portions of the Twin Lakes unit. Broom snakeweed is most concentrated in the northern half of the Mexican Springs unit, particularly in the valleys. 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. In some cases, 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 study 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 study 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). However, Greene's rabbitbrush is not especially abundant in the project area. 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.

6.4 Invasive Species

Russian thistle is an introduced annual forb that is ubiquitous throughout all but the highest elevations in the project area. A second species of concern is cocklebur (*Xanthium strumarium*). This plant is not nearly as widespread as Russian thistle; however, where present, it tends to form dense stands that quickly out-compete more desirable species, it is easily spread, and it is toxic to livestock. Another toxic plant is saltlover (*Halogeton glomeratus*), which is primarily found in the R035XB268AZ ecological site in the Naschitti analysis unit.

Russian thistle

This is a drought-tolerant, disturbance-loving species that does well in sandy soils (Whitson et al. 2002). Although this plant is an invasive species, it does provide forage for sheep and cattle in its immature form and when softened by snow or rain (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 then 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 species of 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.

Cocklebur

This native species does well in low, moist, disturbed areas and grows up to 3 feet tall. Poisonings occur when seedlings are consumed. As plants mature, the foliage becomes rough and loses palatability and toxicity (Cheeke 1998; Soltani et al. 2010). Livestock management should include excluding animals from areas where seedlings are present and adjusting animal numbers to better maintain desirable forage species and prevent overgrazing (Cotton 2009). Control can be achieved using high rates of the herbicide 2,4-D, either as a broadcast spray or more localized spot treatments. The best results are achieved during the spring when conditions are moist and plants are 4 to 6 inches tall (McGinty et al. 2009).

Saltlover

Saltlover is a summer annual that readily invades saline soils, when disturbances remove the pre-existing vegetation. Once established, it can quickly spread and out-compete other species due to its ability to germinate early in the spring, produce large quantities of long-lived seed, resist predation, and withstand harsh conditions (Duda et al. 2003). There also is evidence that this species alters the soil chemistry around individual plants by increasing soil pH, electrical conductivity, and soluble sodium content. This alteration makes it difficult for native species to become re-established even if saltlover plants are removed (Eckert and Kinsinger 1960; Lancaster et al. 1987; Duda et al. 2003).

A second concern is that saltlover is highly toxic to livestock, especially sheep. Sodium oxalate, the lethal component of this species, is sequestered in the leaves and stems and the highest levels are achieved during the fall, winter, and spring when the plant reaches maturity. This also is the time frame when this plant is more likely to be consumed, since desirable forage plants are typically scarce or too dry to be palatable (Whitson et al. 2002; USDA Agricultural Research Service 2006).

Saltlover control is difficult. Seeds, which are abundant, can remain viable in the soil for up to 10 years, requiring annual applications of herbicide for many years to effectively deplete seed reserves (West 1983). In addition to being expensive, this approach is not particularly agreeable as the main herbicide that has proven to be effective is 2,4-D. This chemical, when applied at the rates necessary to control saltlover, also will have a negative impact on native species (Cook and Stoddart 1953). The best approach is to establish alternate species that can grow in saline conditions and compete with saltlover. Two species in particular have successfully become established in saltlover-invaded sites: forage kochia (*Bassia prostrata*) and desert wheatgrass (*Agropyron desertorum*) (Asay and Johnson 1987; McArthur et al. 1990; Stevens and McArthur 1990). Reducing or excluding grazing pressure during the late winter/early spring is important as well to allow desirable species the opportunity to grow and develop prior to consumption. Establishing a diverse, perennial plant community that undergoes light to moderate grazing towards the end of the growing season appears to be the best strategy to prevent saltlover invasions (Keller 1979; West 1983; Blaisdell and Holmgren 1984; Whisenant and Wagstaff 1991).

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, alkali sacaton, muttongrass, and black sagebrush (*Artemisia nova*). 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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