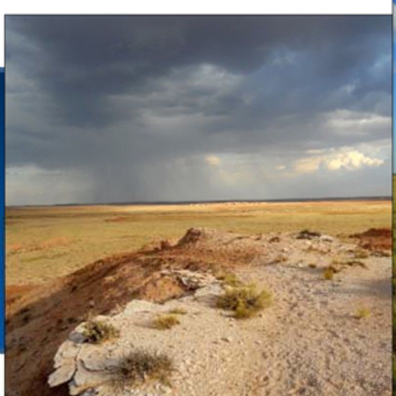
District 9 Vegetation Inventory

Red Mesa Community

Prepared for:

Bureau of Indian Affairs
Northern Navajo Agency
Natural Resources

2014



Ecosphere Environmental Services

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

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ABBREVIATIONS/ACRONYMS

ADW	air-dry weight
AUM	animal unit month
BIA	Bureau of Indian Affairs
BLM	Bureau of Land Management
CRA	Common Resource Area
Ecosphere	Ecosphere Environmental Services
ESD	ecological site description
ft^2	square foot
g	grams
GIS	geographic information systems
GPS	global positioning system
HCPC	historic climax plant community
lb	pound
LMD	Land Management District
MLRA	Major Land Resource Area
NNDOA	Navajo Nation Department of Agriculture
NNDWR	Navajo Nation Division of Water Resources
NRCS	Natural Resource Conservation Service
PNC	potential natural community
SOW	statement of work
USDA	United States Department of Agriculture

ABSTRACT

Ecosphere Environmental Services was contracted by the Bureau of Indian Affairs to collect and compile vegetation data on portions of Land Management District 9, specifically the Red Mesa Community of the Northern (Shiprock) Navajo Agency. The overall study area was approximately 272,229 acres. Data were collected from 454 transect locations during August 2014. 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 three pastures. Carrying capacities and recommended stocking rates were calculated for each pasture and based on available forage. The data were aggregated by ecological site and then analyzed according to the acreage within each soil within each pasture. Spatial analyses of slopes and distances to water sources were layered onto the data to improve stocking rate applications.

Overall, the similarity of the ecological sites in the study area to their historical potential ranged from 0 to 33 percent. Carrying capacity is less than the current permitted numbers.

1. INTRODUCTION

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

1.1 Purpose and Need

Baseline range condition data is critical to establishing quality range management practices. The purpose of the inventory was to provide baseline information about the existing range resource to enable resource managers and permittees to improve and/or maintain the condition of the range resource. The results of this inventory will enable recommendations for adjusted stocking rates in the study area 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). The BIA and the District Grazing Committees coordinate their activities in an effort to utilize and manage the range resources.

1.2.1 BIA Agency Natural Resources Program

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

BIA Range Policy

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

- Comply with applicable environmental and cultural resources laws
- Comply with applicable sections of the Indian Land Consolidation Act, as amended
- Unless prohibited by federal law, recognize and comply with tribal laws regulating activities on Indian Agricultural land, including tribal laws relating to land use, environmental protection, and historic and/or cultural preservation
- Manage Indian agricultural lands either directly or through contracts, compacts, cooperative agreements, or grants under the Indian Self-Determination and Education Assistance Act, as amended
- Administer land use as set forth by 25 CFR 162 – Leases and Permits and 25 CFR 167-Navajo Grazing Regulations
- Seek tribal participation in BIA agriculture and rangeland management decision-making.
- Integrate environmental considerations into the initial stage of planning for all activities with potential impact on the quality of the land, air water, or biological resources

1.2.2 District Grazing Committees

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

The Navajo Nation is organized into 110 Chapters. Chapters, also called communities, are locally organized entities similar to counties and are the smallest political unit. District grazing committees consist of elected representatives from each community who are responsible for monitoring livestock grazing within their respective chapters. District grazing committees approve the carrying capacities of their districts, as discussed in *Navajo Reservation Grazing Handbook and Livestock Laws* published in 1967 by the Navajo Tribal Council.

Individual grazing district committee members are directly accountable to their local chapters and administratively accountable to the Director of the NNDOA. The NNDOA is also responsible for annual livestock tallies to determine if permit holders are in compliance with their permit. In addition, the NNDOA and the district grazing committees are responsible for enforcement of range management and resolving grazing disputes. According to the Navajo Nation Code, Title 3, Subchapter 5, the district grazing committee members are responsible for attending district grazing committee meetings, as well as Chapter meetings, and for ensuring that permit holders respect applicable laws, regulations, and policies. The District Grazing Committee must approve all stocking rates for grazing permits issued by the BIA and "adjust livestock numbers to carrying capacity of ranges in such a manner that the livestock economy of the Navajo Nation is preserved."

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; composition; and location of water, shelter, and minerals (Heitschmidt 1991). The total forage production of a given pasture or grazing area does not necessarily reflect the amount of forage available to livestock; therefore, it is important to recognize specific factors restricting forage availability such as inaccessibility (fences), 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 during seed development. This will remain a problem for rangeland managers as long as livestock grazing permits are issued for year-round grazing. However, Holecheck (1999) argues that stocking rates have a much greater impact on range condition than the season of use.

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

2.1 Geographic Setting

The study area is located within the Colorado Plateau (35) Major Land Resource Area (MLRA). The study area surveyed is characterized by extensive dune fields overlain on badlands and shrub/grassland. A few low mesas and buttes are scattered throughout, and the northern border region contains riparian habitat along the braided channels of the San Juan River.

The Red Mesa Community is located in San Juan County, Utah, and Apache County, Arizona. Topography is broken and rough, and elevations range from about 4,400 to about 6,500 feet. The western boundary mostly parallels Highway 191, while the San Juan River forms the northern boundary. The southern portions of the community cross over Highway 160 and are bounded by a tributary of Chinle Wash. The eastern boundary is formed primarily by Indian Route 35 and White Mesa

A map of the study area (Figure 2-1) is provided in the map on the following page.

Acreages for each compartment were extracted from digital shapefiles provided by the BIA, Northern Navajo Agency. Some areas were removed from the study because they were determined to be non-range. These areas include roads, houses, and water (6,697 acres, not including steep slopes). The exclusion of non-range reduced the analyzed area to 265,533 acres.

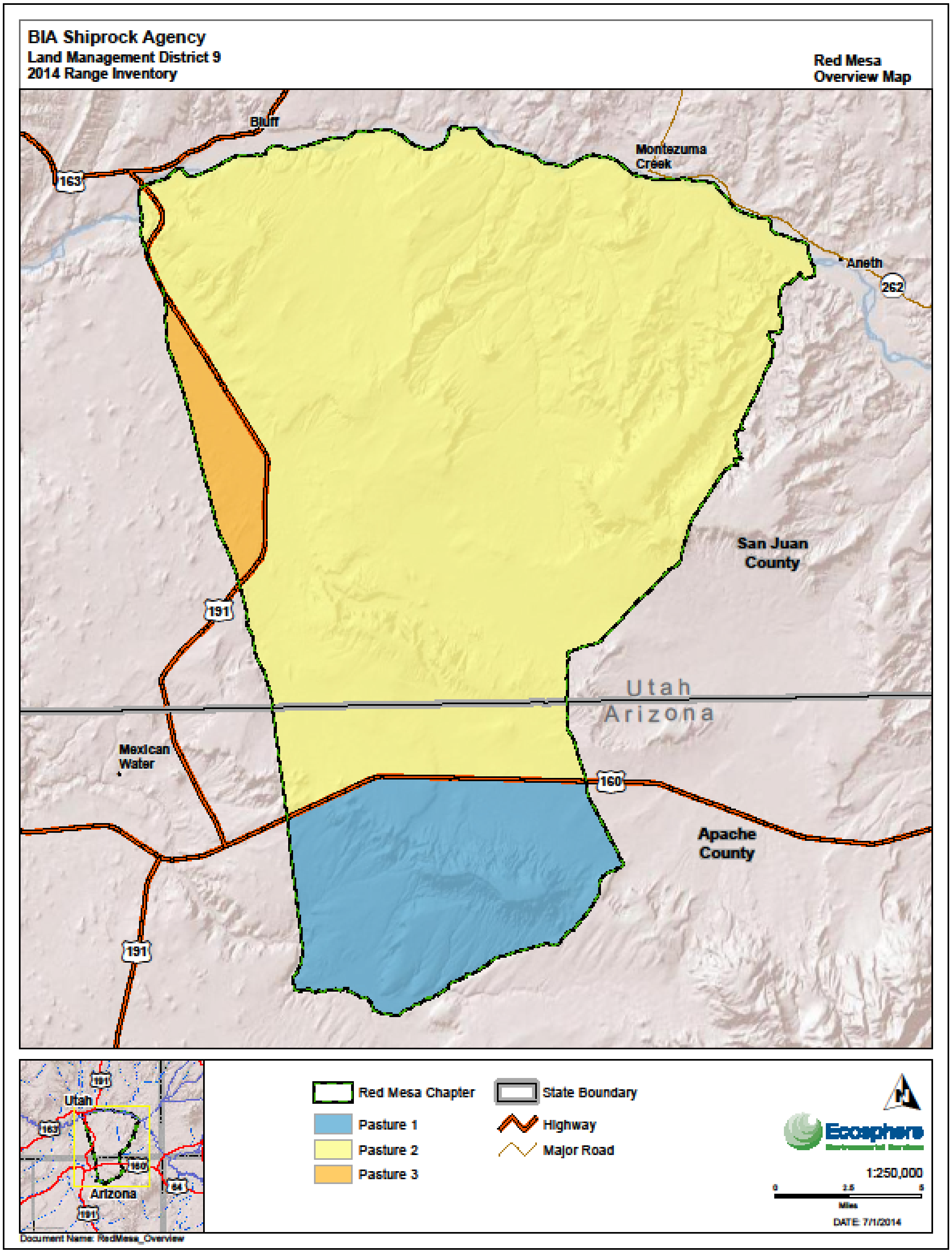


Figure 2-1. Overview Map of Study Area

2.2 Precipitation

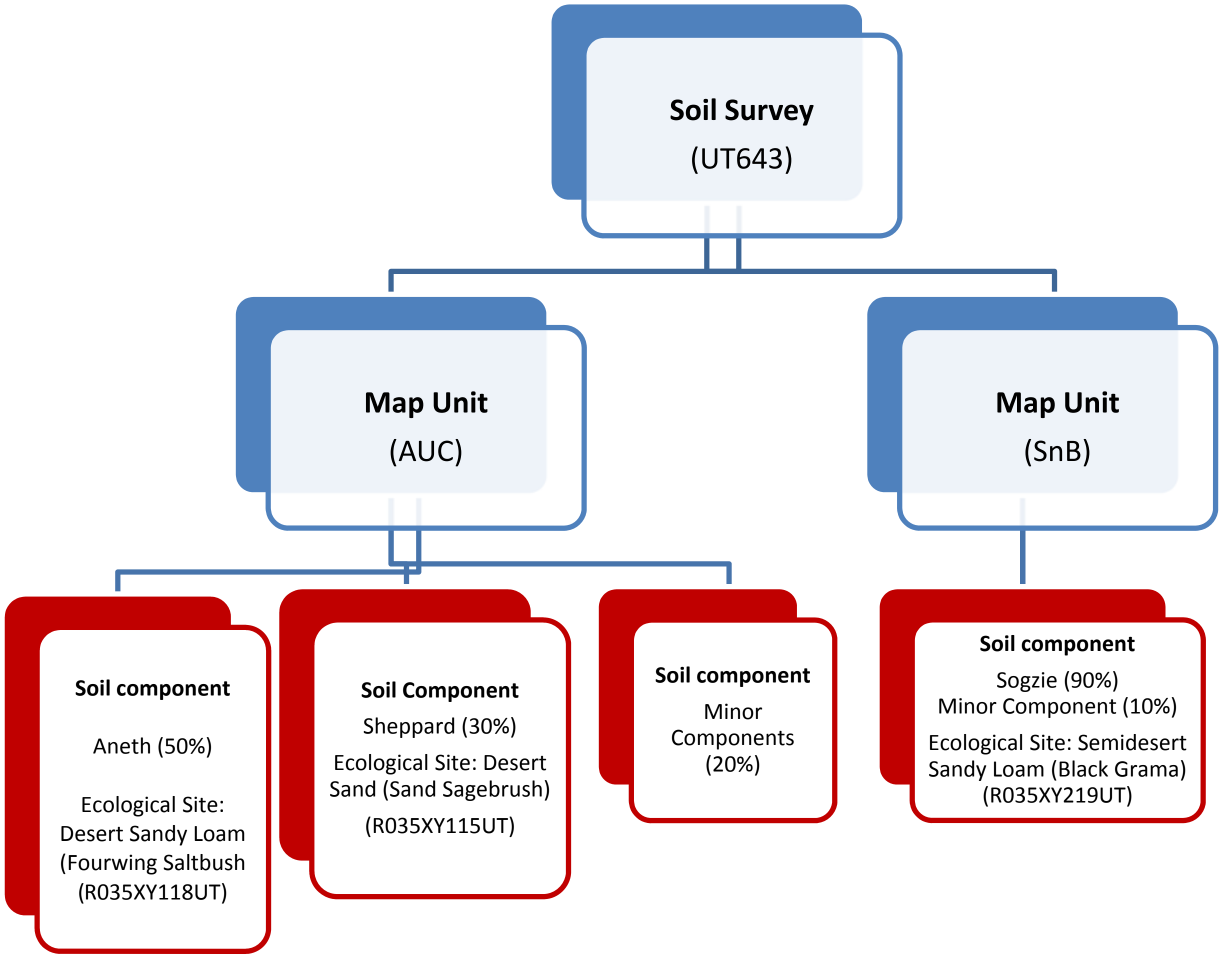
An accurate precipitation monitoring system is essential to range management programs. Biomass production estimates are directly affected by precipitation measurements when reconstructing the plant community to a normal production year. If precipitation is overestimated in the reconstruction factor, the total annual production estimate decreases. If precipitation is under estimated in the reconstruction factor, the total annual production estimate increases. Precipitation gauges are located throughout the Navajo Nation and data are managed by the Navajo Nation Division of Water Resources (NNDWR). The NNDWR provided 14 years of precipitation data averaging all of the gauging stations in Shiprock Agency. The gauging stations are widespread and vary from mountainous areas to the San Juan River area and, therefore, provide a regional average not specific to the study area. The precipitation data are provided as Appendix A.

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 range unit. According to the Agricultural and Range Management Handbook, "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 2003b).

This vegetation inventory study area is located within the boundaries of two soil surveys produced by the United States Department of Agriculture (USDA), Natural Resources Conservation Service: Soil Survey of San Juan County, Utah, Navajo Indian Reservation (UT643) and Soil Survey of Shiprock Area, Parts of San Juan County, New Mexico and Apache County, Arizona (NM717). Each soil survey is Order III mapped, which means it includes soil and plant components at association or complex levels (called map units). Within the map units, finer levels (called soil types) are generally described, but not mapped. Each of the delineated map units contains multiple soil components within it, and the major soil components are correlated with a specific ecological site. Order II mapping would delineate soil types within map units, and boundaries of ecological sites could be determined directly from the soil map. Ecological sites cannot be assigned directly from Order III map information because they are not delineated at that level.

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 one of the soil surveys 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.



Notes: 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 infiltration (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 reference or potential natural community. Reference communities may include non-native plant species and other factors, which differentiate them from an HCPC on the same site.

Ecological sites are directly associated with soil 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 inside a mapped soil complex. The soil components are not mapped. Since each major 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 NRCS Web Soil Survey website (USDA NRCS 2014e). 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 be 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 soil components and ecological sites for each transect were assigned 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 study area are listed below followed by representative photographs of ecological sites that contained transects, with transect identified. Some sites had only one transect located within the ecological site. Many ecological sites contained no transects, especially those with few acres and these ecological sites have no representative photographs. A total of 64 transects could not be assigned to an ecological site as they fell either within a minor soil component or within a site, such as Badland, that does not have a written ecological site description. Ecological site information by analysis unit (pasture) is presented in Section 5 Results. This table and following photographs are listed by consecutive ID number for general reference.

Table 3-1. Ecological Sites in the Study Area

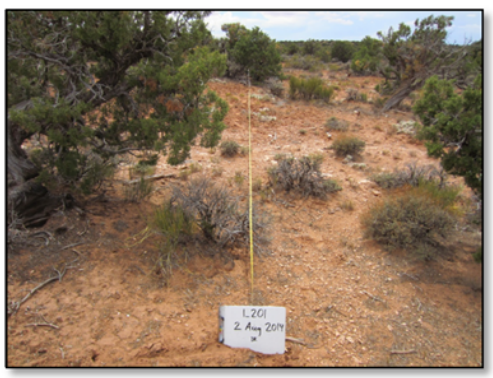
ID[1]	ESD	Description	Number of Transects	Acres (By proportion in Soil Map Unit)
1	F035XG134NM	Pied-Jumo/Quga/Bogr	1	1,055
2	R028AY132UT	Desert Salty Silt (Iodinebush)	0	877
3	R035XA101AZ	Breaks 10-14" p.z.	0	1,959
4	R035XA117AZ	Sandy Loam Upland 10-14" p.z.	7	1,798
5	R035XA118NM	Sandy Upland 10-14" p.z.	0	2,017
6	R035XB021NM	Loamy Upland 7-10" p.z.	1	1,264
7	R035XB022NM	Loamy Upland Sodic	0	34
8	R035XB030NM	Sandy Loam Upland 6-10" p.z.	19	10,191
9	R035XB035NM	Sandy Upland 6-10" p.z.	17	5,979
10	R035XB204AZ	Sandstone Upland 6-10"	0	22
11	R035XB217AZ	Sandy Upland 6-10" p.z.	38	13,434
12	R035XB219AZ	Sandy Loam Upland 6-10" p.z.	3	1,174
13	R035XB224AZ	Clayey Slopes 6-10" p.z. Bouldery	1	901
14	R035XB227AZ	Sandy Loam Upland 6-10" p.z. Saline-Sodic	0	85
15	R035XB228AZ	Sandstone Upland 6-10" p.z. Sodic	0	57
16	R035XB230AZ	Sandstone Upland 6-10" p.z. Very Shallow, Warm	4	2,454
17	R035XB234AZ	Sandstone Upland 6-10" p.z. Warm	0	303
18	R035XB235AZ	Sandy Loam Upland 6-10" p.z. Warm	14	6,169
19	R035XB236AZ	Colluvial Slopes 6-10" p.z. Warm	3	1,288

ID[1]	ESD	Description	Number of Transects	Acres (By proportion in Soil Map Unit)
20	R035XB238AZ	Sandy Terrace 6-10" p.z. Sodic	4	2,090
21	R035XB268AZ	Shale Hills 6-10" p.z.	1	511
22	R035XC316AZ	N/A	0	1,692
23	R035XC335AZ	Sandstone/Shale Hills 10-14" p.z.	0	980
24	R035XY003UT	Alkali Bottom (Greasewood)	0	67
25	R035XY009UT	Alkali Flat (Greasewood)	16	6,994
26	R035XY012UT	Semi-wet Saline Streambank (Fremont Cottonwood)	10	3,459
27	R035XY015UT	Sandy Bottom	7	1,308
28	R035XY109UT	Desert Loam (Shadscale)	2	3,648
29	R035XY115UT	Desert Sand (Sand Sagebrush)	117	52,569
30	R035XY118UT	Desert Sandy Loam (Fourwing Saltbush)	43	43,376
31	R035XY121UT	Desert Sandy Loam (Blackbrush)	54	21,942
32	R035XY130UT	Desert Shallow Sandy Loam (Shadscale)	4	3,460
33	R035XY133UT	Desert Shallow Sandy Loam (Blackbrush)	4	1,947
34	R035XY215UT	Semi-desert Sandy Loam (Fourwing Saltbush)	2	747
35	R035XY219UT	Semi-desert Sandy Loam (Black Grama)	8	4,315
36	R036XB006NM	Loamy	1	184
		Alkaline Soil	0	313
		Aneth	2	228
		Badland	8	36,775
		Bedrock	0	245
		Deep Sandy	0	49
		Gotho	0	64
		Hummocky	0	993
		Monue	0	1,284
		Mota	1	65
		Nakai	0	1,224
		Naki	0	935
		Other	0	25

ID[1]	ESD	Description	Number of Transects	Acres (By proportion in Soil Map Unit)
		Piute	0	1,284
		Riverwash	0	493
		Rock Outcrop	3	13,153
		Shallow and very shallow soils	10	2,819
		Shepherd	22	1,603
		Sheppard	16	2,567
		Sogzie	0	33
		Some shallow or very shallow sandy soils	2	245
		Whit	0	240
	Total		**454**	**265,533**

Notes: p.z. = precipitation zone

1. **F035XG134NM PIED-JUMO/QUGA/BOGR**

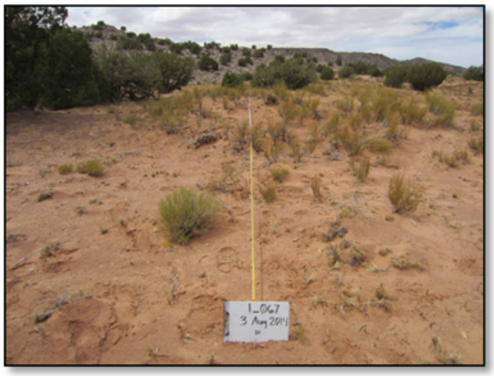


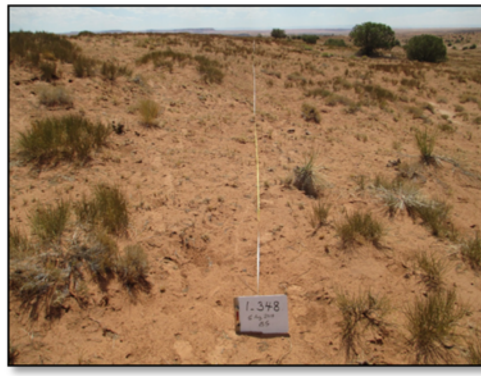
Transect 1_201

2. **R028AY132UTDesert Salty Silt (Iodinebush) -** No transects were located within this ecological site (877 acres are in the study area)

3. **R035XA101AZ Breaks 10-14" p.z. -** No transects were located within this ecological site (1,959 acres are in the study area)

4. R035XA117AZ Sandy Loam Upland 10-14" p.z.

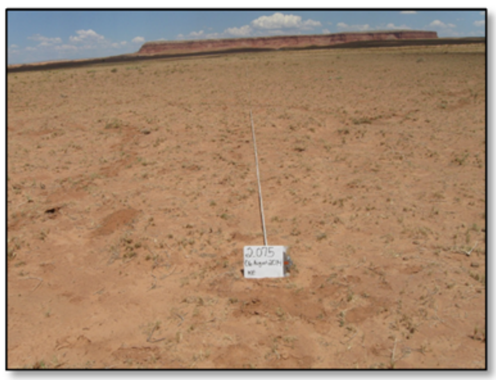




Transects 1_067 and 1_348

5. R035XA118NM Sandy Upland 10-14" p.z. - No transects were located within this ecological site (2,017 acres are in the project area)

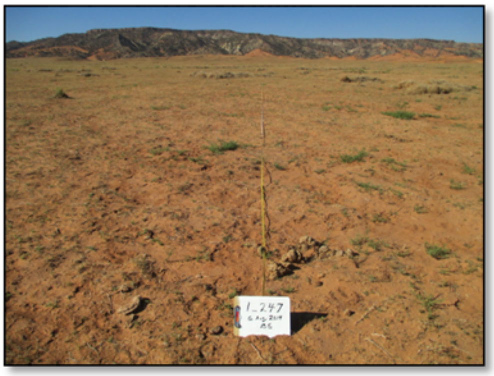
6. R035XB021NM Loamy Upland 7-10" p.z.



Transect 2_075

7. R035XB022NM Loamy Upland Sodic - No transects were located within this ecological site (34 acres are in the study area)

8. R035XB030NM Sandy Loam Upland 6-10" p.z.



Transects 1_247 and 2_363

9. R035XB035NM Sandy Upland 6-10" p.z.

Transects 1_334 and 2_429

10. R035XB204AZ Sandstone Upland 6-10" - No transects were located within this ecological site (22 acres are in the study area)

11. R035XB217AZ Sandy Upland 6-10" p.z.

Transects 1_423 and 2_051

12. R035XB219AZ Sandy Loam Upland 6-10" p.z.

Transects 1_129 and 1_325

13. R035XB224AZ Clayey Slopes 6-10" p.z. Bouldery

Transect 1_337

14. **R035XB227AZ Sandy Loam Upland 6-10” p.z. Saline-Sodic** - No transects were located within this ecological site (85 acres are in the study area)

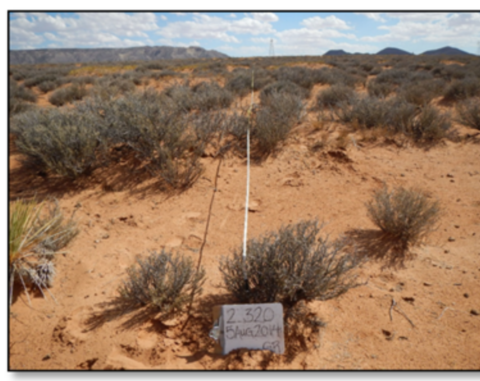
15. **R035XB228AZ Sandstone Upland 6-10” p.z. Sodic** - No transects were located within this ecological site (57 acres are in the study area)

16. **R035XB230AZ Sandstone Upland 6-10” p.z. Very Shallow, Warm**

Transects 1_375 and 1_383

17. **R035XB234AZ Sandstone Upland 6-10” p.z. Warm** - No transects were located within this ecological site (303 acres are in the study area)

18. **R035XB235AZ Sandy Loam Upland 6-10” p.z. Warm**



Transects 1_046 and 2_320

19. R035XB236AZ Colluvial Slopes 6-10" p.z. Warm

Transects 1_236 and 2_354

20. R035XB238AZ Sandy Terrace 6-10" p.z. Sodic

Transects 1_246 and 1_198

21. R035XB268AZ Shale Hills 6-10" p.z.

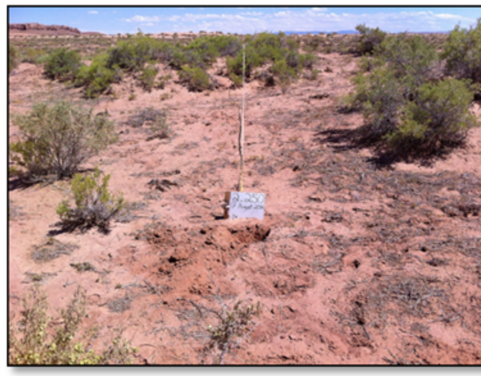
Transect 1_427

22. R035XC316AZ (There is no official name for this site at this time) - No transects were located within this ecological site (1,692 acres are in the study area)

23. R035XC335AZ Sandstone/Shale Hills 10-14" p.z. - No transects were located within this ecological site (980 acres are in the study area)

24. R035XY003UT Alkali Bottom (Greasewood) - No transects were located within this ecological site (67 acres are in the study area)

25. R035XY009UT Alkali Flat (Greasewood)

Transects 2_030 and 2_250

26. R035XY012UT Semiwet Saline Streambank (Fremont Cottonwood)

Transects 2_035 and 2_410

27. R035XY015UT Sandy Bottom


Transects 2_120 and 2_207

28. R035XY109UT Desert Loam (Shadscale)


Transects 2_093 and 2_192

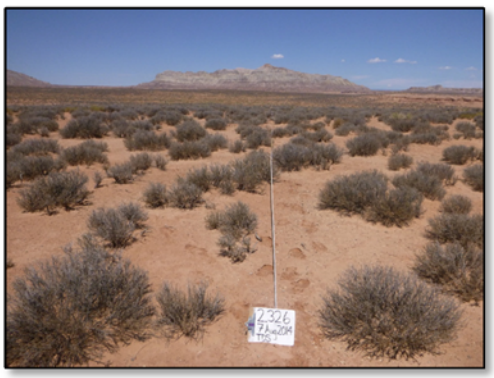
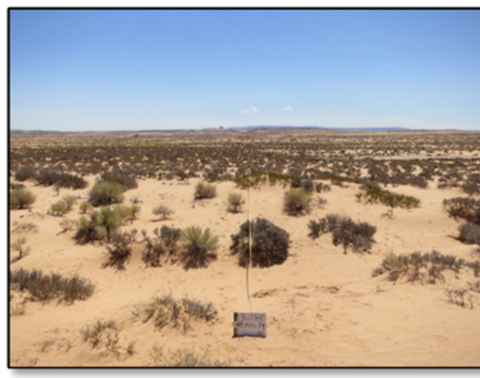
29. R035XY115UT Desert Sand (Sand Sagebrush)


Transects 2_151 and 2_184

30. R035XY118UT Desert Sandy Loam (Fourwing Saltbush)


Transects 2_032 and 2_393

31. R035XY121UT Desert Sandy Loam (Blackbrush)

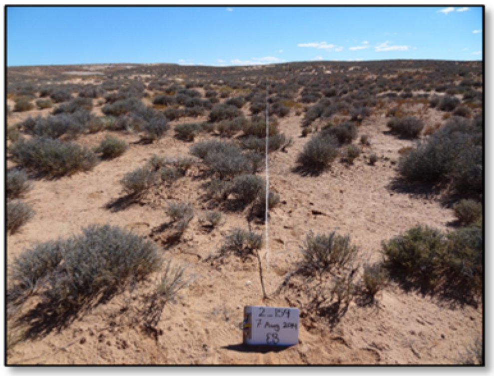



Transects 2_326 and 3_180

32. R035XY130UT Desert Shallow Sandy Loam (Shadscale)

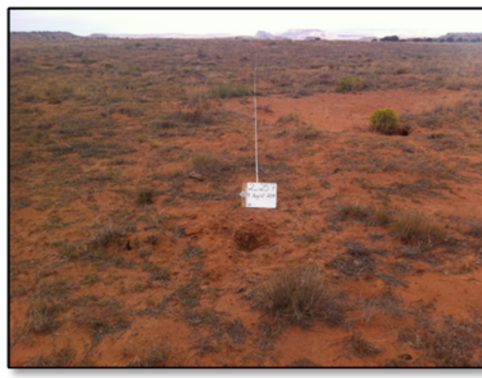

Transects 2_081 and 2_301

33. R035XY133UT   Desert Shallow Sandy Loam (Blackbrush)



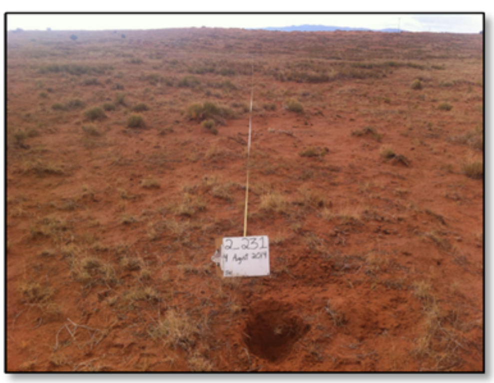
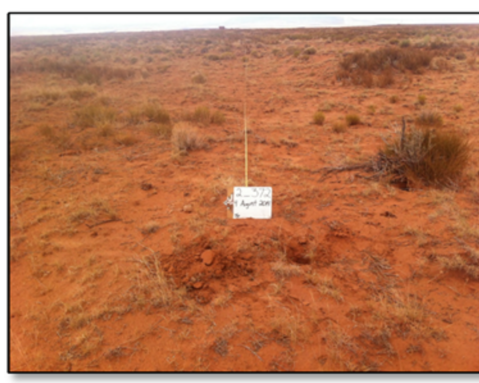

Transects 2_159 and 2_340

34. R035XY215UT   Semi-desert Sandy Loam (Fourwing Saltbush)



Transects 2_146 and 2_257

35. R035XY219UT   Semi-desert Sandy Loam (Black Grama)

Transects 2_231 and 2_372

36. R036XB006NM Loamy

Transect 1_433

4. Methodology

The methods used to collect this data included protocols provided by the BIA and modified to standards used in federally published technical references. The Statement of Work (SOW), provided by the BIA to Ecosphere, described the study design and cited specific methodologies for data collection (Coulloudon et al. 1999a; Habich 2001; USDA NRCS 2003). The field methodology was based on the SOW and the technical references, with modifications approved by the BIA.

4.1 Field Methodology

4.1.1 Transect Establishment

Data collection in the field occurred between 1 August and 10 August, 2014. The BIA provided Ecosphere with predetermined transect locations. The Universal Transverse Mercator coordinates of these transect locations were downloaded into hand held Global Positioning System (GPS) units. The GPS unit was used in combination with topographic maps to navigate by vehicle and foot to the transect locations. Transects were established within ten meters of the GPS coordinates and usually within one or two meters.

Transects consisted of a 200-foot line measured with an open reel tape placed flat and straight along the ground and stretched taut as much as possible. Using field maps and topography as a guide, each transect was placed within a single soil unit and vegetation community. The transect azimuth was randomly determined by selecting a prominent distant landmark, such as a mountain or lone tree. In some cases with no obvious landmark, a pen or pencil was tossed in the air to determine the random direction. The transect azimuth was read with a compass and recorded. The 200-foot tape was then extended along the transect azimuth. Vegetation attributes were recorded from ten plots at 20-foot intervals along the open reel tape. The plots were measured with a square 9.6-foot (ft^2) quadrant frame. The 9.6 ft^2 plot is generally used in areas where vegetation density and production are relatively light (Habich 2001). 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 vegetative attributes measured at each transect were production, ground cover, and species frequency. Aspect, slope, soil texture, and notes were recorded. All plant species names were consistent with the USDA Plants Database (USDA NRCS 2014b).

4.1.2 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. 1999a). 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 double sampling methodology of the USDA, the NRCS modified standards outlined in the SOW, and the modifications generated from the pre-work conference. The double sampling method is detailed in the following sections.

4.1.2.1 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 (*Achnatherum hymenoides*) may be visually estimated to equal 10 grams (g). This clump of grass is then harvested and weighed with a hand scale to determine actual weight. This process is repeated until 10g 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.

4.1.2.2 Double Sampling Methodology (Estimating and Harvesting)

Production (in grams) was estimated by counting the weight units of each species in each plot. All plants and parts of plants inside 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).

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 10g 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.

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 10 days or more before re-weighing to convert from green weight to air-dry weight (ADW). The purpose of the double sampling was to correct any variability between the estimation of production and the actual weighed production. This was accomplished by using an estimation correction factor, which is calculated in the post-field data processing.

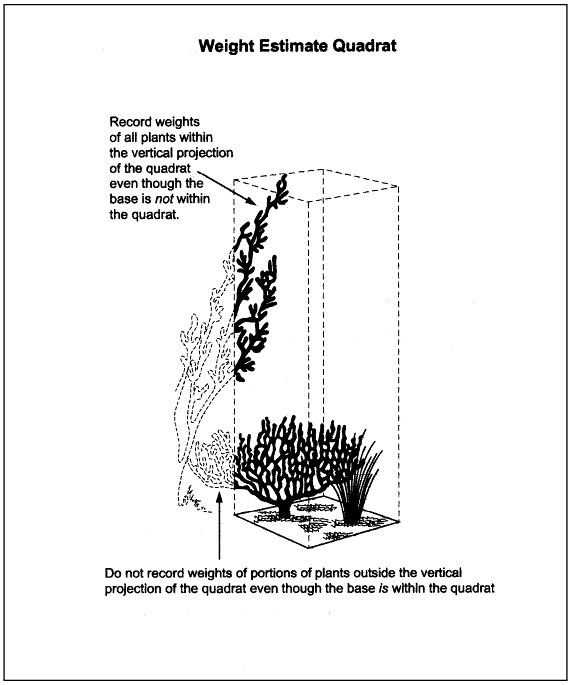


Figure 4-1. Weight Estimate Box

Source: Coulloudon et al. 1999a

4.1.3 Large Shrub Plots

Extended plots were established when the vegetation consisted of "large" shrubs. Neither the SOW or the National Range and Pasture Handbook (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 larger shrubs that are widely distributed and are too wide to be adequately measured within the 9.6 ft^2 frame.

Two extended plots were established at every transect containing shrubs. Shrubs were defined by USDA Plants Database (USDA NRCS 2014b) and in addition to all woody shrubs, included all cacti and yucca. In cases where a species had potential to be a shrub or subshrub, the species in question was placed into a single category (shrub or subshrub) based on the growth form observed in the study area. The shrub species as defined for this project are included in the Plant List in Appendix B. Two extended square plots (0.1 acre) were measured from fixed locations along the 200 foot tape, and only the production weight of new growth on shrub species inside those plots was estimated. The shrub species were not estimated in the ten regular plots.

4.1.3.1 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. 1999a), utilization is determined by visual inspection of 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 utilization of plants. An attempt was made to locate un-grazed plants near the transect. These un-grazed plants were assumed to represent the species approximately 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.

4.1.3.2 Sensitive Plants Protocol

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

4.1.4 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.

4.1.5 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 and 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 evenly (every 4 feet) along a 200–foot measuring tape anchored securely at each end. At each point along the transect, a sighting device (pin flag) was placed perpendicular to the ground along the measuring tape. Three layers of point intercept were recorded as the pin flag was dropped into place: Top Canopy, Lower Canopy, and Soil Surface. The first cover category is determined by the first plant interception of the pin flag. The species of plant that the pin flag hits is recorded as the “Top Canopy.” If no plants are intercepted, “None” is recorded. Up to three additional species intercepted by the pin flag below the top canopy are recorded as “Lower Canopy” layers. If herbaceous or woody litter is intercepted, this is recorded as a lower canopy layer. “Soil Surface” is recorded as either the base of a plant species (See Figure 4.2) or one of the following categories: Rock, Bedrock, Embedded Litter, Duff, Moss, Lichen Crust, or Soil. Bare ground occurs only when the Top Canopy is “None,” and there are no Lower Canopy layers, and the Soil Surface is “Soil.” Measuring cover by points is considered one of the least biased and most objective cover measures (Bonham 1989). Results of the ground cover data analysis are included in Section 5 Results.

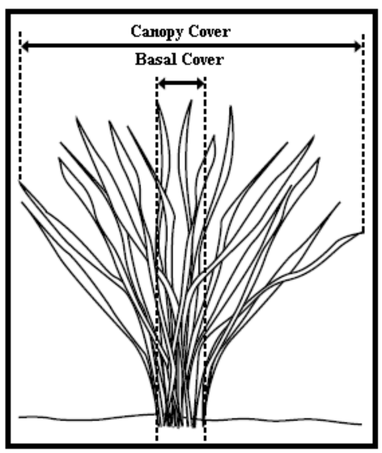


Figure 4-2. Vegetative Cover

Source: Elzinga, Salzer, and Willoughby 1998

4.1.6 Soil Surface Texture Test

At each transect, a small soil pit was dug to expose the soil profile. At diagnostic soil horizons, samples were 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.

4.1.7 Rangeland Health

Rangeland health was evaluated using the qualitative guidelines from the Interagency Technical Reference 1734-6, *Interpreting Indicators of Rangeland Health* (Pellant et al. 2005). The purpose is to measure the degree to which current rangeland conditions are different from what is expected to be there. The current rangeland conditions are compared to a reference state in the ESD. There are 17 condition indicators (such as water flow patterns, soil surface resistance to erosion, invasive plants, etc.) that are combined to evaluate three rangeland health attributes (biotic integrity, hydrologic function, soil and site stability). Not all ecological site descriptions have reference sheets for the 17 indicators, so rangeland health was evaluated only for those sites with reference sheets.

4.2 Post-Field 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 individually 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 analyses included similarity indices, available forage based on forage value and harvest efficiency factors, stocking rates, and carrying capacity.

4.2.1 Reconstructed Annual Production

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

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

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

4.2.1.1 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 10g but the harvested weight was measured as 9g, then all estimates of alkali sacaton for that transect were multiplied by a correction factor of 0.90 as presented below:

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

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

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 4.3.1.1, the green weight of the harvested biomass was 9g. If the dry weight in the lab was measured at 8g, then the percent ADW would be 0.89.

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

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.)

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.

Utilization = 0.9

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

4.2.1.4 Growth Curves

Growth curves are used to reconstruct the aboveground portion of a plant that has not yet reached its full growth potential for the season. The application of a growth curve accounts for the amount of forage that has not yet grown and, thus, was not measured during the vegetation inventory. A 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.

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 curves used in this analysis are associated with the Common Resource Areas (CRAs) found within the project. A CRA is a subdivision of an MLRA and is defined by soils, climate, and landscape conditions. Two CRAs—35.2 and 35.3—were found to be present in the project region. The charts below show the percent production by month for each CRA growth curve.

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

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

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

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

Note: p.z. = precipitation zone

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

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

Then, for the month of August, 21 days would need to be prorated and added to the total. The value is determined by dividing the percent of growth occurring in August (11 percent) by the 31 days that occur during the month of August. This calculation yields a rate of 35 percent per day. The number of days that have occurred up to that date (21) is multiplied by the daily rate (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. 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. All precipitation gauges in Northern (Shiprock) Navajo Agency were used in the calculations to determine the percent of normal production. The 13 years prior to 2014 were averaged and used as an historic comparison. The 2014 water year was 78 percent of the average, or below "normal." It should be taken into consideration that the current long-term drought has been in effect longer than the 13 years of averaged "normal" condition.

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

Percent Normal Production = 1.02

The total weight of the species in the transect is divided by 1.02 to bring the measured water year down to 100 percent. Normalizing the precipitation to an average year helps to 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 80g of alkali sacaton, multiplied by the estimation correction factor for a corrected green weight of 72g. This corrected green weight of 72g was then multiplied by the reconstruction equation:

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

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:

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

The corrected green weight from the example above (72g) multiplied by the reconstruction factor (1.10) results in a total reconstructed annual production of 79.20g.

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 ft^2 to acres (43,560 ft^2 per acre), which calculates into a 1:1 conversion (Coulloudon et al. 1999a). 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.

$$\frac{\textit{30 “bare ground” hits}}{\textit{50 total hits}} \times 100 = 75\%\ \textit{bare ground}$$

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 was averaged by analysis unit.

4.2.3 Calculating Frequency

Species frequency was measured when weights were estimated for all species in each production plot using the intensive method (Herrick et al. 2005). For example, if 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 five most common species (including large shrubs) to occur on transects within each analysis unit is presented in Section 5.

4.2.4 Calculating Similarity Index

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

The plant community that is currently present on a site may never reach its HCPC, but instead may have changed such that its final successional state would result in a Potential Natural Community (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 vegetation inventory 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 reference community. 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/acre of alkali sacaton. Based on the information in the ESD, the allowable production for alkali sacaton is 50 pounds/acre. No more than 50 pounds may be allowed for toward the similarity index for the transect. If the ESD had listed the allowable percentage of alkali sacaton at 200 pounds/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. ESDs list only the values for common plant species; however, the Utah NRCS developed a comprehensive list of species from the Colorado Plateau area. This list was the primary source used to assign forage values to all species recorded in the survey. The list is included with the digital Excel data for this report. The plant list in Appendix B includes the forage values for the least palatable season for different livestock (sheep, goats, cattle). Species are grouped into categories, and each category is weighted according to palatability. The categories recognized by the National Range and Pasture Handbook (USDA NRCS 2003) have been amended to include both toxic and injurious notations in addition to palatability and are as follows:

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

Toxic plants (denoted in tables and in the database with a superscript t) – These plants are poisonous to grazing animals. They have various palatability ratings and may or may not be consumed. Toxic plants may become abundant if unpalatable and if the more highly preferred species are removed.

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

Many species have more than one forage value according to the season of use. For example, scarlet globemallow (*Sphaeralcea coccinea*) is considered preferred by sheep in the spring, but is not consumed in the winter. Northern Navajo agency currently allows for year-round grazing, 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, for sheep. Available forage for cattle would need to be calculated separately.

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, and 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 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 systems (GIS) files from the BIA. Home sites, farmland, and roads were buffered and removed from the total acreage available for livestock grazing. Roads were buffered 1.5 to 15 meters from their center line. Washes and streams were also given a ten foot buffer.

Based on livestock behavior, carrying capacity was adjusted to account for distance to water and the steepness of slopes. Distance to water and slope percent were adjusted incrementally (Table 4-1). Slopes up to ten percent had no reduction in carrying capacity; moderate slopes had a 30 percent reduced carrying capacity, while steep slopes had a 60 reduction in carrying capacity. Slopes that are 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 two miles from a water source Holechek (1988). Areas further than 2 miles from a water source can be considered un-grazeable and that acreage should be removed from stocking rate calculations. Permitting in areas beyond two miles will lead to overgrazing and deterioration.

However, if permittees are hauling water to their stock, this should be considered when adjusting carrying capacity.

BIA recommendations include 100 percent stocking rates and carrying capacity between zero and one mile from a water source, 50 percent between one and two 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 continually 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 sites within each pasture. 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 ecological site of each soil map unit within each grazing unit. Soil map units that had no transects were not included in the GIS analysis. Carrying capacity numbers are derived by dividing the stocking rate by the total acreage of a given ecological site within a pasture.

Stocking rates represent the number of acres needed to support one sheep unit for 1 year. For this project, yearlong numbers are derived from a BIA-approved animal unit month (AUM) of 790 pounds. 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 sheep for a year. The stocking rate is determined by dividing this number by the average amount of available forage in each ecological site within a pasture. 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 year
Amount of forage needed to support one animal unit for a year divided by sheep forage equivalent of AUM (4) = Amount of forage to support one sheep for a year.	9,480/4 = 2,370 lbs per year
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).	2,370/100 lbs per acre = 23.7 acres per year

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

By law (25 CFR §167), the sheep forage equivalent of one animal unit in Northern Navajo Agency is four sheep. In other words, 790 pounds of forage can support one animal unit per month, or four sheep for a month, as shown in Figure 4.3.

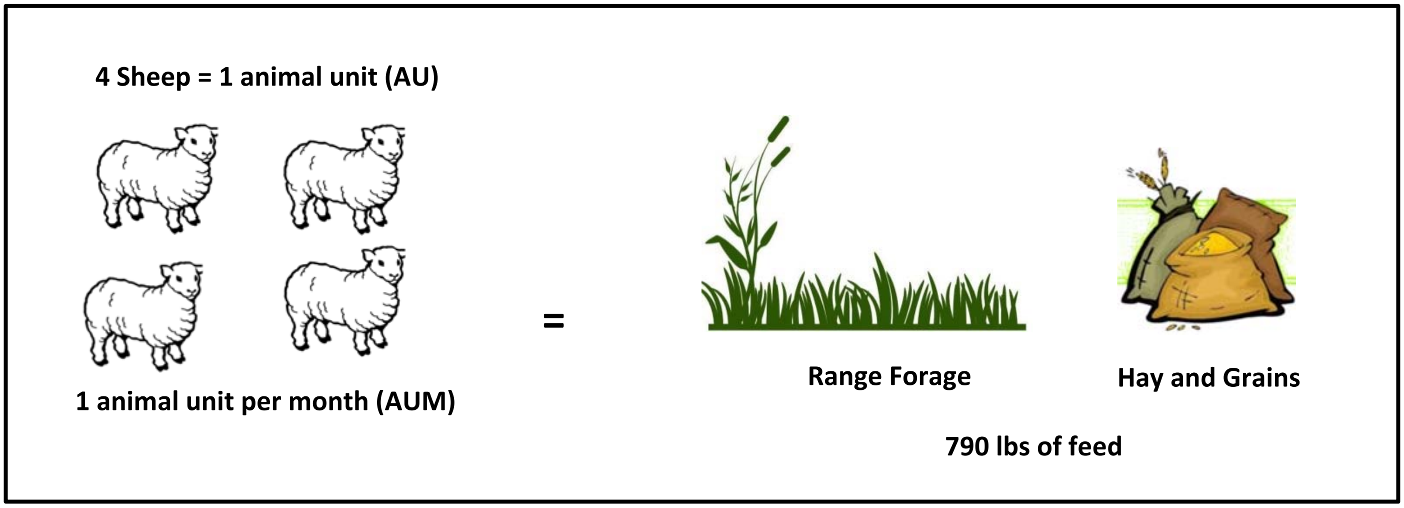


Figure 4-3. Amount of Forage to Support One Animal Unit (AU).

5. RESULTS

A total of 454 transects were located in the District 9, Red Mesa Community study area. The attributes collected at each transect were total annual production, ground cover, and species frequency. From the production data, forage production and initial stocking rates were calculated by ecological sites and soil types in soil map units within each of the three pastures.

The total size of the study area is 272,229 acres. Areas that were considered non-range were removed from the analysis; these included 6,697 acres of roads, home sites, and water. An additional 4,340 acres of land deemed to be inaccessible to livestock (slopes over 60 percent) were also removed. The remaining amount, 261,193 acres, is considered to be grazeable. Of these acres, 18,175 could not be analyzed due to a lack of transects within the ecological sites in each pasture.

The results of the data analysis indicate the carrying capacity of the range resource is currently exceeded. Initial calculations show the slope adjusted carrying capacity to be 315 sheep units for the entire study area. Sections 5 and 6 discuss which areas are in relatively good or poor condition and how to improve the range resource.

5.1 Study Area Summary Results

The results of this study have been arranged into the following categories: initial stocking rates and carrying capacity, 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 (pasture).

Initial Stocking Rates and Carrying Capacity

In general, the derived stocking rates reflect an accurate depiction of available forage. However, in some cases, only one transect was located in an ecological site. If the single transect happened to have extra high or extra low production, the resulting high or low stocking rate was applied to all acres of the ecological site within the 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 analysis unit. Sites without transects, and therefore no carrying capacity, can be identified and range managers can collect site-specific data in those areas in order to assess the available forage and calculate carrying capacity.

A carrying capacity is not evenly dispersed across an analysis unit; therefore, it is important to examine the stocking rates of each ecological site to determine which areas may be able to tolerate more livestock and which areas may be exceeding the carrying capacity.

Available Forage Production

Available forage is the portion of the total reconstructed production classified as preferred, desirable, and emergency forage (excludes toxic, injurious and non-consumed plants). Available forage is used to calculate stocking rates. Forage production is low to extremely low throughout the study area. Available forage averages 4.1 pounds per acre in Pasture 1, 3.5 pounds per acre in Pasture 2, and 4.6 pounds per acre in Pasture 3. The highest producing ecological sites are Rock Outcrop and R036XB006NM in Pasture 1, R035XB021NM in Pasture 2, and R035XY115UT in Pasture 3.

The ecological site 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 initial grazeable acres, initial and adjusted stocking rates and carrying capacities.

Frequency and Composition

A list of the most commonly encountered species by transect and the top contributors of biomass production is included in the results section of each analysis unit. The individual species frequency data (by the ten plots within each transect) are included in the electronic database. Several species are repeatedly found in the top five of the frequency and composition data for most of the analysis units. These include prickly Russian thistle (*Salsola tragus*), James' galleta (*Pleuraphis jamesii*), rubber rabbitbrush (*Ericameria nauseosa*), Indian ricegrass, and Rusby's goldenbush (*Isocoma rusbyi*).

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 9 study area is included for comparison (Figure 5-1). The most represented ground cover category across the study area is bare ground. The highest percentage of bare ground is found in the south central region of Pasture 2, especially in the R035XY115UT Desert Sand ecological site. Active erosion is occurring throughout the study area, but is most concentrated in the badland areas of Pastures 1 and 2. Bare ground is of particular concern in the study area as the prevalence of sandy and clayey soils increases the likelihood of both wind and water erosion.

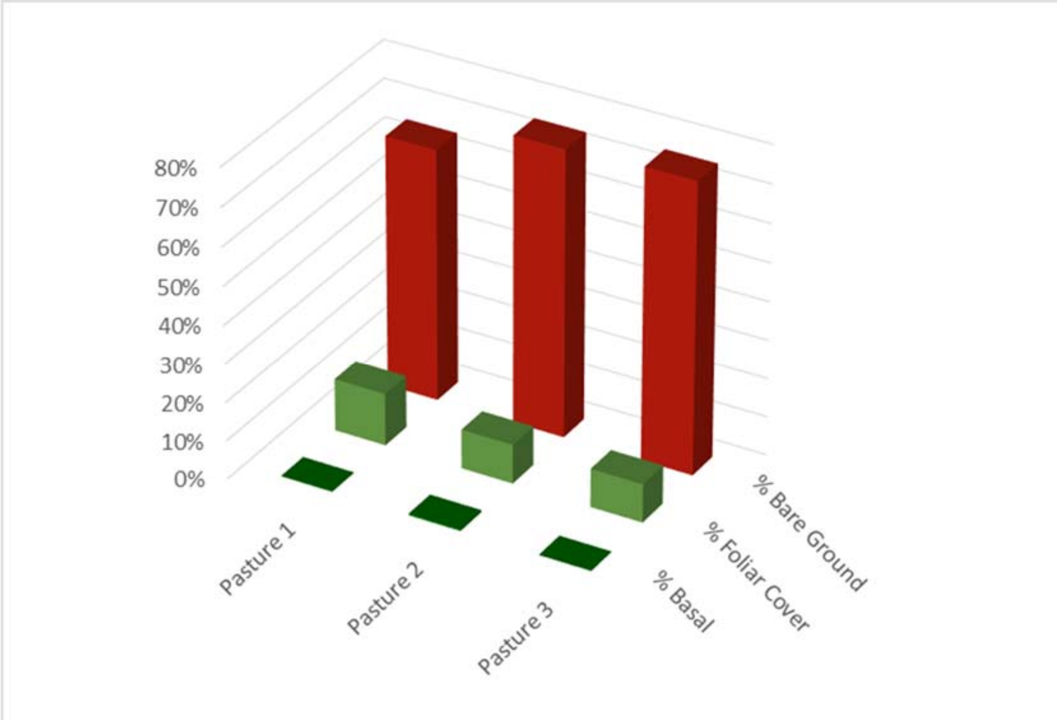


Figure 5-1. Cover Results for Study Area

Rangeland Health

The 17 Indicators of Rangeland Health are explained in Interagency Technical Reference 1734-6, *Interpreting Indicators of Rangeland Health*. The purpose is to measure the degree to which current rangeland conditions are different from what is expected to be there. The current rangeland conditions are compared to a reference state in an appropriate ecological site description. Reference sheets were available for 154 transects in the study area. The 17 Indicator data for each transect is included in the electronic data with this report. Averages of each indicator within an ecological site are presented in charts in the results sections.

Similarity Index

Similarity index is not discussed by pasture as it is only relevant to individual transects. The minimum, maximum and median similarity index is presented in the results plate.

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 that contains a mix of grasses, forbs, and shrubs.

An overall map of similarity indices on the study area is presented in Figure 5-2. When an ecological site description was not available, no similarity index could be calculated. A poor similarity index ranged from 0 to 25 percent, and a fair similarity index ranged from 26 to 50 percent. There were no good (51-75 percent) or excellent (greater than 75 percent) similarity indices.

Results by Pasture

The following sections provide a brief discussion of the results and current plant communities found in each Pasture. This is followed by a plate displaying acreage summaries, cover calculations, similarity index, and initial and adjusted carrying capacity for each ecological site. Maps are also included of each area, showing soils, transect locations, slopes and distance to water.

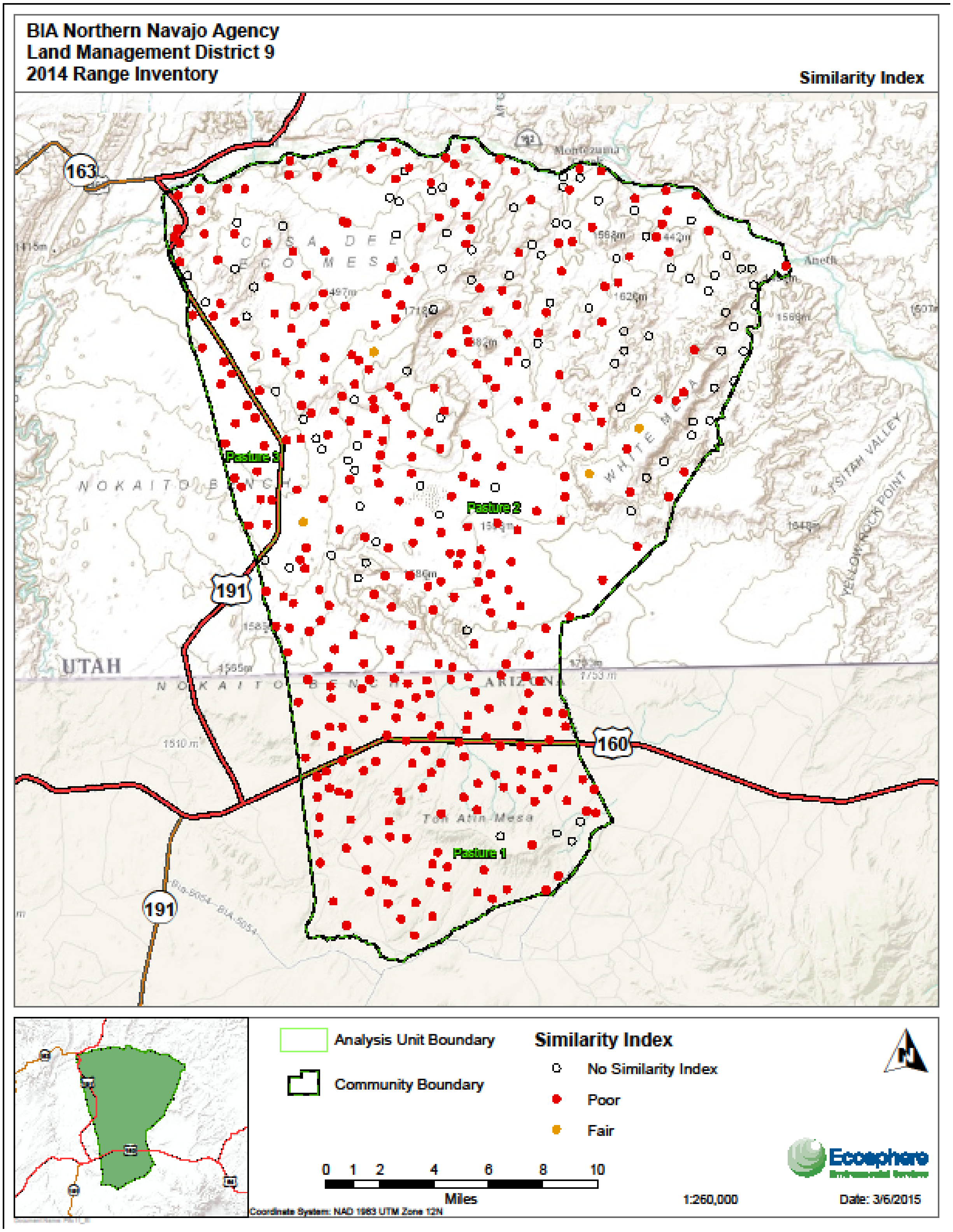


Figure 5-2. Similarity Indices in the Study Area

5.2 Pasture 1

Ecological Site Summary

Pasture 1 is located at the southern end of the study area, below Highway 160. The western third contains large expanses of dunes and loose sands, while much of the remaining land is grass and shrublands. Toh Atin Mesa occupies the center of the pasture. The mesa top contains a mix of shrubs, trees, and grassland while the slopes are steep, have soils derived from shale, and often contain little vegetation. This pasture has 42,440 grazeable acres and 75 transects in 13 ecological sites and one undescribed site (Rock Outcrop).

In terms of available forage, the Rock Outcrop site is, unexpectedly, the most productive site in this pasture. There is no formal description of Rock Outcrop, but it tends to be low in production and high in species diversity with numerous types of shrubs, forbs, grasses and a small amount of tree canopy. The sampled plant community is dominated by shrubs, including broom snakeweed (*Gutierrezia sarothrae*), Greene's rabbitbrush (*Chrysothamnus greenei*), banana yucca (*Yucca baccata*), and fourwing saltbush (*Atriplex canescens*). The primary forage grass is James' galleta (*Pleuraphis jamesii*). Two invasive annuals were also observed: prickly Russian thistle (*Salsola tragus*) and cheatgrass (*Bromus tectorum*).

Only one transect was placed within the R036XB006NM but, without additional transect data, this site currently has the second highest amount of available forage. Soils in this site are deep, well drained, and can be very productive. The reference plant community is predominantly grassland with scattered shrubs. Common species found in the reference community are western wheatgrass (*Pascopyrum smithii*), Indian ricegrass (*Achnatherum hymenoides*), needle and thread (*Hesperostipa comata*), New Mexico feathergrass (*Hesperostipa neomexicana*), fringed sagewort (*Artemisia frigida*), big sagebrush (*Artemisia tridentata*), and fourwing saltbush. Prolonged disturbance, such as grazing, will lead to a decrease in desirable species and an increase in less desirable grasses and shrubs. Juniper (*Juniperus* spp.) and two-needle pinyon (*Pinus edulis*) may invade from adjacent sites, as well. Sample data and field observations indicate that big sagebrush and Cutler's jointfir (*Ephedra cutleri*) have significantly increased on the site. The most frequently encountered forage grass is James' galleta.

Two sites, F035XG134NM and R035XB268AZ, are each averaging less than 1 pound per acre of available forage. A written site description has not yet been developed for the F035XG134NM site, but it tends to occur in woodland settings with low herbaceous production and a tree canopy consisting of two-needle pinyon, juniper, and Gambel oak (*Quercus gambelii*). The sampled transect was located in area with light tree cover, moderate shrub cover, and few herbaceous species. Predominant species include black sagebrush (*Artemisia nova*), big sagebrush, Greene's rabbitbrush, joint fir (*Ephedra* spp.), broom snakeweed, and annual forbs. The R035XB268AZ site is located on fairly steep slopes with shallow soils. The reference plant community contains a mix of grasses and shrubs such as alkali sacaton (*Sporobolus airoides*), James' galleta, sickle saltbush (*Atriplex falcata*), and mound saltbush (*Atriplex obovata*). Species likely to invade or increase following disturbance are prickly Russian thistle, mound saltbush, sickle saltbush, and shadscale (*Atriplex confertifolia*). Due to the presence of sickle saltbush, which is not expected to occur in the study area, this ecological site description may not be a good fit for the study area but until the description is refined we will include it in our analysis. The sampled location is largely devoid of vegetation with only a few annual forbs and scattered shrubs observed during the survey. Both of these low-producing sites only have one transect, so additional data collection is recommended in order to gain a more complete picture of available forage resources.

Species Frequency and Composition

The most commonly encountered species and the ones contributing the most biomass in Pasture 1 are listed below:

Frequently Encountered Species

1. prickly Russian thistle (*Salsola tragus*) (occurred on 85% of all transects)
2. Indian ricegrass (*Achnatherum hymenoides*) (occurred on 69% of all transects)
3. Cutler's jointfir (*Ephedra cutleri*) (occurred on 60% of all transects)
4. James' galleta (*Pleuraphis jamesii*) (occurred on 56% of all transects)
5. cryptantha (*Cryptantha* sp.) (occurred on 41% of all transects)

Species by Weight (average weight)

1. prickly Russian thistle (*Salsola tragus*) (46 lbs/acre)
2. James' galleta (*Pleuraphis jamesii*) (7 lbs/acre)
3. blazing star (*Mentzelia* sp.) (7 lbs/acre)
4. Indian ricegrass (*Achnatherum hymenoides*) (4 lbs/acre)
5. rubber rabbitbrush (*Ericameria nauseosa*) (4 lbs/acre)

Ground Cover

Pasture 1 has slightly more foliar cover and slightly less bare ground than the other two pastures in the Red Mesa Community, but ground cover is still relatively low, and the amount of bareground is high. Much of the observed active erosion is located in the sandy areas found in the northwestern corner of the pasture.

Rangeland Health

Rangeland health reference sheets have been developed for nine of the ecological sites in Pasture 1. There are 49 transects located within these ecological sites and Table 5-1 shows the degree of departure from the reference community for each rangeland health attribute. All ecological sites have at least one indicator that has been significantly altered from the reference state.

Table 5-1. Rangeland Health in Pasture 1

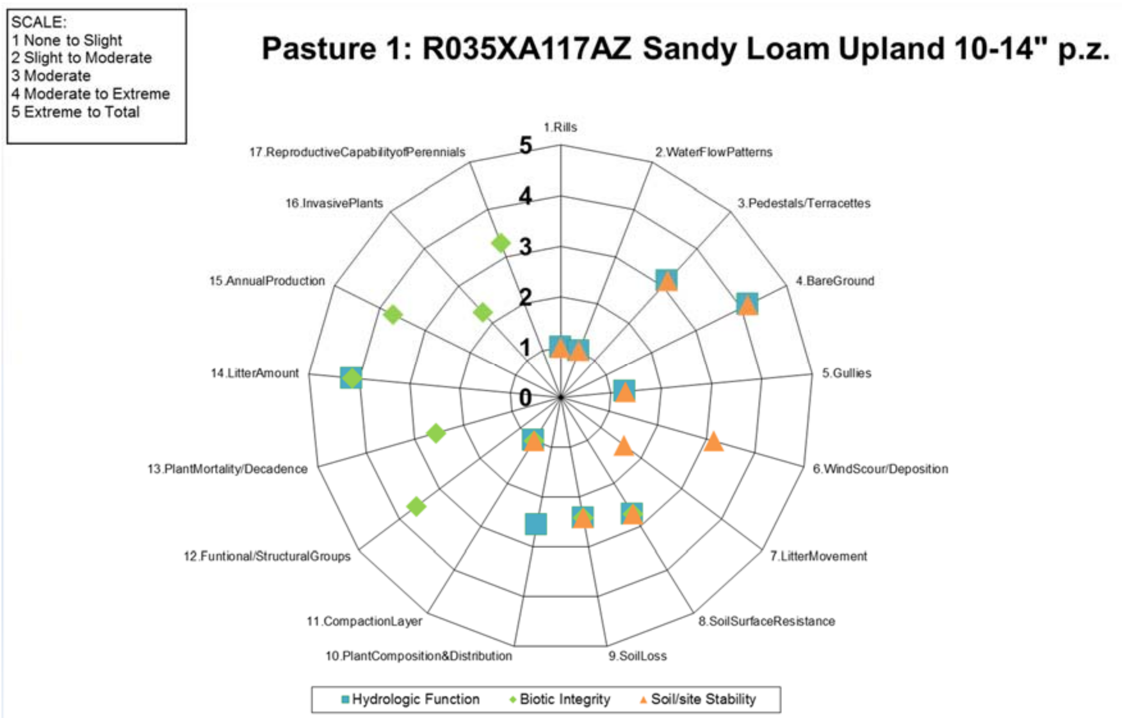
Ecological Site	Departure from Reference Community		
	Soil and Site Stability	Hydrological Function	Biotic Integrity
R035XA117AZ Sandy Loam Upland 10-14” p.z.	Slight to Moderate	Slight to Moderate	Moderate
R035XB035NM Sandy Upland 6-10"	Moderate	Moderate	Moderate to Extreme
R035XB217AZ Sandy Upland 6-10" p.z.	Slight to Moderate	Slight to Moderate	Moderate
R035XB219AZ Sandy Loam Upland 6-10" p.z.	Slight to Moderate	Slight to Moderate	Slight to Moderate
R035XB230AZ Sandstone Upland 6-10" p.z. Very Shallow, Warm	Slight to Moderate	Slight to Moderate	Slight to Moderate
R035XB235AZ Sandy Loam Upland 6-10" p.z. Warm	Slight to Moderate	Slight to Moderate	Slight to Moderate
R035XB236AZ Colluvial Slopes 6-10" p.z. Warm	Slight to Moderate	Slight to Moderate	Slight to Moderate
R035XB238AZ Sandy Terrace 6-10" p.z. Sodic	Slight to Moderate	Slight to Moderate	Slight to Moderate
R035XB268AZ Shale Hills 6-10" p.z.	Moderate	Moderate	Slight to Moderate

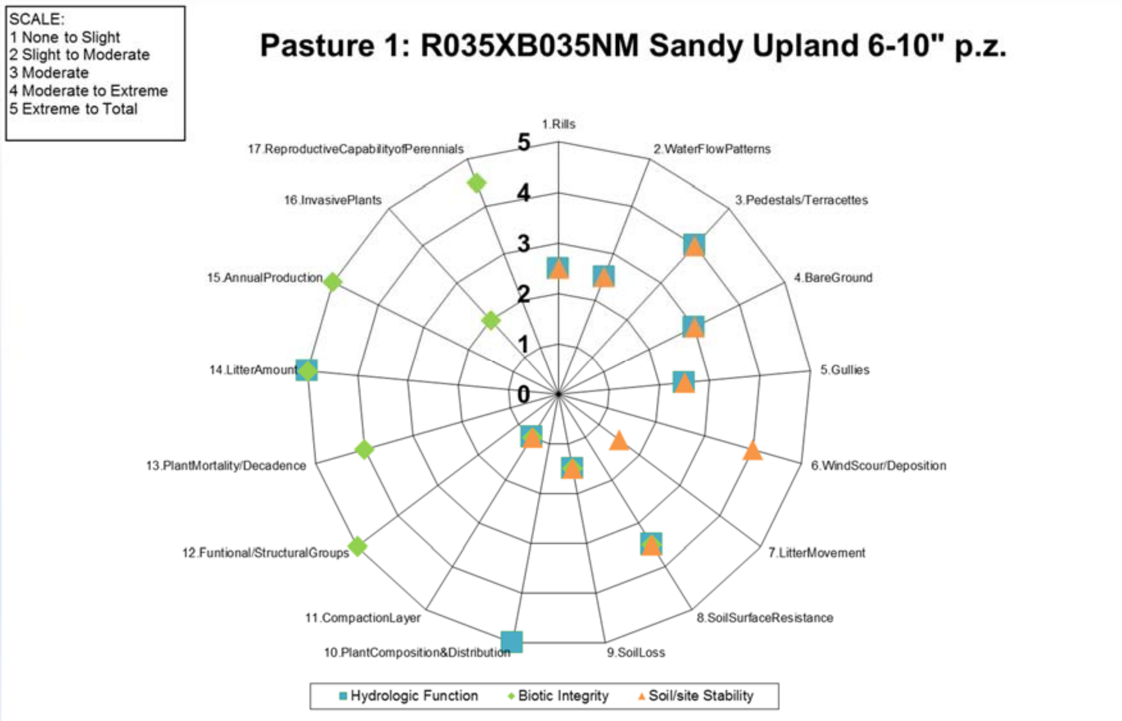
The soil and site stability attribute has seen negative changes in the form of increases in the formation of pedestals/terracettes, amount of bare ground, amount of wind scouring and a decrease in soil surface resistance to erosion. Pedestalling and bare ground are most prominent in the R035XA117AZ, R035XB035NM, and R035XB268AZ sites, while wind scouring is a frequent problem in the R035XB217AZ, R035XB230AZ, R035XB235AZ, and R035XB236AZ sites. Loose soils, prone to erosion, are common in the R035XB035NM and R035XB219AZ sites.

Hydrological function is directly correlated to many of the same indicators associated with soil and site stability, such as bare ground and soil surface resistance, so they, too, display a negative departure from reference conditions. The one “stand alone” hydrological indictor is plant composition and distribution. In all ecological sites, the majority of transects encountered plant communities that contained fewer grasses, and greater spaces between individual grass plants, than described in the reference sheet. In most cases, the grass species have been replaced by shrubs, but in several transects were almost entirely lacking plant cover or the cover consisted primarily of annual forbs.

Most indicators of biotic integrity no longer reflect the description found in the ecological site reference sheets. For example nearly all of the nine ecological sites have seen a significant shift in functional/structural groups. For the most part, this is due to an increase in shrubs and corresponding decrease in perennial grasses. However, some of the sampled plant communities have gone from being dominated by perennial grasses to being composed primarily of annual species. Invasive species, particularly prickly Russian thistle, are prevalent in about half of the nine ecological sites and annual production is lower than expected in nearly all ecological sites. Low production and a high percentage of bare ground translate to less than expected amounts of litter in all but two sites. One indicator, plant mortality/decadence, has remained close to the reference state for all sites in the pasture.

Data for the 17 indicators for each ecological site are included in the following graphs.

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2 Slight to Moderate
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4 Moderate to Extreme
5 Extreme to Total
Pasture 1: R035XB035NM Sandy Upland 6-10" p.z.
1.Rills
2.WaterFlowPatterns
3.Pedestals/Terracettes
4.BareGround
5.Gullies
6.WindScour/Deposition
7.LitterMovement
8.SoilSurfaceResistance
9.SoilLoss
10.PlantComposition&Distribution
11.CompactionLayer
12.Funtional/StructuralGroups
13.PlantMortality/Decadence
14.LitterAmount
15.AnnualProduction
16.InvasivePlants
17.ReproductiveCapabilityofPerennials
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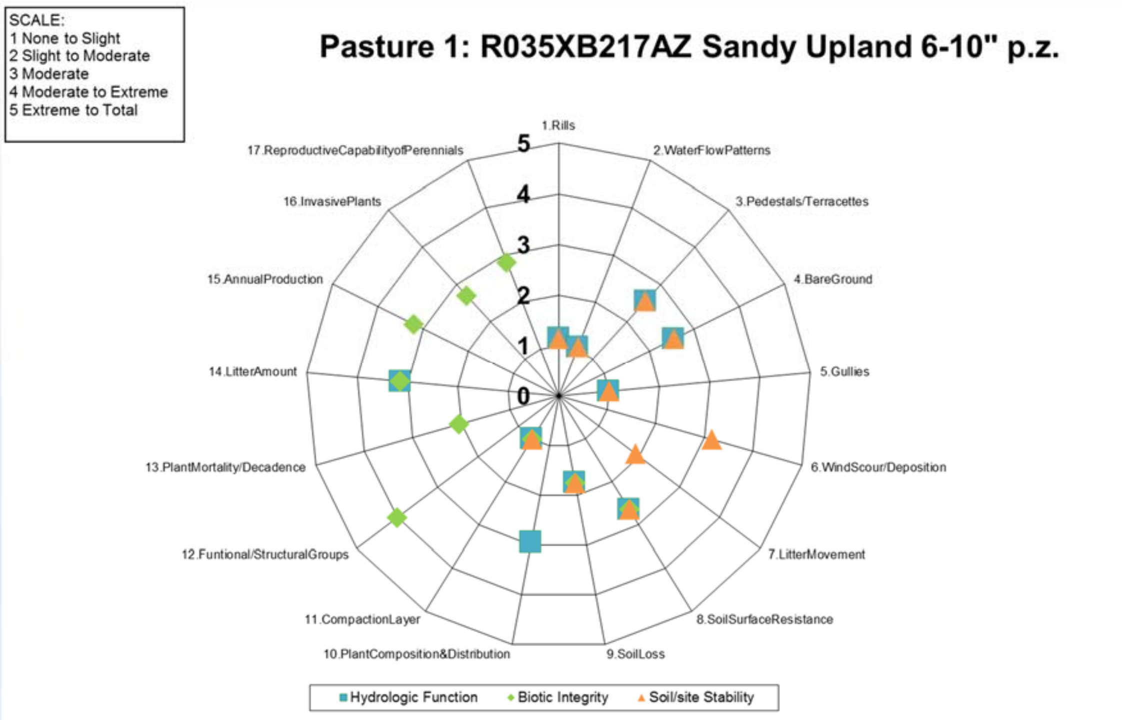
Hydrologic Function
Biotic Integrity
Soil/site Stability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4 Moderate to Extreme
5 Extreme to Total
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1.Rills
2.WaterFlowPatterns
3.Pedestals/Terracettes
4.BareGround
5.Gullies
6.WindScour/Deposition
7.LitterMovement
8.SoilSurfaceResistance
9.SoilLoss
10.PlantComposition&Distribution
11.CompactionLayer
12.Funtional/StructuralGroups
13.PlantMortality/Decadence
14.LitterAmount
15.AnnualProduction
16.InvasivePlants
17.ReproductiveCapabilityofPerennials
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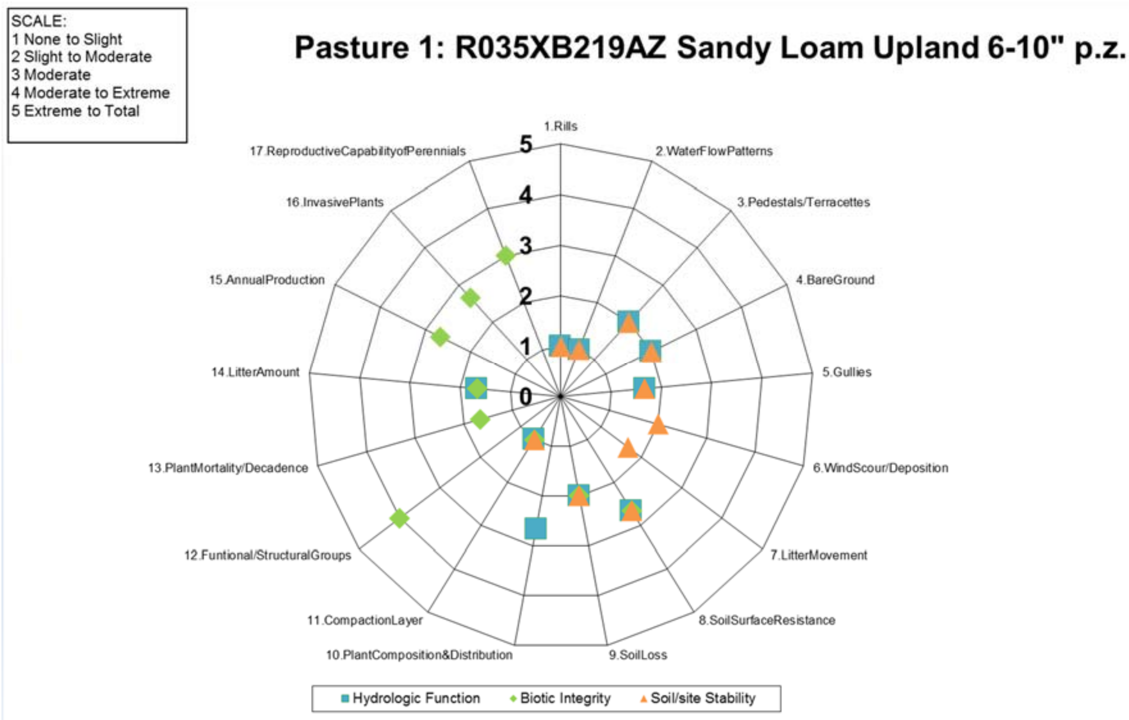
Hydrologic Function
Biotic Integrity
Soil/site Stability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1.Rills
2.WaterFlowPatterns
3.Pedestals/Terracettes
4.BareGround
5.Gullies
6.WindScour/Deposition
7.LitterMovement
8.SoilSurfaceResistance
9.SoilLoss
10.PlantComposition&Distribution
11.CompactionLayer
12.Funtional/StructuralGroups
13.PlantMortality/Decadence
14.LitterAmount
15.AnnualProduction
16.InvasivePlants
17.ReproductiveCapabilityofPerennials
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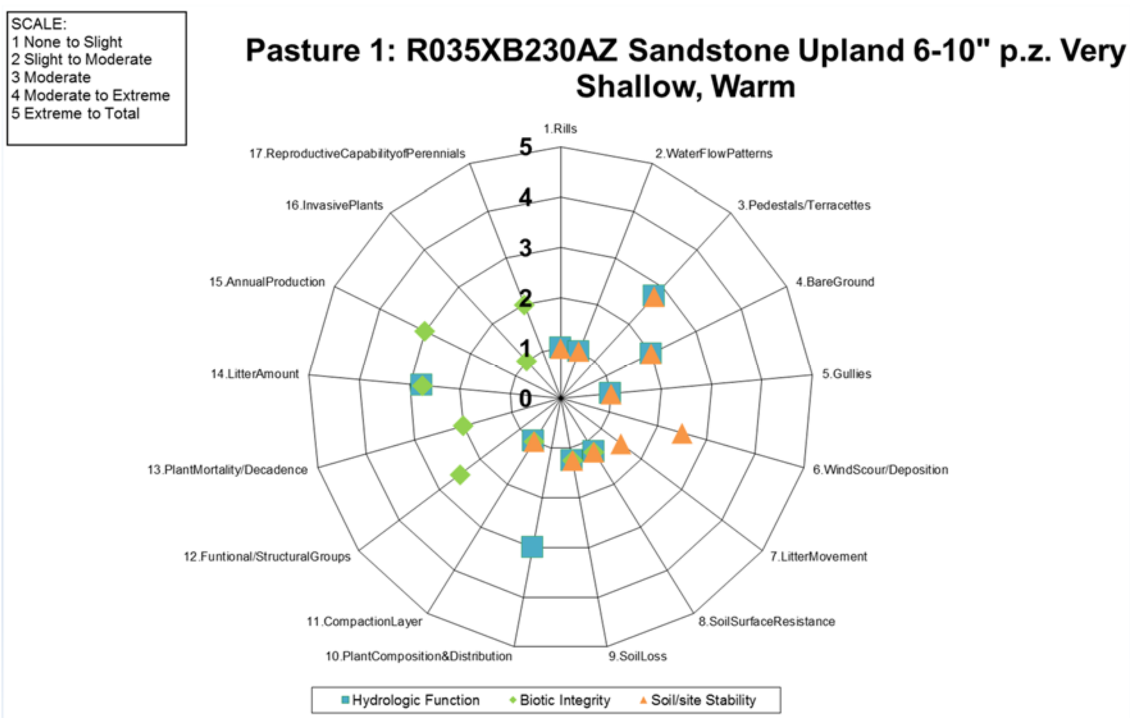
Hydrologic Function
Biotic Integrity
Soil/site Stability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4 Moderate to Extreme
5 Extreme to Total
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1.Rills
2.WaterFlowPatterns
3.Pedestals/Terracettes
4.BareGround
5.Gullies
6.WindScour/Deposition
7.LitterMovement
8.SoilSurfaceResistance
9.SoilLoss
10.PlantComposition&Distribution
11.CompactionLayer
12.Funtional/StructuralGroups
13.PlantMortality/Decadence
14.LitterAmount
15.AnnualProduction
16.InvasivePlants
17.ReproductiveCapabilityofPerennials
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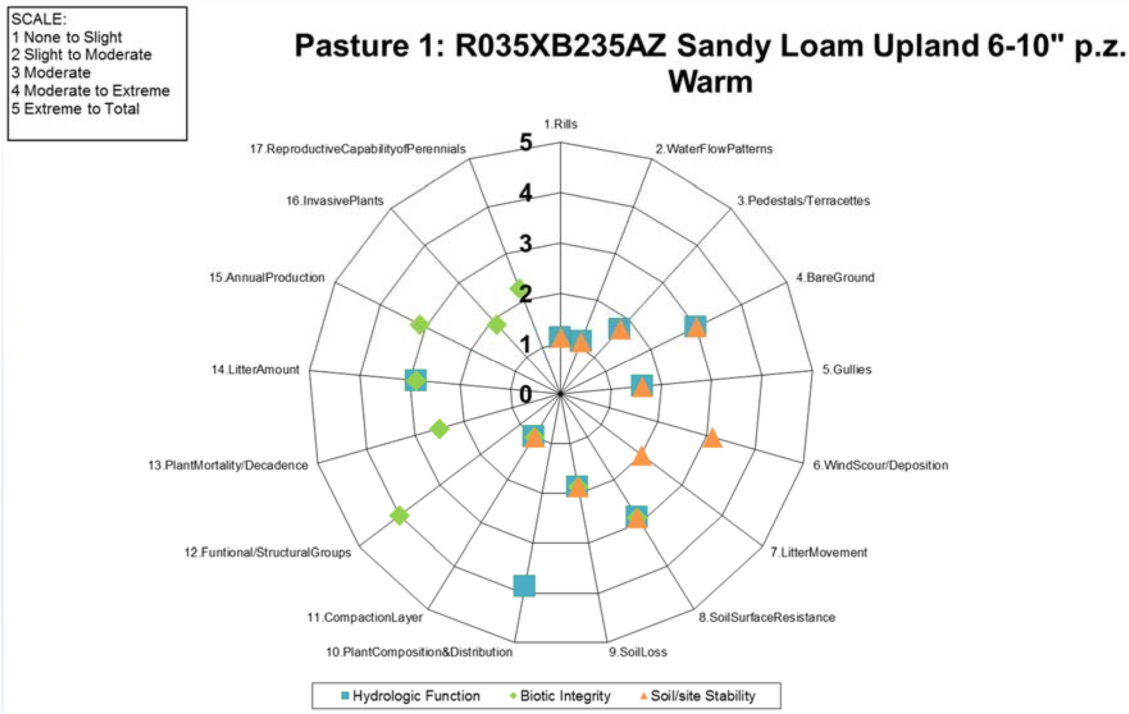
Hydrologic Function
Biotic Integrity
Soil/site Stability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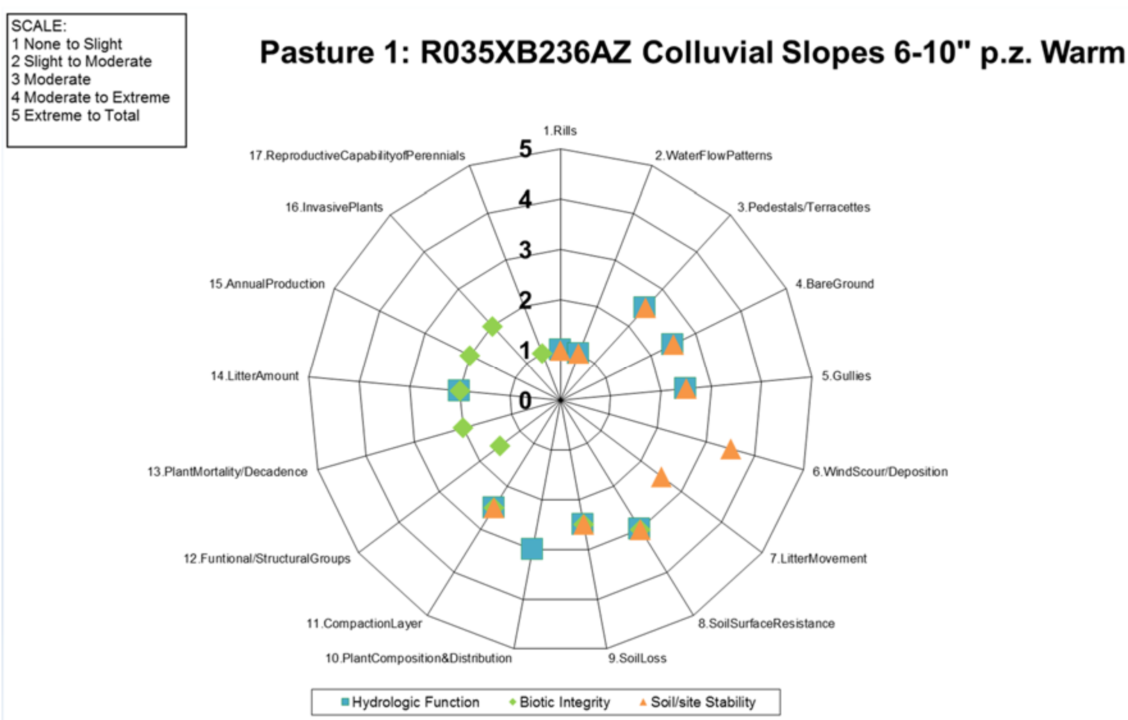
3 Moderate
4 Moderate to Extreme
5 Extreme to Total
Pasture 1: R035XB235AZ Sandy Loam Upland 6-10" p.z. Warm
1.Rills
2.WaterFlowPatterns
3.Pedestals/Terracettes
4.BareGround
5.Gullies
6.WindScour/Deposition
7.LitterMovement
8.SoilSurfaceResistance
9.SoilLoss
10.PlantComposition&Distribution
11.CompactionLayer
12.Funtional/StructuralGroups
13.PlantMortality/Decadence
14.LitterAmount
15.AnnualProduction
16.InvasivePlants
17.ReproductiveCapabilityofPerennials
Hydrologic Function
Biotic Integrity
Soil/site Stability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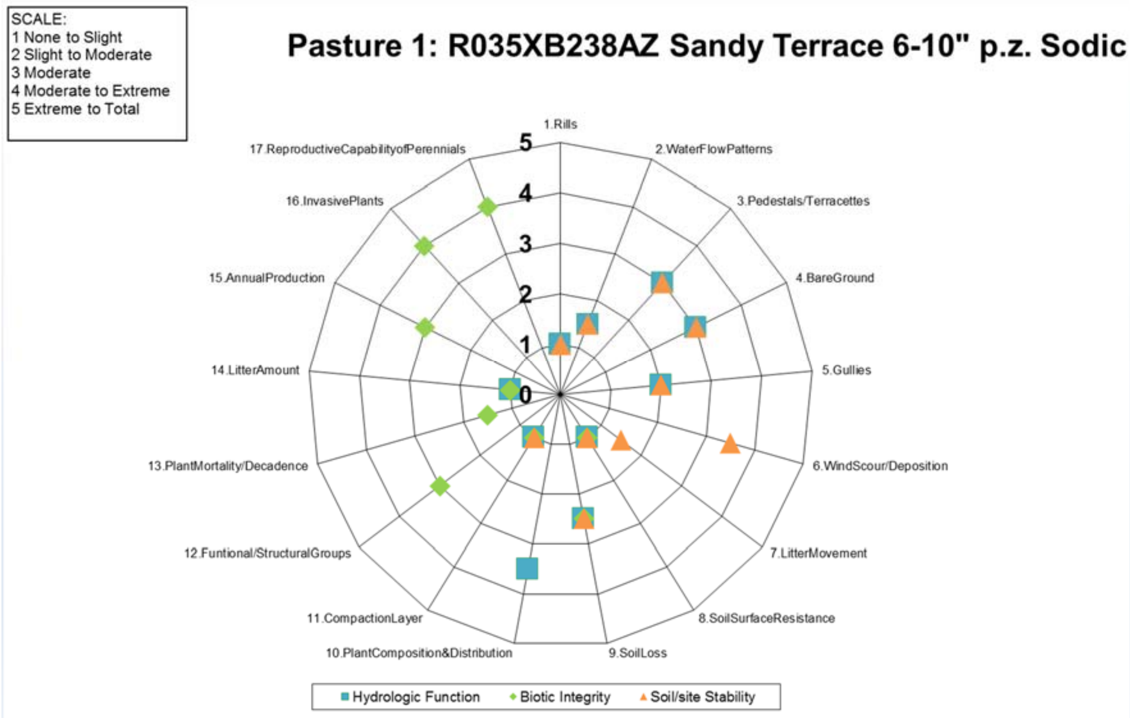
2 Slight to Moderate
3 Moderate
4 Moderate to Extreme
5 Extreme to Total
Pasture 1: R035XB236AZ Colluvial Slopes 6-10" p.z. Warm
1.Rills
2.WaterFlowPatterns
3.Pedestals/Terracettes
4.BareGround
5.Gullies
6.WindScour/Deposition
7.LitterMovement
8.SoilSurfaceResistance
9.SoilLoss
10.PlantComposition&Distribution
11.CompactionLayer
12.Funtional/StructuralGroups
13.PlantMortality/Decadence
14.LitterAmount
15.AnnualProduction
16.InvasivePlants
17.ReproductiveCapabilityofPerennials
Hydrologic Function
Biotic Integrity
Soil/site Stability


SCALE:
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2 Slight to Moderate
3 Moderate
4 Moderate to Extreme
5 Extreme to Total
Pasture 1: R035XB238AZ Sandy Terrace 6-10" p.z. Sodic
1.Rills
2.WaterFlowPatterns
3.Pedestals/Terracettes
4.BareGround
5.Gullies
6.WindScour/Deposition
7.LitterMovement
8.SoilSurfaceResistance
9.SoilLoss
10.PlantComposition&Distribution
11.CompactionLayer
12.Funtional/StructuralGroups
13.PlantMortality/Decadence
14.LitterAmount
15.AnnualProduction
16.InvasivePlants
17.ReproductiveCapabilityofPerennials
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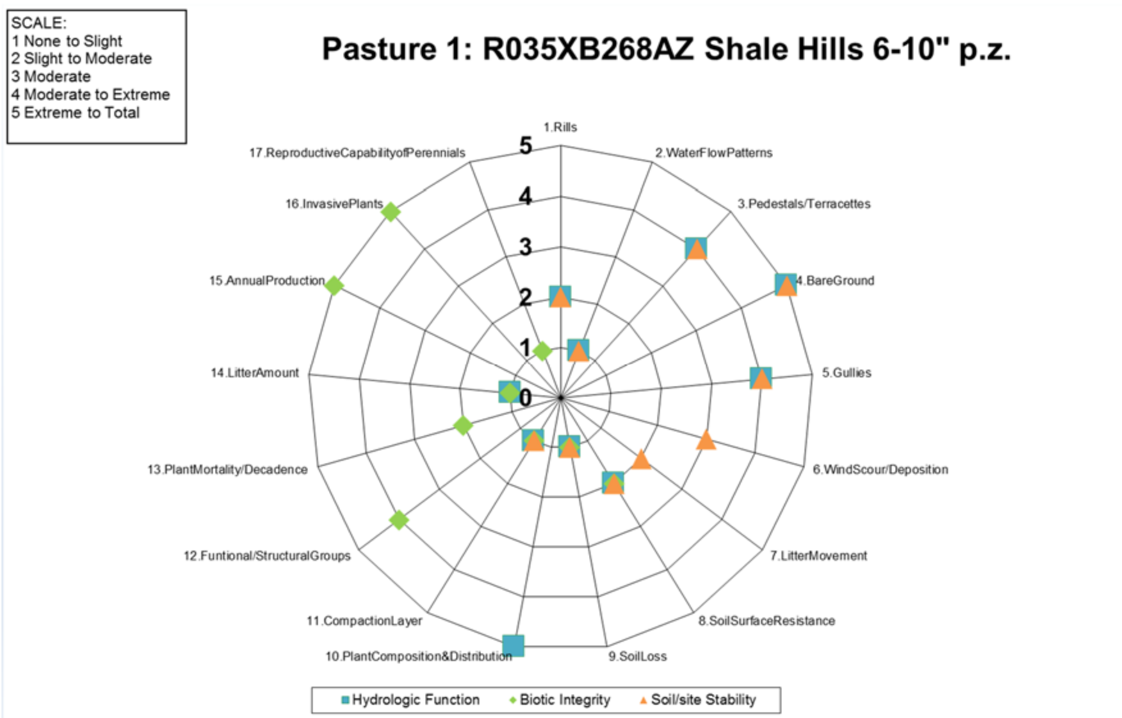
5
Hydrologic Function
Biotic Integrity
Soil/site Stability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2 Slight to Moderate
3 Moderate
4 Moderate to Extreme
5 Extreme to Total
Pasture 1: R035XB268AZ Shale Hills 6-10" p.z.
1.Rills
2.WaterFlowPatterns
3.Pedestals/Terracettes
4.BareGround
5.Gullies
6.WindScour/Deposition
7.LitterMovement
8.SoilSurfaceResistance
9.SoilLoss
10.PlantComposition&Distribution
11.CompactionLayer
12.Funtional/StructuralGroups
13.PlantMortality/Decadence
14.LitterAmount
15.AnnualProduction
16.InvasivePlants
17.ReproductiveCapabilityofPerennials
0
1
2
3
4
5
Hydrologic Function
Biotic Integrity
Soil/site Stability

Analysis Unit 1

Summary of Grazeable and Non-Grazeable Acres in Analysis Unit

TotalAcres		43,683.61
Non-Grazeable Acres	**Developed**	146.23
	Hydro	217.47
	Roads	478.15
	Slope >60	400.96
Range Acres		42,440.78

Summary of Similarity Indices, Cover, and Carrying Capacities

Similarity Indices (%)	
Minimum	0
Maximum	19
Mean	4

Cover (%)	
Foliar Cover	13.55%
Bare Ground	65.39%
Basal	0.24%

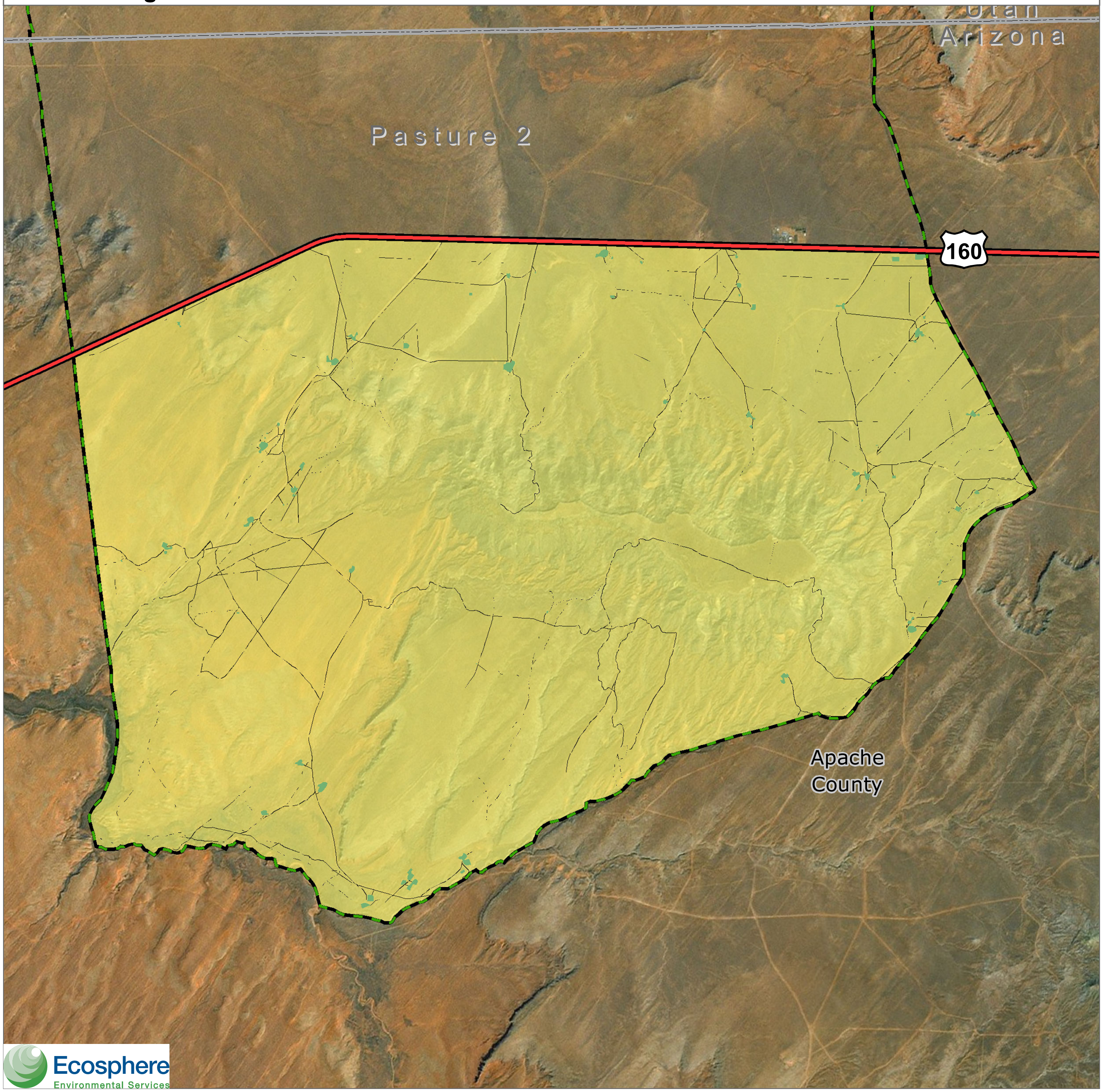
Carrying Capacity (Sheep Unit/Year)	
Initial CC	67.34
Slope Adjusted CC	61.52
Distance to Water CC	40.13

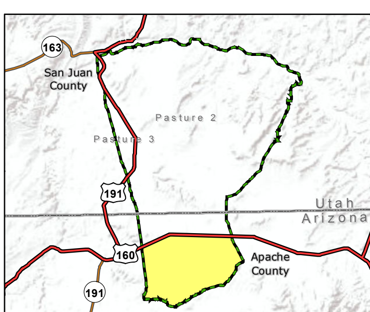
Results by Ecological Site in Sheep Units Year long

Ecological Site	Number of Transects	Percent of Analysis Unit Acres	Average Available Forage (Lbs/Acre)	Acres	Sheep Stocking Rate (Sheep Units)	Sheep Carrying Capacity (Sheep Units per Year
R035XB217AZ Sandy Upland 6-10" p.z.	20	14	4.49	6,077.99	527.84	11.51
R035XB035NM Sandy Upland 6-10"	12	11	3.73	4,800.94	635.39	7.56
R035XB030NM Sandy Loam Upland 6-10"	10	13	5.4	5,591.28	438.89	12.74
R035XB235AZ Sandy Loam Upland 6-10" p.z. Warm	8	11	1.66	4,873.74	1427.71	3.41
R035XA117AZ Sandy Loam Upland 10-14" p.z.	7	4	5.93	1,798.48	399.66	4.5
R035XB230AZ Sandstone Upland 6-10" p.z. Very Shallow, Warm	4	5	2.05	2,092.78	1156.1	1.81
R035XB219AZ Sandy Loam Upland 6-10" p.z.	3	2	1.77	865.86	1338.98	0.65
Rock Outcrop	2	9	11.4	4,122.90	207.89	19.83
R035XB236AZ Colluvial Slopes 6-10" p.z. Warm	2	3	3.78	1,120.59	626.98	1.79
R035XB238AZ Sandy Terrace 6-10" p.z. Sodic	2	3	3.12	1,447.26	759.62	1.91
F035XG134NM Pied-Jumo/Quga/Bogr	1	2	0.29	1,055.06	8172.41	0.13
R035XB224AZ Clayey Slopes 6-10" p.z. Bouldery	1	2	2.29	784.41	1034.93	0.76
R036XB006NM Loamy	1	<1	9.53	183.72	248.69	0.74
R035XA101AZ Breaks 10-14" p.z.	0	4		1,959.24		
Riverwash	0	<1		30.61		
R035XA118NM Bottomland	0	5		2,017.30		
R035XB021NM Loamy Upland 7-10”	0	<1		356.73		
R035XB022NM Loamy Upland sodic	0	<1		34.01		
R035XB227AZ Sandy Loam Upland 6-10" p.z. Saline-Sodic	0	<1		85.40		
R035XB228AZ Sandstone Upland 6-10" p.z. Sodic	0	<1		56.94		
R035XB234AZ Sandstone Upland 6-10" p.z. Warm	0	<1		303.48		
R035XB268AZ Shale Hills 6-10" p.z.	0	1		511.01		
R035XC316AZ	0	4		1,692.41		
R035XC335AZ Sandstone/Shale Hills 10-14" p.z.	0	2		979.62		

2014 Range Inventory
BIA Northern Navajo Agency
Land Management District 9

Red Mesa Chapter
Pasture 1





Analysis Unit Boundary

Community Boundary

State Line

Non Grazeable Range

Developed

Hydrology

Roads

0 2.5 5

Miles

1:100,000

Date: 2/10/2015

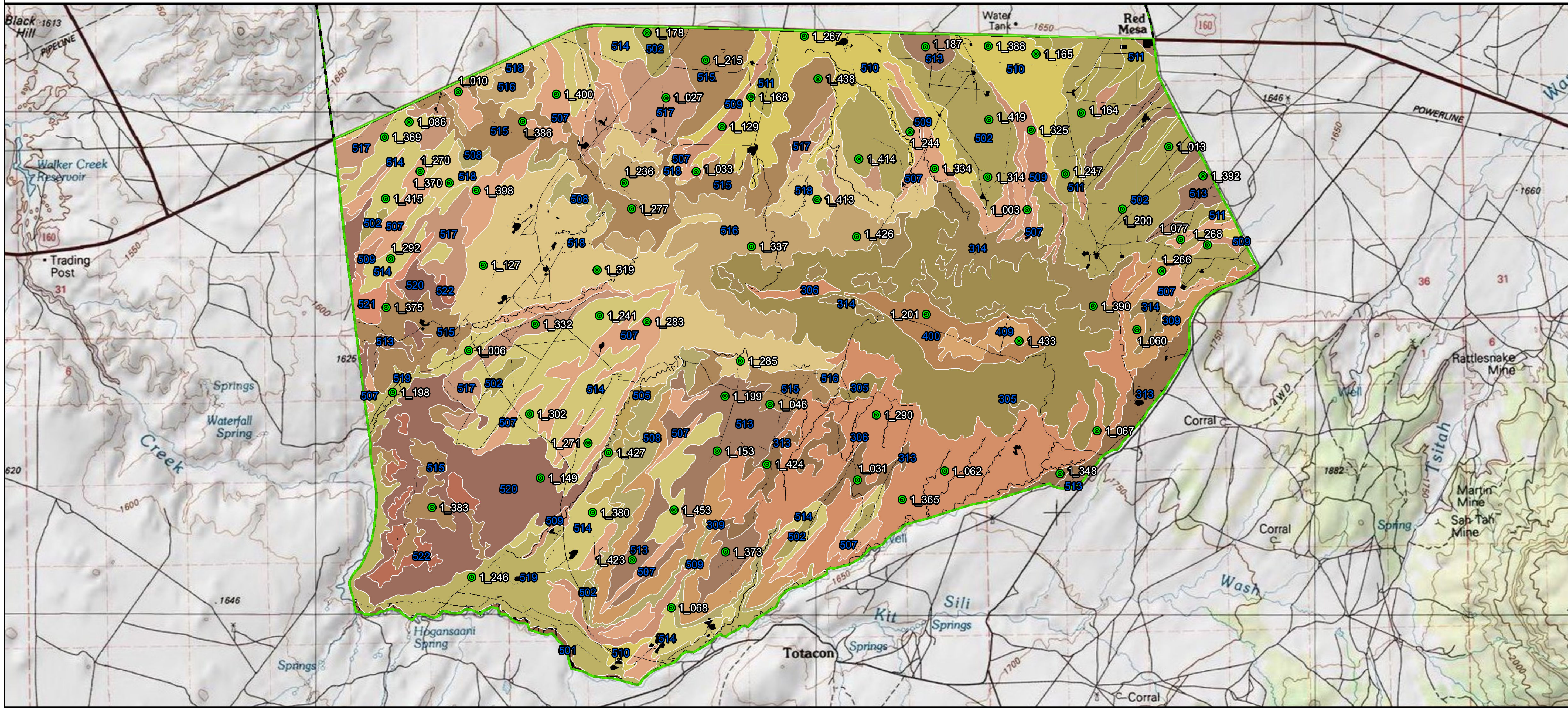
Coordinate System: NAD 1983 UTM Zone 12N

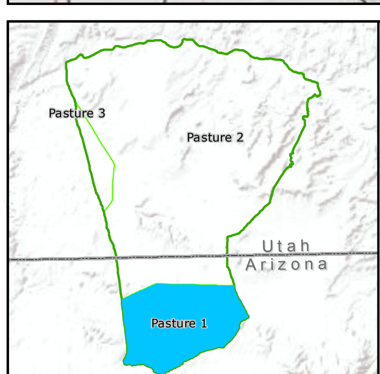
Document Name: P8X11_UNIT1

2014 Range Inventory
BIA Northern Navajo Agency
Land Management District 9
Red Mesa Chapter, Pasture 1

Total Acres: 43,684
Grazeable Acres*: 42,441
*Total acres minus non grazeable areas and areas with > 60% slope.

Total Annual Carrying Capacity: 67 Sheep





Coordinate System: NAD 1983 UTM Zone 12N

Transect Location
Analysis Unit Boundary
Community Boundary
Non Grazeable Range
Soil Map Unit

0 0.5 1 2 3 4 5
Miles

1:75,000

Ecosphere Environmental Services

Date: 2/10/2015

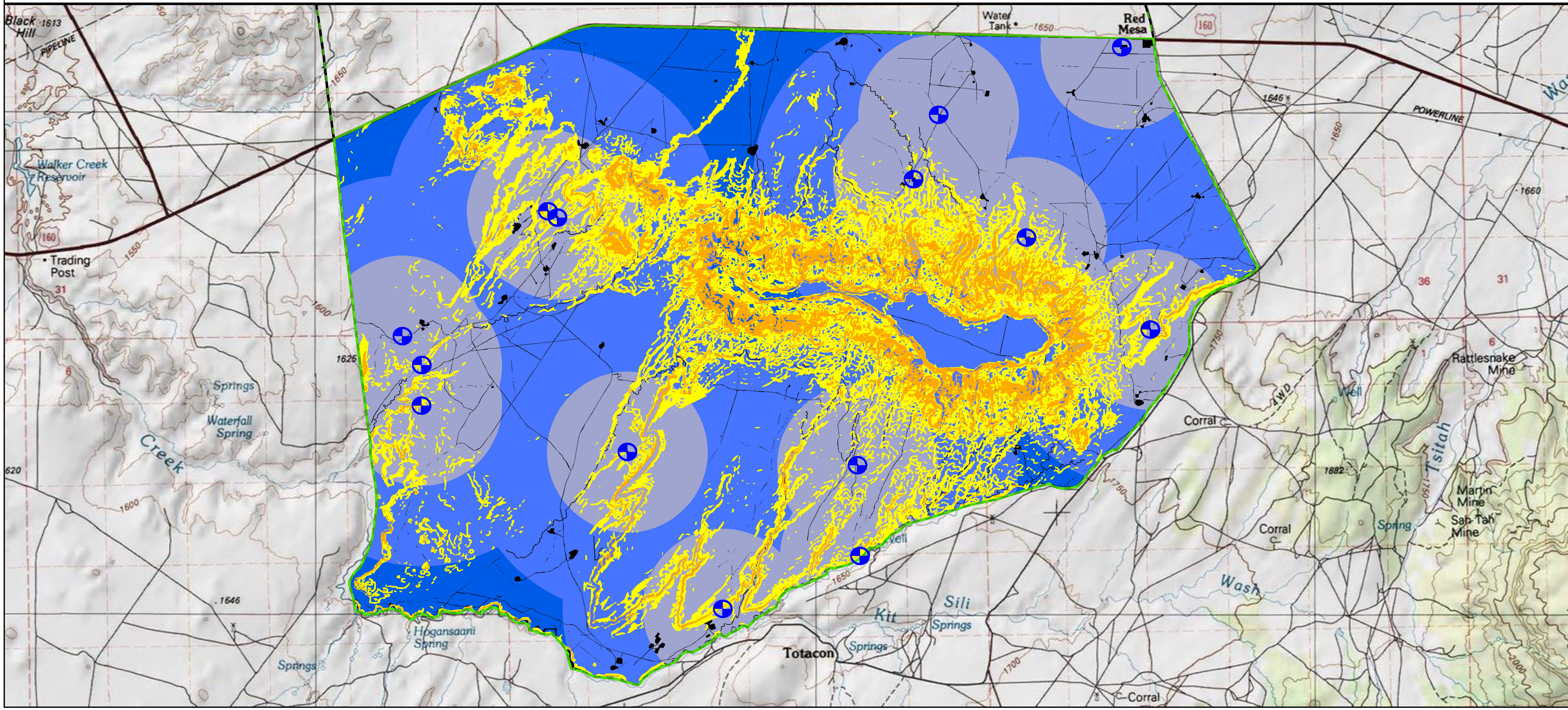
Document Name: L11X17_Soils_InitialCC_1and2

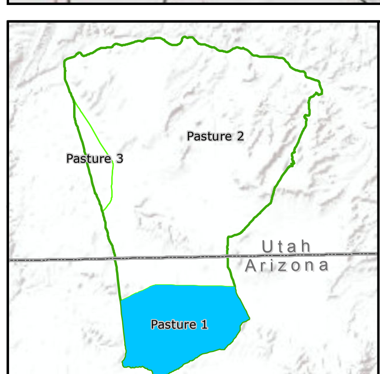
2014 Range Inventory
BIA Northern Navajo Agency
Land Management District 9

Red Mesa Chapter, Pasture 1

Total Acres: 43,684
Grazeable Acres*: 42,441
*Total acres minus non grazeable areas and areas with > 60% slope.

Adjusted Annual Carrying Capacity: 40 Sheep





Water Source
Pasture Boundary
Community Boundary
Non Grazeable Range
State Line

Distance to Water
0-1 Mile
1-2 Miles
>2 Miles

Slope
10 - 30%
30 - 60%
> 60%

0 0.5 1 2 3 4 5
Miles

1:75,000

Coordinate System: NAD 1983 UTM Zone 12N

Ecosphere Environmental Services

Date: 2/10/2015

Document Name: L11X17_SlopeAdjCC_1and21

5.3 Pasture 2

Ecological Site Summary

Pasture 2 occupies much of the study area and stretches from Highway 160, north to the San Juan River. The pasture contains several small mesas, sand dunes, and several badlands areas to the north. There are a total of 219,763 acres, of which 210,254 acres are considered to be grazeable rangeland. A total of 362 transects were placed within 18 ecological sites and eight undescribed sites. In this pasture, there were several transects that were very clearly not located in major soil components associated with ecological sites. Rather than group these transects with a poorly matching ecological site, they were assigned to the minor soil component, but only when the soil, ecological site, and transect data were abundantly clear.

Available forage is highest in the R035XB021NM site, but this is one of the smaller sites in the pasture, and it only has one transect. This site tends to occur on fan remnants below mesas and on stream terraces. Soils range from sandy loam to clay loam and tend to be deep. The reference plant community is a mix of shrubs and grasses. Common species in the reference community include alkali sacaton (*Sporobolus airoides*), Indian ricegrass (*Achnatherum hymenoides*), James' galleta (*Pleuraphis jamesii*), fourwing saltbush (*Atriplex canescens*), and Greene's rabbitbrush (*Chrysothamnus greenei*). Site deterioration leads to an increase in James' galleta, broom snakeweed (Gutierrezia sarothrae), Greene's rabbitbrush and invasion by non-native species like prickly Russian thistle (*Salsola tragus*) and cheatgrass (*Bromus tectorum*). The sampled plant community is comprised primarily of James' galleta, but overall production is low and the location contains large, connected areas of bareground. A small amount of prickly Russian thistle is present, but at this time, non-native species are not abundant.

The Sheppard minor component and ecological sites R035XY219UT and R035XY109UT, all have similar amounts of available forage as well as the highest amounts after the R035XB021NM site. The Sheppard component has very sandy soils and although it does not have an associated ESD in this map unit, it often supports productive grasslands when in a relatively undisturbed condition. At this time available forages mostly being supplied by shrubs such as rubber rabbitbrush (*Ericameria nauseosa*) and Cutler's jointfir (*Ephedra cutleri*). The most commonly encountered forage species is Indian ricegrass. The R035XY219UT site is composed of sandy loam soils which can be calcareous. Perennial grasses dominate the reference plant community and often include Indian ricegrass, needle and thread (*Hesperostipa comata*), James' galleta, grama (*Bouteloua* spp.) and dropseed (*Sporobolus* spp.). Continuous, year-round grazing will cause cool-season grasses to drop out of the plant community and shift the composition towards a warm season dominated grassland. Prolonged disturbance increases the amount of bare ground which opens up the site for invasion by non-native species such as cheatgrass and prickly Russian thistle. The most common forage species in the sampled plant community are James' galleta and Indian ricegrass. Broom snakeweed and prickly Russian thistle were found to occur on most transects, with prickly Russian thistle producing some of the highest amounts of biomass within the site. Warm season grasses and shadscale (*Atriplex confertifolia*) are the primary components of the reference plant community associated with the R035XY109UT ecological site. Disturbance factors lead to an increase in shrubs and a decrease in perennial grasses. Eventually, non-native species such as cheatgrass, prickly Russian thistle, and saltlover (*Halogeton* *glomeratus*) will begin to colonize the site. Transects were located in areas of semi-stabilized sand dunes and shrubs are the most common vegetation type, including Rusby's goldenbush (*Isocoma rusbyi*), broom snakeweed, and black greasewood (*Sarcobatus vermiculatus*). One transect encountered numerous, annual milkvetch plants (*Astragalus* sp.). These plants are generally palatable, but if large amounts are consumed, they can be toxic to livestock. Although shrubs are dominant, several forage grasses were often present in the interspaces, such as alkali sacaton, Indian ricegrass, James' galleta, and tall dropseed (*Sporobolus contractus*).

The largest sites, and the ones with the most transects and highest carrying capacities, are the R035XY115UT and R035XY118UT sites. The high carrying capacities are tied directly to the large acreages as available forage averages less than 3 pounds per acre for both sites. The R035XY115UT site occurs on sandy flats and has a reference plant community dominated by sand sagebrush (*Artemisia filifolia*) and Indian ricegrass. Increases in sandhill muhly (*Muhlenbergia pungens*), rabbitbrush (*Chrysothamnus* spp.), sand sagebrush, broom snakeweed, and annual forbs tend to follow disturbance associated with continuous grazing. Survey data show that the site has deteriorated and much of the production is from prickly Russian thistle, rubber rabbitbrush, sandhill muhly, and broom snakeweed. However, some transects do have a fair amount of more desirable forage species like tall dropseed and fourwing saltbush. Although sandhill muhly has increased on the site, and is not a palatable forage grass, this species does serve to stabilize areas of shifting sand. Like the R035XY115UT site, the R035XY118UT site also occurs on mostly level sand sheets, but the dominant shrubs are fourwing saltbush and jointfir (*Ephedra* spp.) rather than sand sagebrush. Common grass species in the reference plant community are Indian ricegrass and James' galleta. Initially, grazing disturbances will favor shrub development, followed by the conversion of the site to an annual grass state dominated by cheatgrass. At this time, most production is coming from prickly Russian thistle, threadleaf snakeweed (*Gutierrezia microcephala*), rubber rabbitbrush, James' galleta, Cutler's jointfir, and scarlet globemallow (*Sphaeralcea coccinea*). Although the prevalence of prickly Russian thistle and shrubs suggests that the site has declined, cheatgrass was only encountered in trace amounts on one transect.

Several ecological sites and non-described sites have are currently averaging less than 1 pound per acre of available forage. Rock Outcrop and the Mota minor component have the lowest amounts in the study area. Each of these sites contain only one transect. The transect in the Mota component is in a sandy site with a dense cover of blackbrush (*Coleogyne ramosissima*) and very few herbaceous species. The transect at the Rock Outcrop location occurs on a very large expanse of slick rock. Vegetation occurs only in isolated depressions that have collected enough soil to support plant growth. Encountered species include broom snakeweed, Bigelow's sagebrush (*Artemisia bigelovii*), Cutler's jointfir, and crispleaf buckwheat (*Eriogonum corymbosum*).

The R035XY012UT site is a unique site for the study areas as it occurs only in the riparian corridor along the San Juan River. In its reference state, coyote willow (*Salix exigua*) and alkali sacaton are dominant species in the plant community. However, with prolonged disturbance, this site becomes vulnerable to invasions from non-native species. This is the case for six transects where the noxious weed Russian knapweed (*Acroptilon repens*) has become established in the plant community. This species can be toxic to livestock, especially horses, and greatly outcompetes native plants once it has become established.

Species Frequency and Composition

The most commonly encountered species and the ones contributing the most biomass in Pasture 2 are listed below:

Frequently Encountered Species

1. prickly Russian thistle (*Salsola tragus*) (occurred on 74% of all transects)
2. Cutler's jointfir (*Ephedra cutleri*) (occurred on 66% of all transects)
3. James' galleta (*Pleuraphis jamesii*) (occurred on 54% of all transects)
4. Indian ricegrass (*Achnatherum hymenoides*) (occurred on 51% of all transects)
5. rubber rabbitbrush (*Ericameria nauseosa*) (occurred on 37% of all transects)

Species by Weight (Average Weight)

1. prickly Russian thistle (*Salsola tragus*) (21 lbs/acre)
2. rubber rabbitbrush (*Ericameria nauseosa*) (6 lbs/acre)
3. Russian knapweed (*Acroptilon repens*) (6 lbs/acre)
4. James' galleta (*Pleuraphis jamesii*) (4 lbs/acre)
5. Broom snakeweed (*Gutierrezia sarothrae*) (3 lbs/acre)

Ground Cover

Sites in Pasture 2 average 75 percent bare ground, and foliar cover makes up only ten percent of total ground cover. The high amount of bare ground indicates that this pasture is vulnerable to erosion. Several transects in the northeast portion of the pasture are in badland sites and are currently experiencing severe water erosion. Advanced wind erosion is common in sandy sites throughout the pasture.

Rangeland Health

Rangeland health reference sheets exist for 11 ecological sites in Pasture 2. Data was collected from 84 transects within these sites, and Table 5-2 shows the degree of departure from the reference community for each rangeland health attribute.

Table 5-2. Rangeland Health in Pasture 2

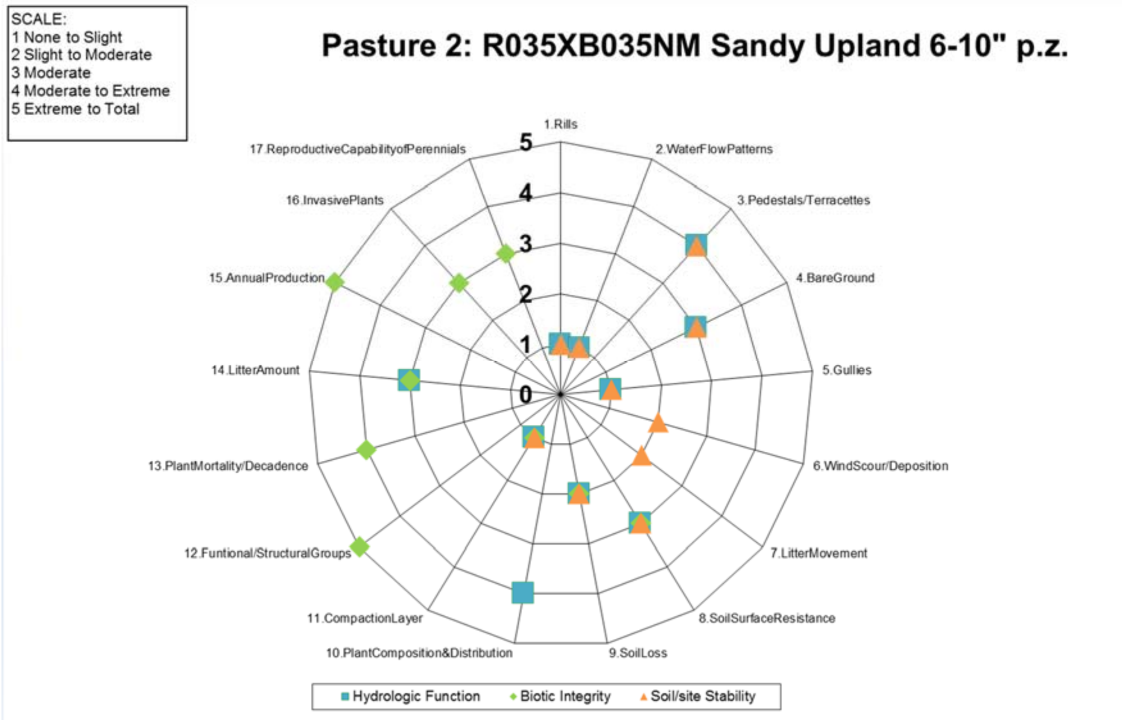
Ecological Site	Departure from Reference Community		
	Soil and Site Stability	Hydrological Function	Biotic Integrity
R035XB035NM Sandy Upland 6-10"	Slight to Moderate	Slight to Moderate	Moderate
R035XB217AZ Sandy Upland 6-10" p.z.	Slight to Moderate	Slight to Moderate	Moderate
R035XB235AZ Sandy Loam Upland 6-10" p.z. Warm	Slight to Moderate	Slight to Moderate	Moderate
R035XB236AZ Colluvial Slopes 6-10" p.z. Warm	Slight to Moderate	Slight to Moderate	Slight to Moderate
R035XB238AZ Sandy Terrace 6-10" p.z. Sodic	Slight to Moderate	Slight to Moderate	Moderate
R035XY009UT Alkali Flat (Greasewood)	Slight to Moderate	Slight to Moderate	Slight to Moderate
R035XY109UT Desert Loam (Shadscale)	Slight to Moderate	Slight to Moderate	Slight to Moderate
R035XY118UT Desert Sandy Loam (Fourwing Saltbush)	Slight to Moderate	Slight to Moderate	Moderate
R035XY130UT Desert Shallow Sandy Loam (Shadscale)	Slight to Moderate	Slight to Moderate	Moderate
R035XY133UT Desert Shallow Sandy Loam (Blackbrush)	Slight to Moderate	Slight to Moderate	Slight to Moderate
R035XY215UT Semi-desert Sandy Loam (4-Wing Saltbush)	Slight to Moderate	Slight to Moderate	Slight to Moderate

Overall, soil and site stability and hydrological function are only showing slight to moderate departure from reference conditions in all ecological sites. However, each of these attributes have at least one indicator in each site that is significantly different from the reference sheet description. For example, sites R035XB217AZ, R035XB238AZ, R035XY009UT, R035XY109UT, and R035XY118UT have evidence of severe wind scouring, coppicing, sand deposition, and dune encroachment. In all of these sites, the occurrence of wind erosion is expected to be either slight or absent in the reference state due to the presence of an extensive cover of perennial grasses. Pedestals are taller and much more present than expected in sites R035XB238AZ, R035XY009UT, R035XY109UT, and R035XY118UT. Soils in these sites are mostly sandy and the observed pedestalling is primarily a result of accelerated wind scouring rather than water erosion. Other indicators correlated with loose soils and wind erosion are bare ground, soil loss, soil surface resistance, and litter movement. In all cases, these indicators are experiencing some degree of negative modification. Soil and site stability indicators related to water erosion (rills, water flow patterns, and gullies) are all close to the reference sheet descriptions with the exception of gullies in the R035XB236AZ site. In this site, no gullies should exist, but a moderate amount are now present. However, this may not be an accurate portrayal of overall conditions as only one transect was placed in the site.

Most hydrological function indicators overlap with soil and site stability indicators. To illustrate, advanced pedestalling indicates that soils are unstable and are subject to both wind and water erosion. As a result, the indicator graphs presented below will often have blue square (hydrological function indicator) overlain by a brown triangle (soil and site stability indicator). However, as mentioned above, pedestalling in Pasture 2 is largely due to wind erosion rather than water (hydrology-related) erosion. The one indicator not directly correlated with soil indicators is the effect of plant composition and distribution on infiltration and runoff. This indicator has at least a moderate departure from the reference state in all but the R035XY130UT ecological site. The reasons for the changes are largely due to the loss of perennial grass cover. In some cases, the grasses have been replaced by shrubs and in other instances, they have either been replaced by annual forbs or virtually all vegetation is absent. These shifts often result in accelerated water erosion due increased runoff and decreased infiltration. As most sites have very sandy soils, infiltration tends to remain fairly constant regardless of plant cover, but the lack of perennial grasses contributes to a loss of soil integrity and increases the incidence of wind erosion.

The third attribute, biotic integrity, shows the most significant departure from reference conditions. Sites R035XB035NM, R035XB217AZ, R035XB235AZ, R035XY130UT, R035XY133UT, and R035XY215UT all have at least a moderate departure from the reference sheet in regards to annual production. In all cases, the change is due to lower amounts of annual production than expected. Functional/structural groups have also shifted in all ecological sites. This is primarily due to either a general absence of perennial grasses or the dominance of shrubs or forbs in sites where perennial grasses should be dominant. In the R035XY133UT site, biocrusts are supposed to be equally dominant with blackbrush, but are now either not present or much reduced. Invasive species, especially prickly Russian thistle, are now established in the plant communities of the R035XB238AZ, R035XY118UT, and R035XY133UT sites and reproductive capability of perennial species has been reduced in the R035XB235AZ, R035XB236AZ, R035XB238AZ, R035XY109UT, and R035XY118UT sites.

Data for the 17 indicators for each ecological site are included in the following graphs.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2 Slight to Moderate
3 Moderate
4 Moderate to Extreme
5 Extreme to Total
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1.Rills
2.WaterFlowPatterns
3.Pedestals/Terracettes
4.BareGround
5.Gullies
6.WindScour/Deposition
7.LitterMovement
8.SoilSurfaceResistance
9.SoilLoss
10.PlantComposition&Distribution
11.CompactionLayer
12.Funtional/StructuralGroups
13.PlantMortality/Decadence
14.LitterAmount
15.AnnualProduction
16.InvasivePlants
17.ReproductiveCapabilityofPerennials
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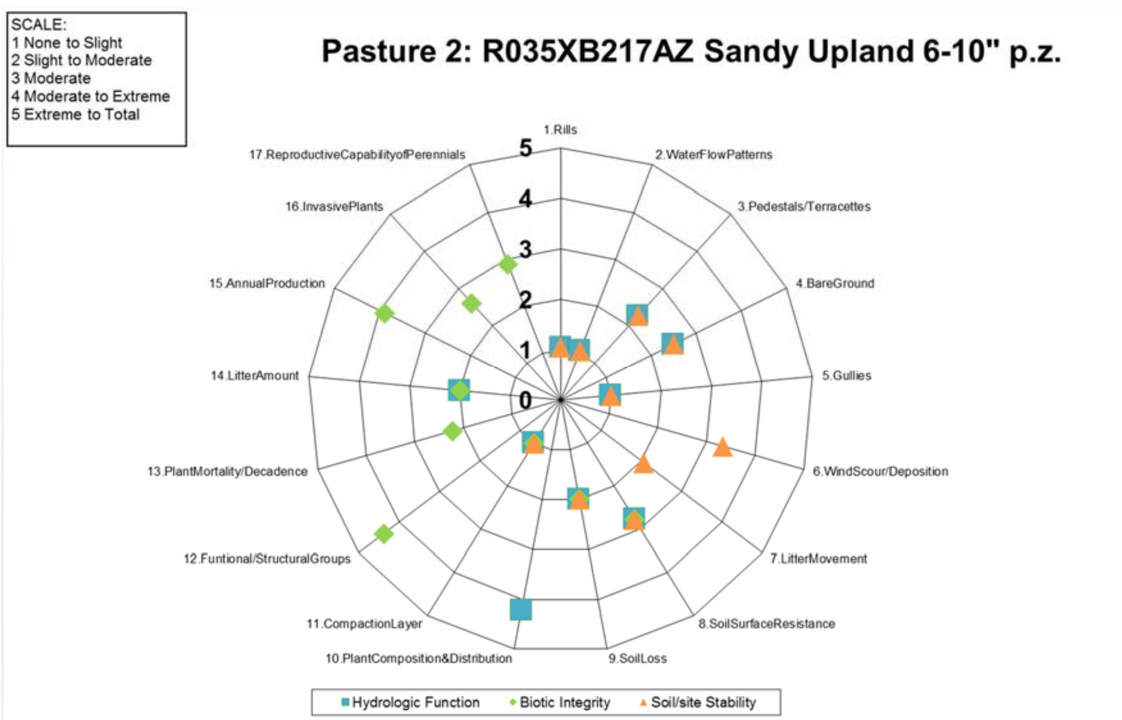
Hydrologic Function
Biotic Integrity
Soil/site Stability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3 Moderate
4 Moderate to Extreme
5 Extreme to Total
Pasture 2: R035XB217AZ Sandy Upland 6-10" p.z.
1.Rills
2.WaterFlowPatterns
3.Pedestals/Terracettes
4.BareGround
5.Gullies
6.WindScour/Deposition
7.LitterMovement
8.SoilSurfaceResistance
9.SoilLoss
10.PlantComposition&Distribution
11.CompactionLayer
12.Funtional/StructuralGroups
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14.LitterAmount
15.AnnualProduction
16.InvasivePlants
17.ReproductiveCapabilityofPerennials
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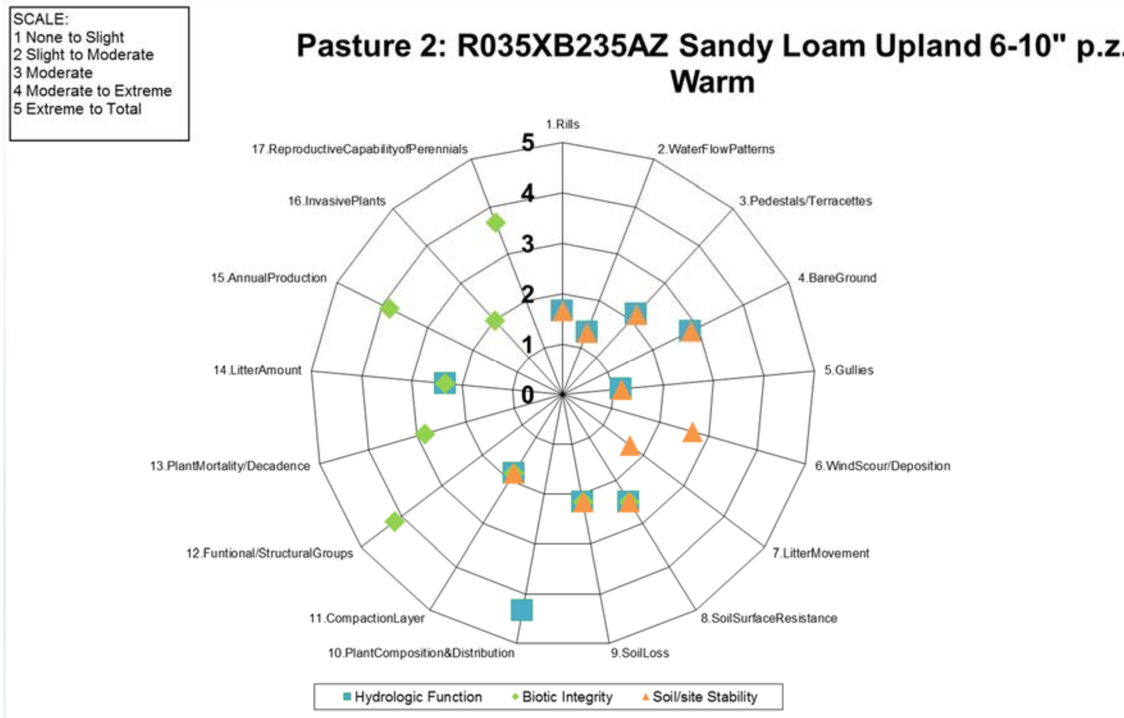
Hydrologic Function
Biotic Integrity
Soil/site Stability


SCALE:
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2 Slight to Moderate
3 Moderate
4 Moderate to Extreme
5 Extreme to Total
Pasture 2: R035XB235AZ Sandy Loam Upland 6-10" p.z. Warm
1.Rills
2.WaterFlowPatterns
3.Pedestals/Terracettes
4.BareGround
5.Gullies
6.WindScour/Deposition
7.LitterMovement
8.SoilSurfaceResistance
9.SoilLoss
10.PlantComposition&Distribution
11.CompactionLayer
12.Funtional/StructuralGroups
13.PlantMortality/Decadence
14.LitterAmount
15.AnnualProduction
16.InvasivePlants
17.ReproductiveCapabilityofPerennials
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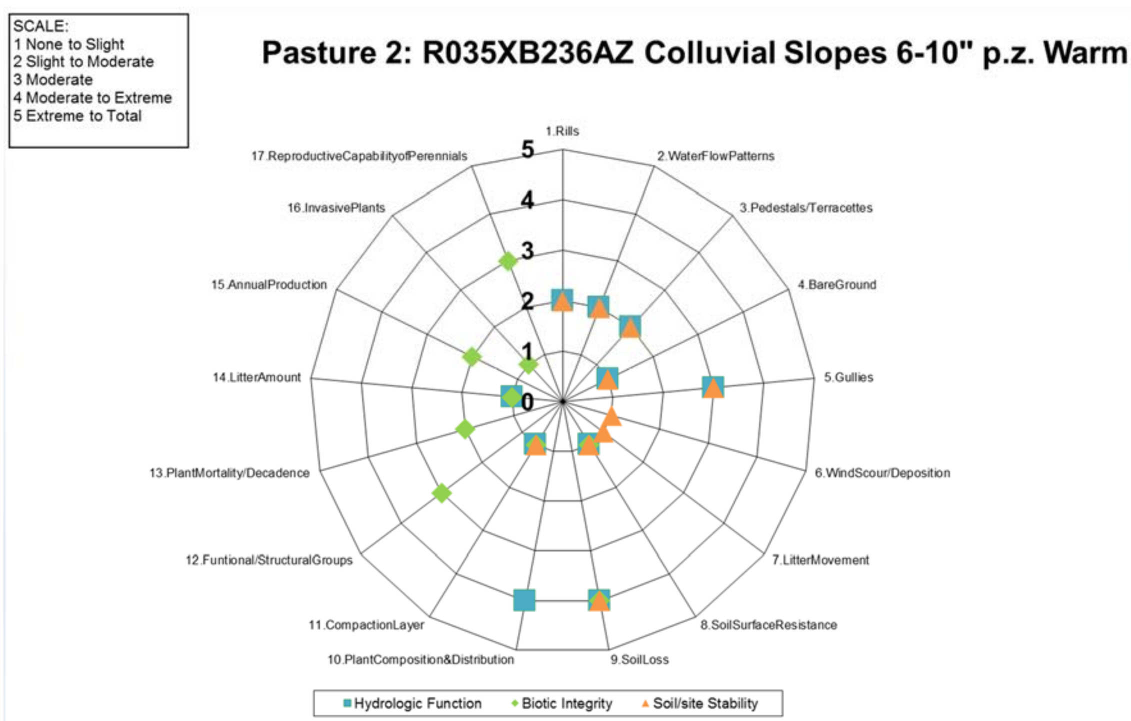
Hydrologic Function
Biotic Integrity
Soil/site Stability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2 Slight to Moderate
3 Moderate
4 Moderate to Extreme
5 Extreme to Total
Pasture 2: R035XB236AZ Colluvial Slopes 6-10" p.z. Warm
1.Rills
2.WaterFlowPatterns
3.Pedestals/Terracettes
4.BareGround
5.Gullies
6.WindScour/Deposition
7.LitterMovement
8.SoilSurfaceResistance
9.SoilLoss
10.PlantComposition&Distribution
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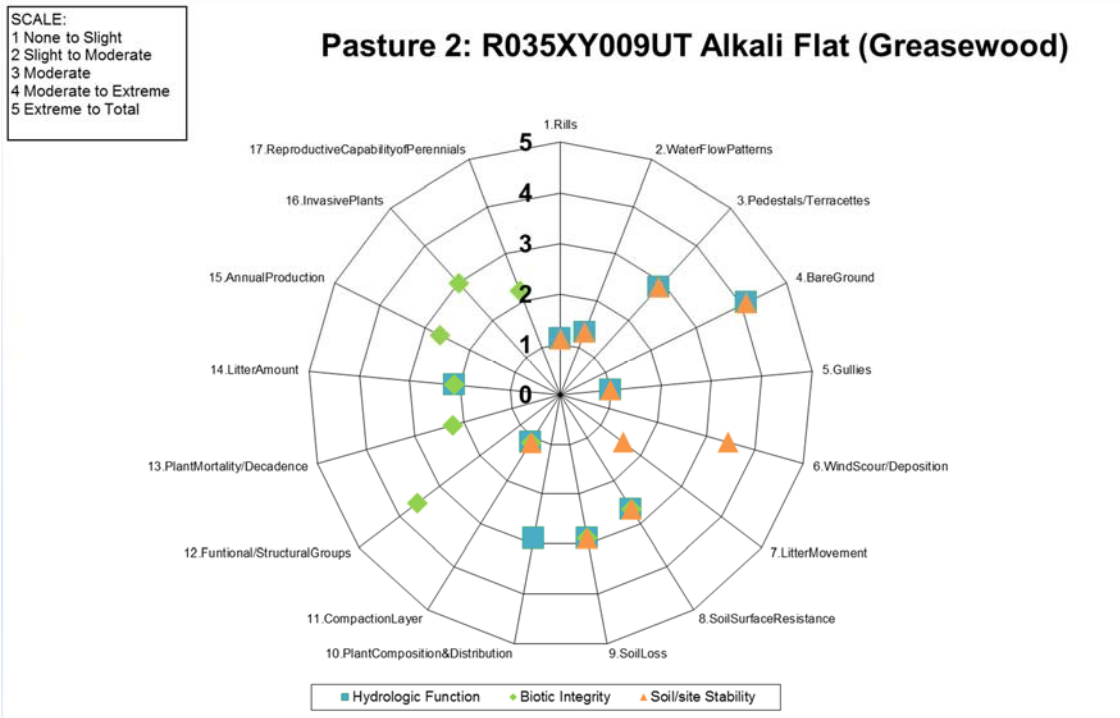
Hydrologic Function
Biotic Integrity
Soil/site Stability


SCALE:
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2 Slight to Moderate
3 Moderate
4 Moderate to Extreme
5 Extreme to Total
Pasture 2: R035XY009UT Alkali Flat (Greasewood)
1.Rills
2.WaterFlowPatterns
3.Pedestals/Terracettes
4.BareGround
5.Gullies
6.WindScour/Deposition
7.LitterMovement
8.SoilSurfaceResistance
9.SoilLoss
10.PlantComposition&Distribution
11.CompactionLayer
12.Funtional/StructuralGroups
13.PlantMortality/Decadence
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15.AnnualProduction
16.InvasivePlants
17.ReproductiveCapabilityofPerennials
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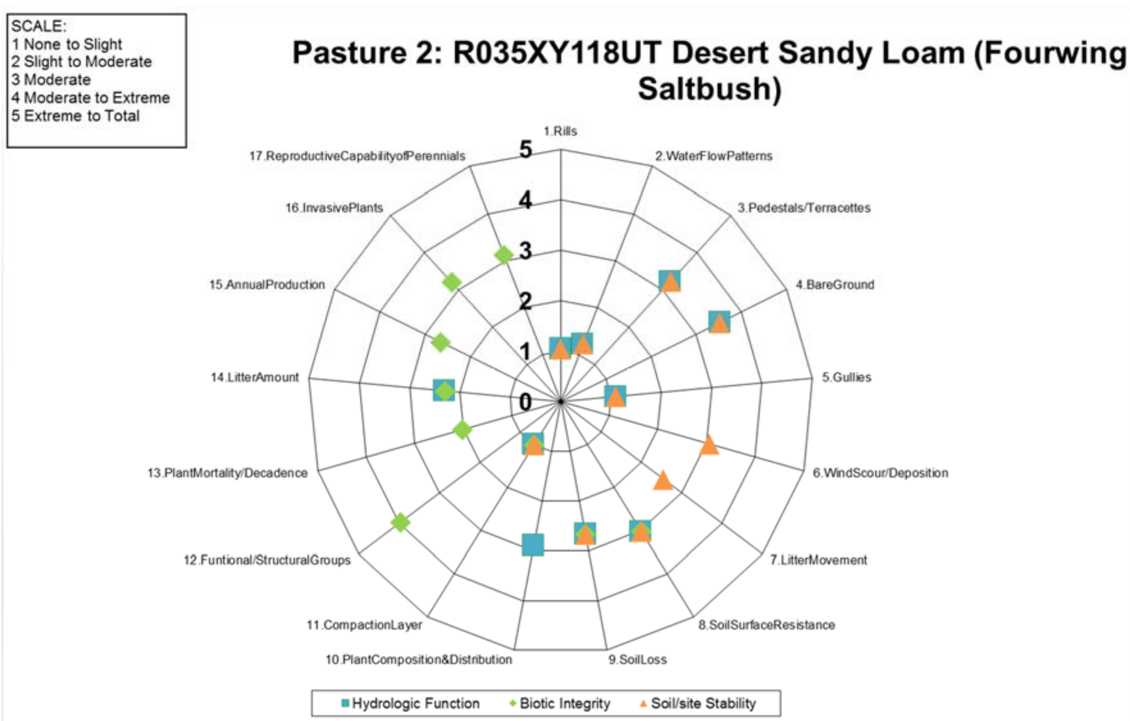
Hydrologic Function
Biotic Integrity
Soil/site Stability


SCALE:
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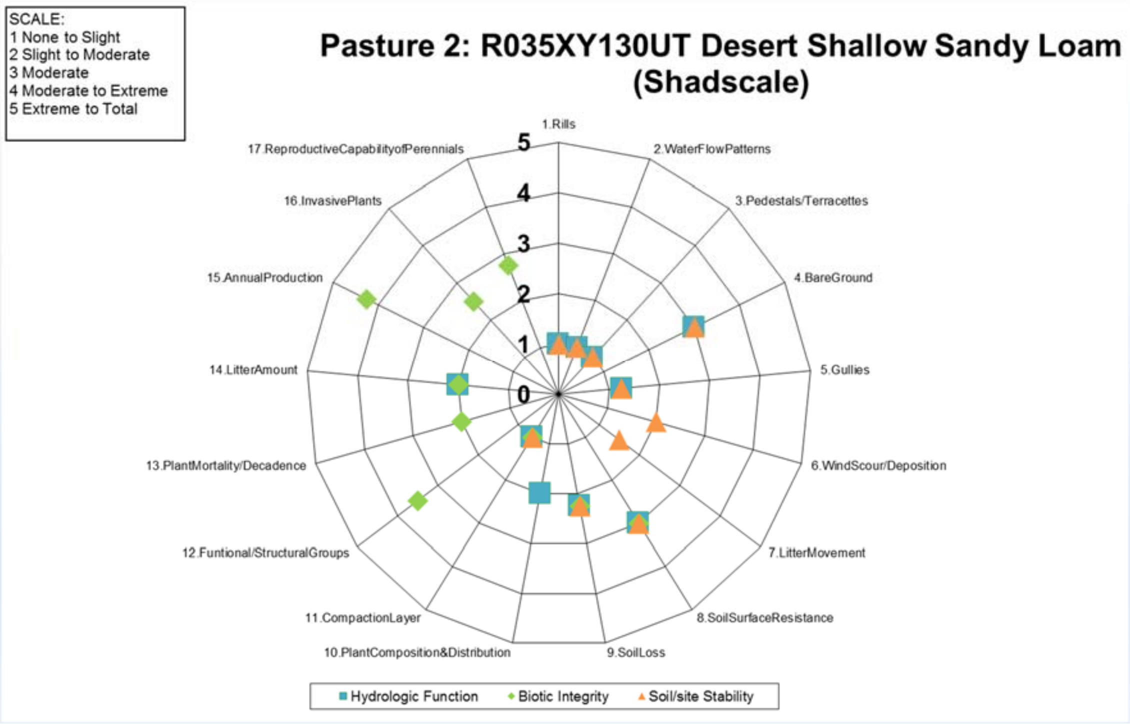
2 Slight to Moderate
3 Moderate
4 Moderate to Extreme
5 Extreme to Total
Pasture 2: R035XY118UT Desert Sandy Loam (Fourwing Saltbush)
1.Rills
2.WaterFlowPatterns
3.Pedestals/Terracettes
4.BareGround
5.Gullies
6.WindScour/Deposition
7.LitterMovement
8.SoilSurfaceResistance
9.SoilLoss
10.PlantComposition&Distribution
11.CompactionLayer
12.Funtional/StructuralGroups
13.PlantMortality/Decadence
14.LitterAmount
15.AnnualProduction
16.InvasivePlants
17.ReproductiveCapabilityofPerennials
0
1
2
3
4
5
Hydrologic Function
Biotic Integrity
Soil/site Stability


SCALE:
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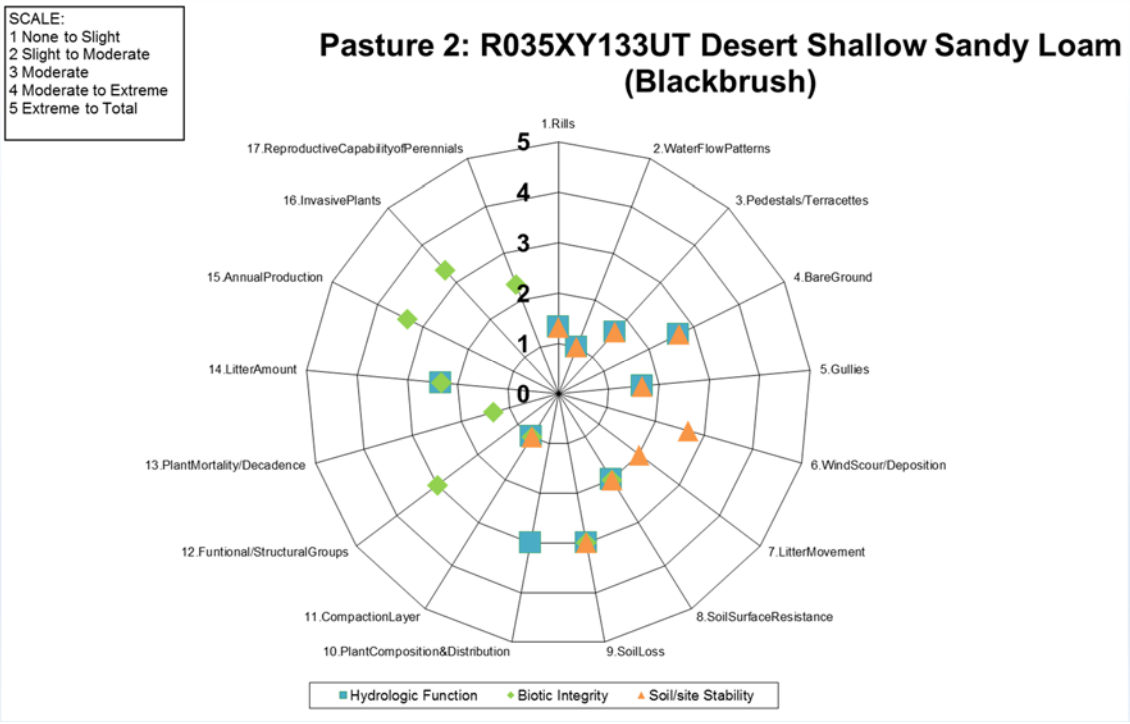
2 Slight to Moderate
3 Moderate
4 Moderate to Extreme
5 Extreme to Total
Pasture 2: R035XY130UT Desert Shallow Sandy Loam (Shadscale)
1.Rills
2.WaterFlowPatterns
3.Pedestals/Terracettes
4.BareGround
5.Gullies
6.WindScour/Deposition
7.LitterMovement
8.SoilSurfaceResistance
9.SoilLoss
10.PlantComposition&Distribution
11.CompactionLayer
12.Funtional/StructuralGroups
13.PlantMortality/Decadence
14.LitterAmount
15.AnnualProduction
16.InvasivePlants
17.ReproductiveCapabilityofPerennials
0
1
2
3
4
5
Hydrologic Function
Biotic Integrity
Soil/site Stability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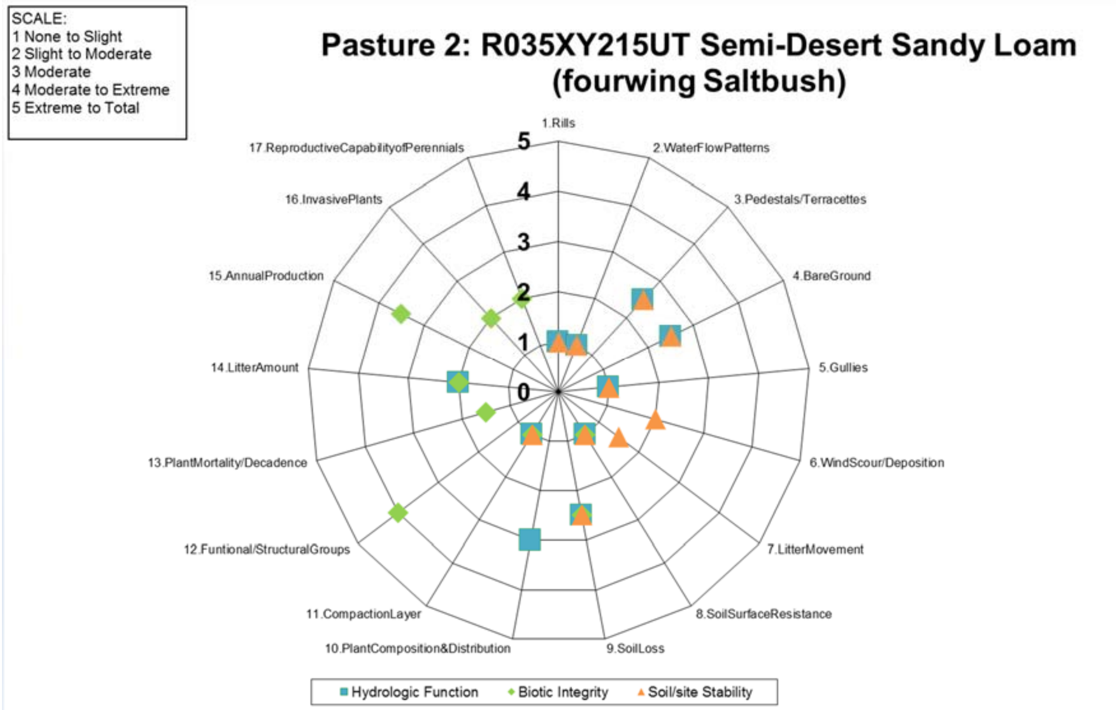
2 Slight to Moderate
3 Moderate
4 Moderate to Extreme
5 Extreme to Total
Pasture 2: R035XY133UT Desert Shallow Sandy Loam (Blackbrush)
1.Rills
2.WaterFlowPatterns
3.Pedestals/Terracettes
4.BareGround
5.Gullies
6.WindScour/Deposition
7.LitterMovement
8.SoilSurfaceResistance
9.SoilLoss
10.PlantComposition&Distribution
11.CompactionLayer
12.Funtional/StructuralGroups
13.PlantMortality/Decadence
14.LitterAmount
15.AnnualProduction
16.InvasivePlants
17.ReproductiveCapabilityofPerennials
0
1
2
3
4
5
Hydrologic Function
Biotic Integrity
Soil/site Stability


SCALE:
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2 Slight to Moderate
3 Moderate
4 Moderate to Extreme
5 Extreme to Total
Pasture 2: R035XY215UT Semi-Desert Sandy Loam (fourwing Saltbush)
1.Rills
2.WaterFlowPatterns
3.Pedestals/Terracettes
4.BareGround
5.Gullies
6.WindScour/Deposition
7.LitterMovement
8.SoilSurfaceResistance
9.SoilLoss
10.PlantComposition&Distribution
11.CompactionLayer
12.Funtional/StructuralGroups
13.PlantMortality/Decadence
14.LitterAmount
15.AnnualProduction
16.InvasivePlants
17.ReproductiveCapabilityofPerennials
0
1
2
3
4
5
Hydrologic Function
Biotic Integrity
Soil/site Stability

Analysis Unit 2

Summary of Grazeable and Non-Grazeable Acres in Analysis Unit

TotalAcres		219,762.47
Non-Grazeable Acres	Developed	1,101.71
	Hydro	1,504.35
	Roads	2,963.26
	Slope >60	3,938.88
Range Acres		210,254.28

Summary of Similarity Indices, Cover, and Carrying Capacities

Similarity Indices (%)	
Minimum	0
Maximum	33
Mean	5

Cover (%)	
Foliar Cover	10.17%
Bare Ground	74.60%
Basal	0.49%

Carrying Capacity (Sheep Unit/Year)	
Initial CC	260.87
Slope Adjusted CC	236.53
Distance to Water CC	164.54

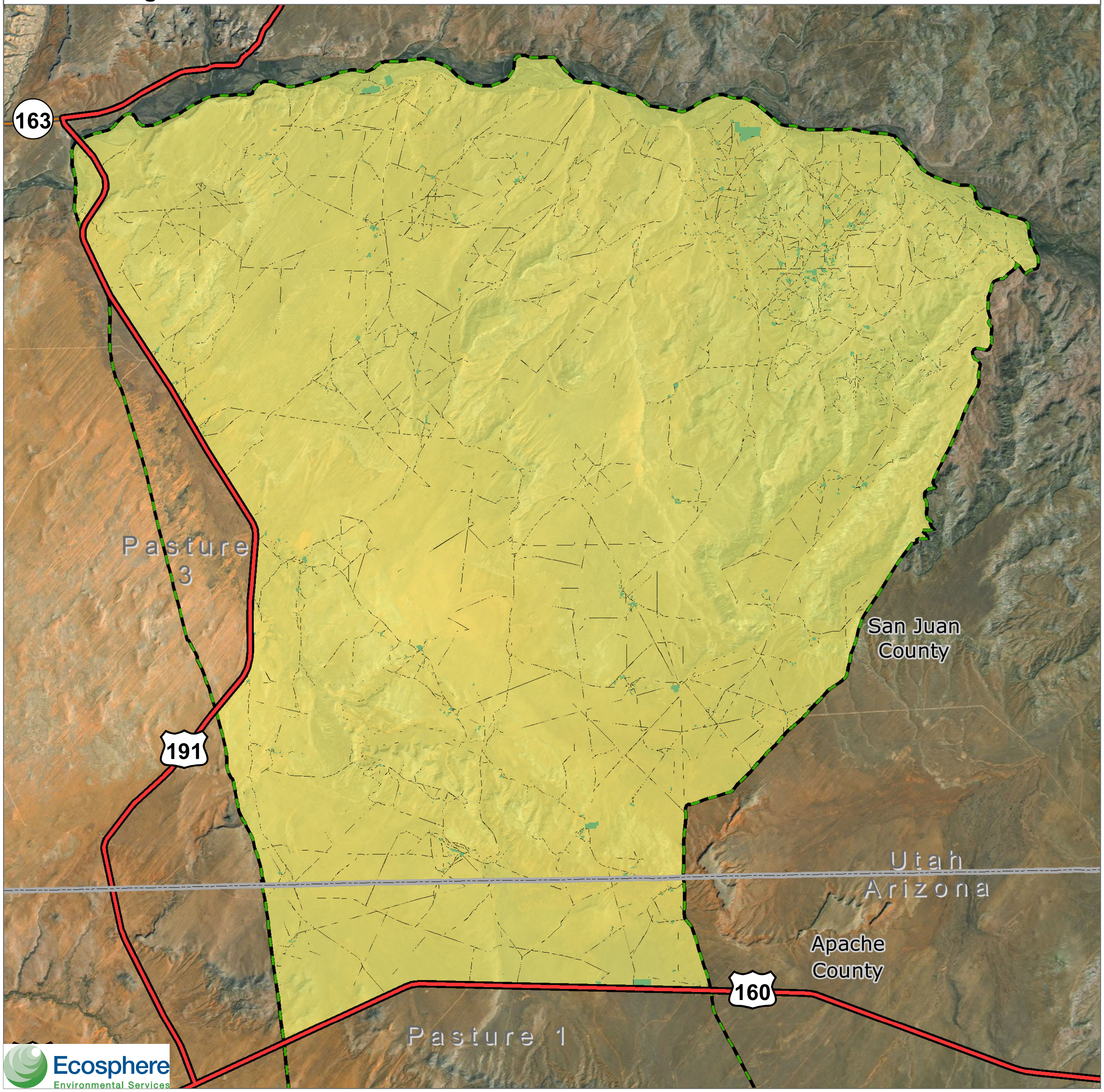
Results by Ecological Site in Sheep Units Year long

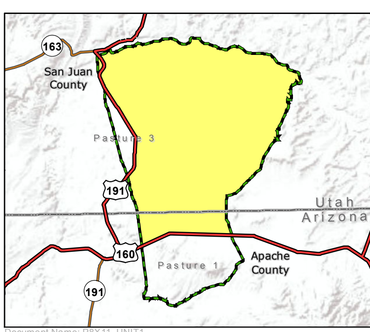
Ecological Site	Number of Transects	Percent of Analysis Unit Acres	Average Available Forage (Lbs/Acre)	Acres	Sheep Stocking Rate (Sheep Units)	Sheep Carrying Capacity (Sheep Units per Year
R035XY115UT Desert Sand (Sand Sagebrush)	111	22	3.96	48,774.14	598.48	81.5
R035XY121UT Desert Sandy Loam (Blackbrush)	50	10	1.14	21,256.60	2078.95	10.22
R035XY118UT Desert Sandy Loam (Fourwing Saltbush)	43	20	3.66	43,376.32	647.54	66.99
Shepherd	22	<1	3.98	1,602.65	595.48	2.69
R035XB217AZ Sandy Upland 6-10" p.z.	18	3	3.3	7,356.48	718.18	10.24
Sheppard	16	1	7.71	2,414.39	307.39	7.85
R035XY012UT Semiwet Saline Streambank (Fremont Cottonwood)	10	2	1.66	3,458.77	1427.71	2.42
shallow and very shallow soils	10	1	4.78	2,818.77	495.82	5.69
R035XY009UT Alkali Flat (Greasewood)	9	2	4.09	4,589.29	579.46	7.92
R035XB030NM Sandy Loam Upland 6-10"	9	2	4.67	4,599.73	507.49	9.06
R035XY219UT Semidesert Sandy Loam (Black Grama)	8	2	8.48	4,314.56	279.48	15.44
Badland	8	17	1.14	36,775.12	2078.95	17.69
R035XY015UT Sandy Bottom	7	<1	1.47	1,308.41	1612.24	0.81
R035XB235AZ Sandy Loam Upland 6-10" p.z. Warm	6	<1	0.52	1,294.78	4557.69	0.28
R035XB035NM Sandy Upland 6-10"	5	<1	1.21	1,178.16	1958.68	0.6
R035XY133UT Desert Shallow Sandy Loam (Blackbrush)	4	<1	1.08	1,947.22	2194.44	0.89
R035XY130UT Desert Shallow Sandy Loam (Shadscale)	4	1	0.96	2,774.96	2468.75	1.12
Some shallow or very shallow sandy soils	2	<1	2.62	245.14	904.58	0.27
Aneth	2	<1	4.68	196.92	506.41	0.39
R035XY109UT Desert Loam (Shadscale)	2	2	6.96	3,648.34	340.52	10.71
R035XY215UT Semidesert Sandy Loam (4-Wing Saltbush)	2	<1	2.74	746.50	864.96	0.86
R035XB238AZ Sandy Terrace 6-10" p.z. Sodic	2	<1	0.86	643.03	2755.81	0.23
R035XB236AZ Colluvial Slopes 6-10" p.z. Warm	1	<1	0.59	167.16	4016.95	0.04
R035XB021NM Loamy Upland 7-10	1	<1	17.59	907.03	134.74	6.73
Rock Outcrop	1	4	0.06	8,687.42	39500	0.22
Mota	1	<1	0.19	64.88	12473.68	0.01
Riverwash	0	<1		462.17		
Sogzie	0	<1		33.34		
Water	0	<1		543.07		
R035XB204AZ Sandstone Upland 6-10" p.z.	0	<1		21.69		
R028AY132UT Desert Salty Silt (Iodinebush)	0	<1		877.39		
Piute	0	<1		1,223.89		
R035XY003UT Alkali Bottom (Greasewood)	0	<1		66.80		
Naki	0	<1		935.28		
R035XB224AZ Clayey Slopes 6-10" p.z. Bouldery	0	<1		117.02		
Nakai	0	<1		1,224.16		
Monue	0	<1		1,223.89		
Hummocky	0	<1		840.98		
Gotho	0	<1		32.97		
Deep Sandy	0	<1		48.74		

Bedrock	0	<1		245.14		
Whit	0	<1		239.70		
Alkaline Soil	0	<1		216.04		
R035XB230AZ	0	<1		361.44		
R035XB219AZ Sandy Loam Upland 6-10" p.z.	0	<1		307.81		
Other	0	<1		24.88		

2014 Range Inventory
BIA Northern Navajo Agency
Land Management District 9

Red Mesa Chapter
Pasture 2





Analysis Unit Boundary

Community Boundary

State Line

Non Grazeable Range

Developed

Hydrology

Roads

0 2.5 5
Miles

Coordinate System: NAD 1983 UTM Zone 12N

1:200,000

Date: 2/10/2015

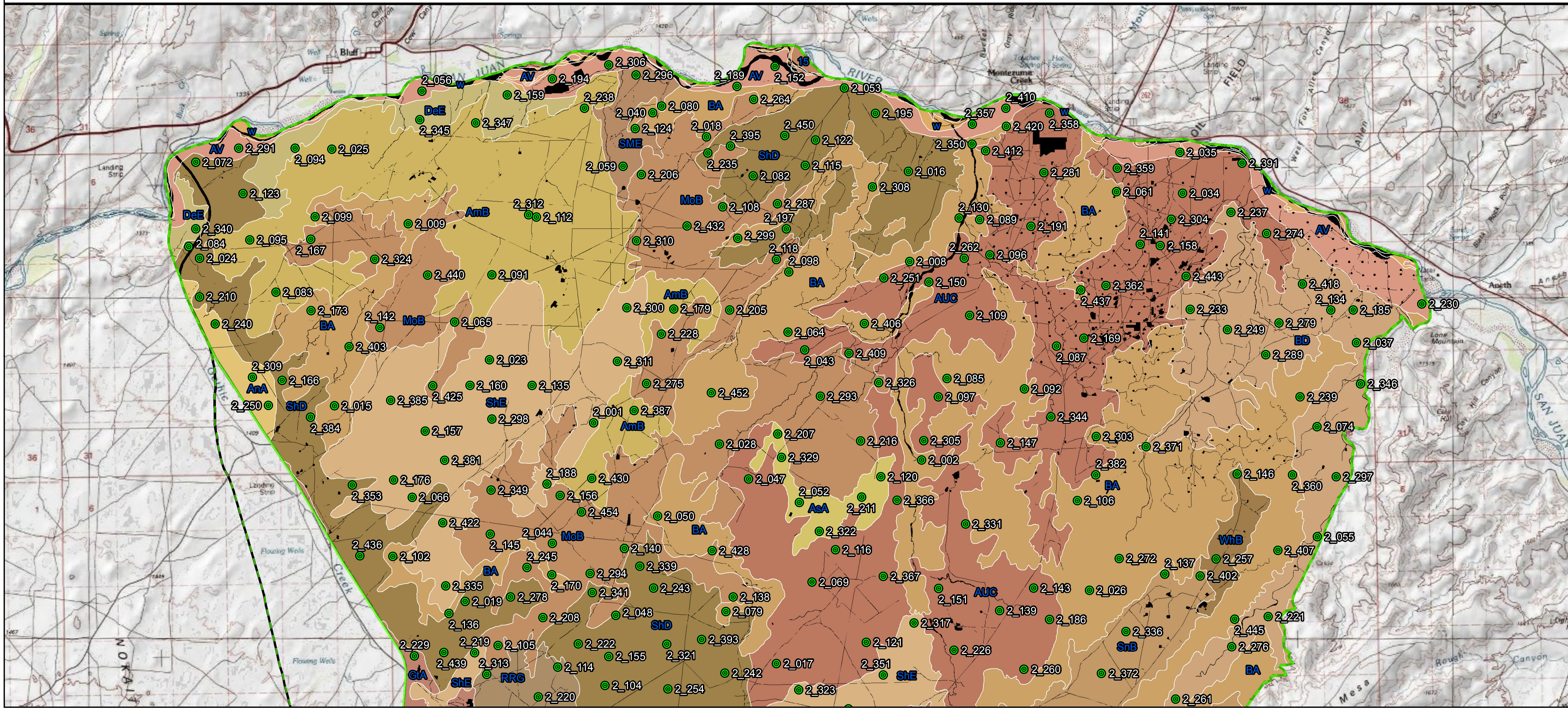
Document Name: P8X11_UNIT1

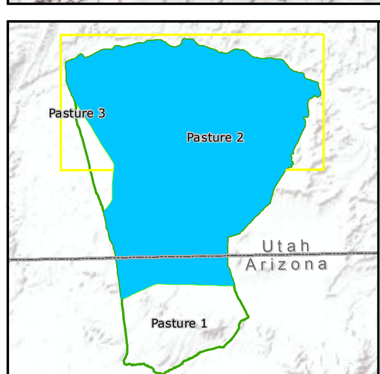
2014 Range Inventory
BIA Northern Navajo Agency
Land Management District 9

Red Mesa Chapter, Pasture 2 North Half

Total Acres: 219,763
Grazeable Acres*: 210,254
*Total acres minus non grazeable areas and areas with > 60% slope.

Total Annual Carrying Capacity: 261 Sheep





Transect Location
Pasture Boundary
Community Boundary
Non Grazeable Range
Soil Map Unit
State Line

0 0.5 1 2 3 4 5
Miles

Coordinate System: NAD 1983 UTM Zone 12N

1:110,000

Ecosphere Environmental Services

Date: 2/10/2015

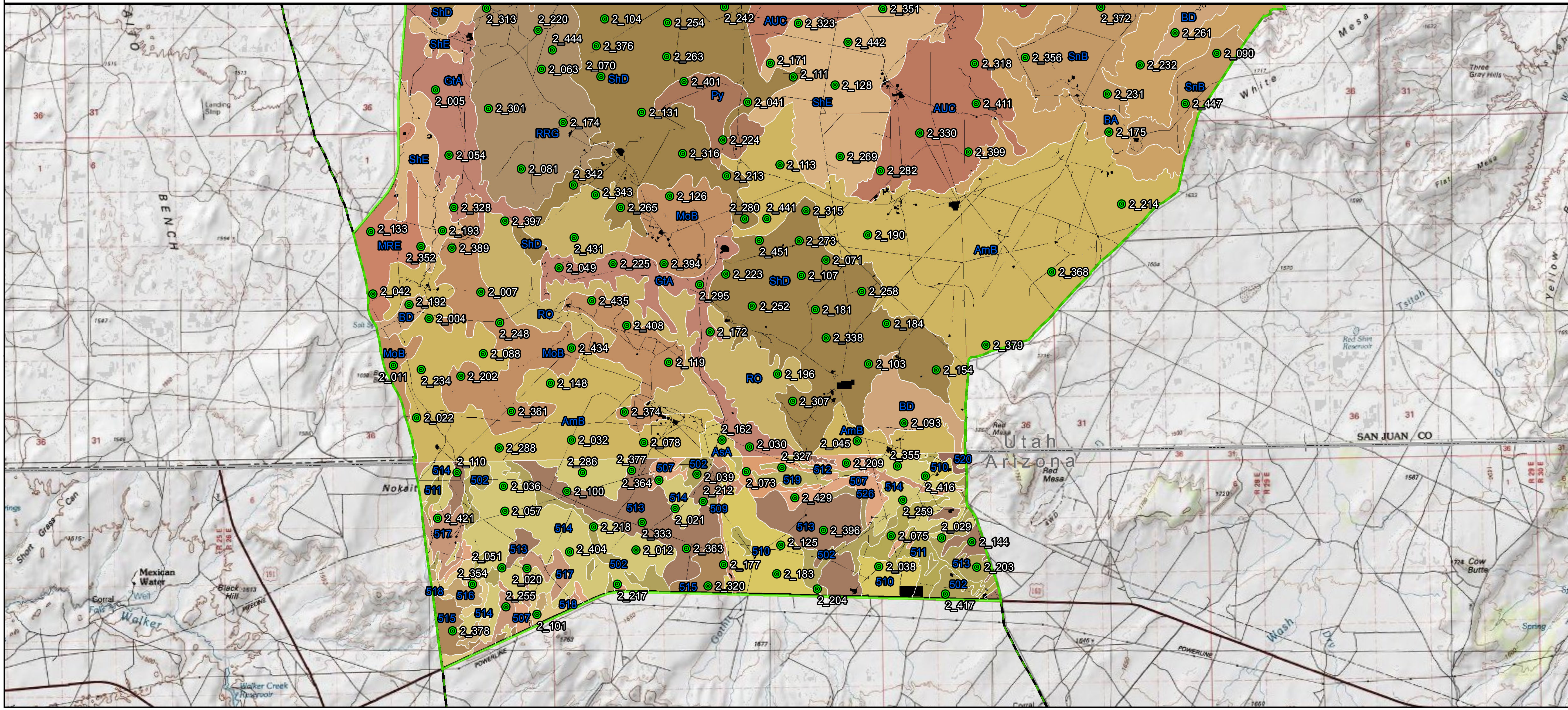
Document Name: L11X17_Soils_InitialCC_1and2

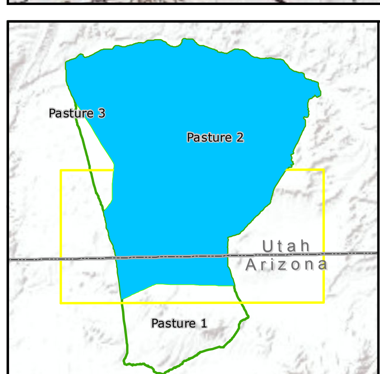
2014 Range Inventory
BIA Northern Navajo Agency
Land Management District 9

Red Mesa Chapter, Pasture 2 South Half

Total Acres: 219,763
Grazeable Acres*: 210,254
*Total acres minus non grazeable areas and areas with > 60% slope.

Total Annual Carrying Capacity:
261 Sheep





Transect Location
Pasture Boundary
Community Boundary
Non Grazeable Range
Soil Map Unit
State Line

0 0.5 1 2 3 4 5
Miles

1:110,000

Coordinate System: NAD 1983 UTM Zone 12N

Ecosphere Environmental Services

Date: 2/10/2015

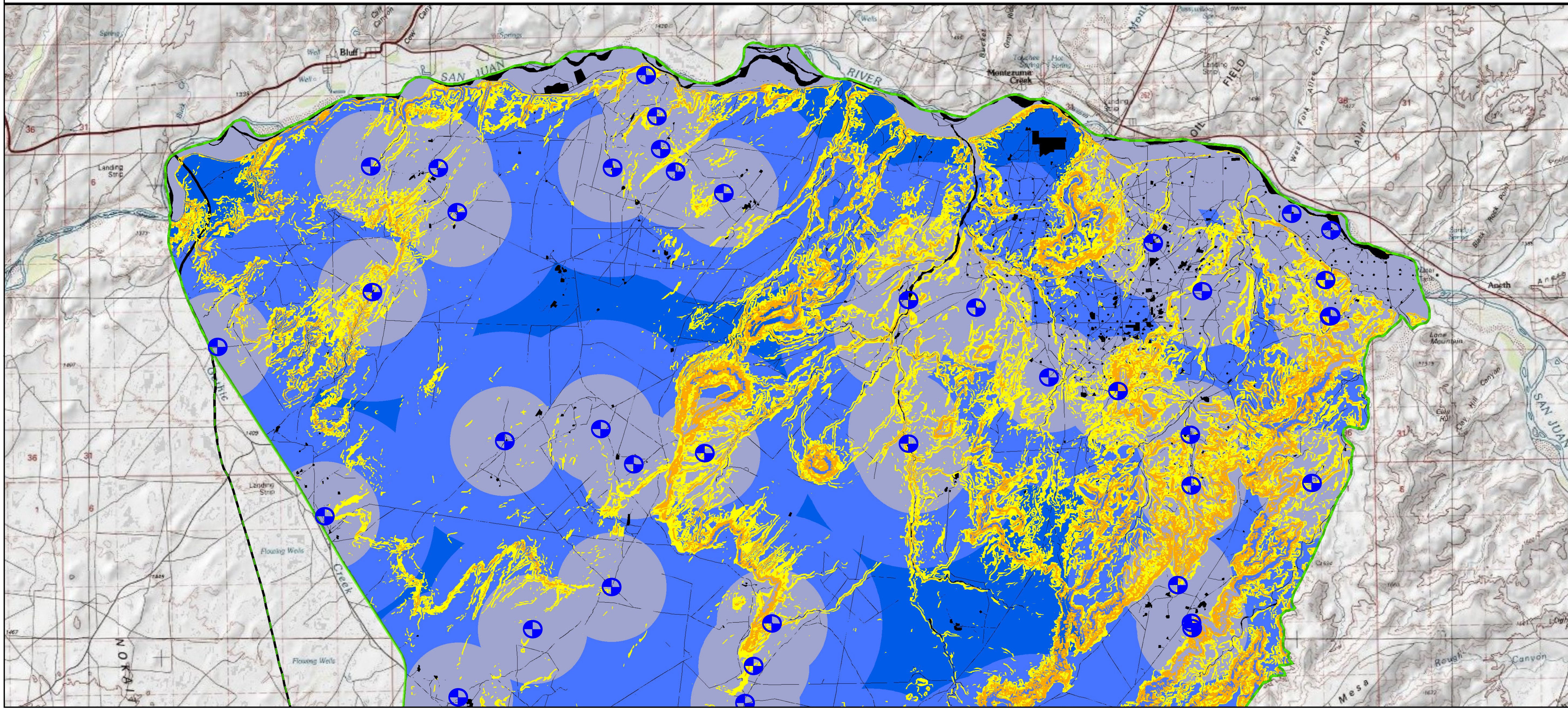
Document Name: L11X17_Soils_InitialCC_1and2

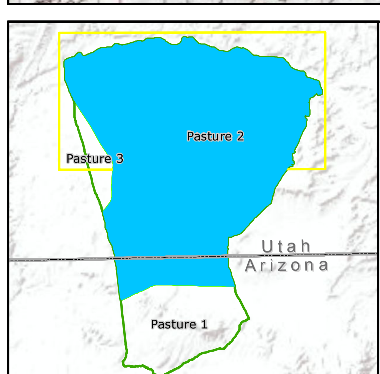
2014 Range Inventory
BIA Northern Navajo Agency
Land Management District 9

Red Mesa Chapter, Pasture 2 North Half

Total Acres: 219,763
Grazeable Acres*: 210,254
*Total acres minus non grazeable areas and areas with > 60% slope.

Adjusted Annual Carrying Capacity: 165 Sheep





Water Source
Pasture Boundary
Community Boundary
Non Grazeable Range
State Line

Distance to Water
0-1 Mile
1-2 Miles
>2 Miles

Slope
10 - 30%
30 - 60%
> 60%

0 0.5 1 2 3 4 5
Miles

1:110,000

Coordinate System: NAD 1983 UTM Zone 12N

Date: 2/10/2015

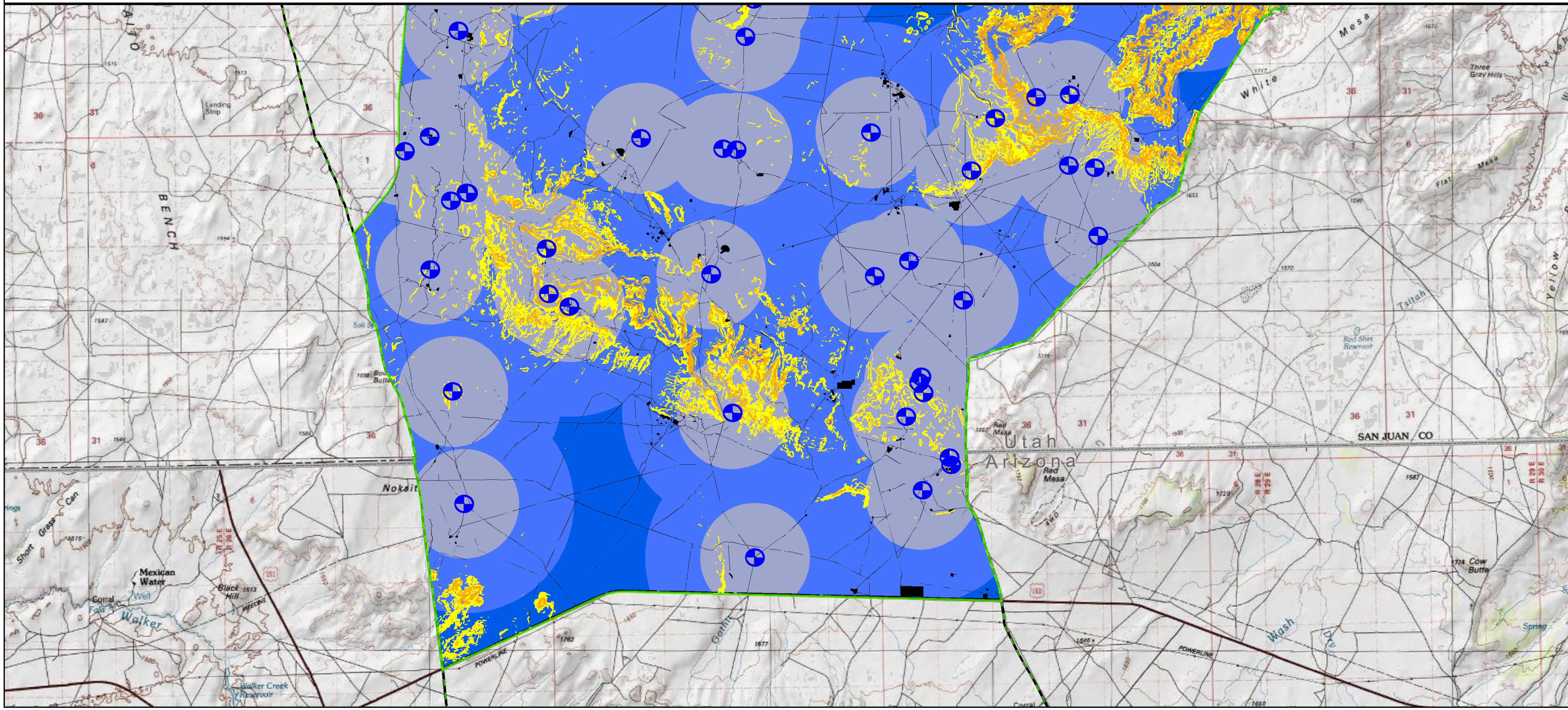
Document Name: L11X17_SlopeAdjCC_1and21

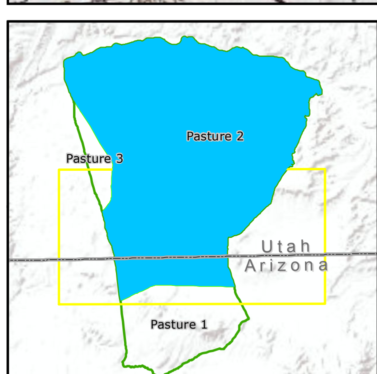
2014 Range Inventory
BIA Northern Navajo Agency
Land Management District 9

Red Mesa Chapter, Pasture 2 South Half

Total Acres: 219,763
Grazeable Acres*: 210,254
*Total acres minus non grazeable areas and areas with > 60% slope.

Adjusted Annual Carrying Capacity: 165 Sheep





Water Source
Pasture Boundary
Community Boundary
Non Grazeable Range
State Line

Distance to Water
0-1 Mile
1-2 Miles
>2 Miles

Slope
10 - 30%
30 - 60%
> 60%

0 0.5 1 2 3 4 5 Miles

1:110,000

Coordinate System: NAD 1983 UTM Zone 12N

Ecosphere Environmental Services

Date: 2/10/2015

Document Name: L11X17_SlopeAdjCC_1and21

5.4 Pasture 3

Ecological Site Summary

Pasture 3 is the smallest pasture in the study area and lies just west of Highway 191 and a little south of the San Juan River. It contains 8,783 total acres, of which 8,498 are considered to be grazeable by livestock, and 17 transects within three ecological sites. This pasture is mostly shrubland with the dominant shrub species depending upon whether a site is sandy or clayey.

Available forage and carrying capacity is highest in the R035XY115UT site. This site occurs on sandy flats and has a reference plant community dominated by sand sagebrush (*Artemisia filifolia*) and Indian ricegrass (*Achnatherum hymenoides*). Increases in sandhill muhly (*Muhlenbergia pungens*), rabbitbrush (*Chrysothamnus* spp.), sand sagebrush, broom snakeweed (*Gutierrezia sarothrae*), and annual forbs tend to follow disturbance associated with continuous grazing. Currently, shrubs like rubber rabbitbrush (*Ericameria nauseosa*), big sagebrush (*Artemisia tridentata*), Greene's rabbitbrush (*Chrysothamnus greenei*), and Rusby's goldenbush (*Isocoma rusbyi*) are the main components of the plant community, and perennial grasses are uncommon. Prickly Russian thistle (*Salsola tragus*) was also observed, but at this time, production of this non-native species is low.

The next highest amount of available forage is in the R035XY009UT ecological site. Soils range from sandy loam to clay and often have a high saline content, especially when the site is dominated by black greasewood (*Sarcobatus vermiculatus*). The reference plant community tends to be naturally dominated by black greasewood, but the introduction of fire will often promote perennial grasses for several years. Greasewood re-sprouts following fire and will eventually regain a dominant status. Other species that may be present include Indian ricegrass, James' galleta (*Pleuraphis jamesii*), dropseed (*Sporobolus* spp.), fourwing saltbush (*Atriplex canescens*), broom snakeweed (*Gutierrezia sarothrae*), and various forbs. Prolonged grazing disturbance will reduce perennial grasses, increase shrubs, and lead to colonization by invasive, non-native annuals. At this time, most production is being supplied by black greasewood, followed by mound saltbush (*Atriplex obovata*) and prickly Russian thistle. On one transect the toxic plant saltlover (*Halogeton glomeratus*) was found in the plant community.

The final ecological site, R035XY121UT, has the lowest amount of available forage. These are sandy sites and are often calcareous, making them suitable for plants like blackbrush (*Coleogyne ramosissima*) that prefer soils with a high pH. The reference plant community does tend to be dominated by blackbrush and may or may not have non-woody species in the shrub interspaces. When present, common herbaceous species are Indian ricegrass, needle and thread (*Hesperostipa comata*), sand dropseed (*Sporobolus cryptandrus*), tall dropseed (*Sporobolus contractus*), and various annual and perennial forbs. Disturbances do not tend change the overall composition of the plant community, but can put the community at risk of invasion by non-native species. All transects but one are in blackbrush communities with moderate to dense stands. On the single transect in a non-blackbrush community, mostly shrub species such as rubber rabbitbrush, frosted mint (*Poliomintha incana*), and pillar false gumweed (*Vanclevea stylosa*) were encountered. The primary forage grasses in this site are Indian ricegrass and James' galleta.

Species Frequency and Composition

The most commonly encountered species and the ones contributing the most biomass in Pasture 3, are listed below:

Frequently Encountered Species

1. prickly Russian thistle (*Salsola tragus*) (occurred on 82% of all transects)
2. broom snakeweed (*Gutierrezia sarothrae*) (occurred on 53% of all transects)
3. rubber rabbitbrush (*Ericameria nauseosa*) (occurred on 53% of all transects)
4. Rusby's goldenbush (*Isocoma rusbyi*) (occurred on 53% of all transects)
5. black greasewood (*Sarcobatus vermiculatus*) (occurred on 41% of all transects)

Species by Weight (Average Weight)

1. black greasewood (*Sarcobatus vermiculatus*) (18 lbs/acre)
2. rubber rabbitbrush (*Ericameria nauseosa*) (16 lbs/acre)
3. prickly Russian thistle (*Salsola tragus*) (9 lbs/acre)
4. Rusby's goldenbush (*Isocoma rusbyi*) (7 lbs/acre)
5. mound saltbush (*Atriplex obovata*) (6 lbs/acre)

Ground Cover

Bare ground in Pasture 3 is at 76 percent, and foliar cover is at 10 percent. Active water erosion is not a significant issue, but the high amount of bare ground does put the pasture at risk for wind erosion due to the prevalence of sandy soils. The most severe wind erosion is currently taking place in the southeastern corner of the pasture.

Rangeland Health

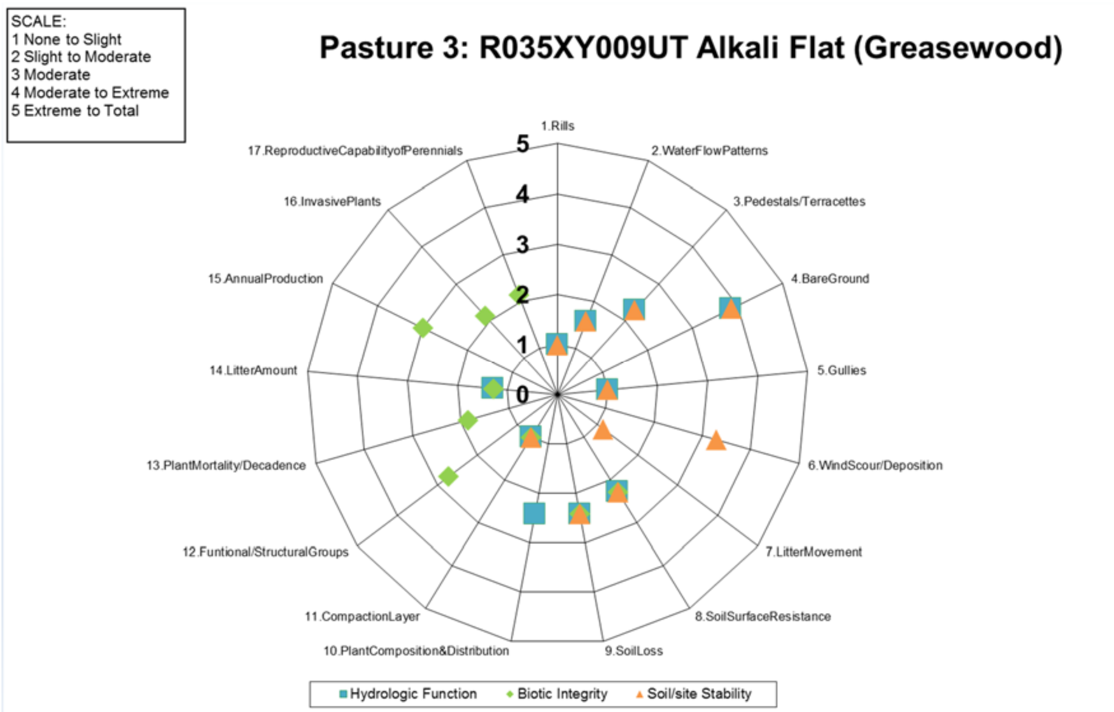
Only one of the three ecological sites in Pasture 3 has a developed reference sheet. This site, R035XY009UT, contains seven transects, and Table 5-3 shows the degree of departure from the reference community for each rangeland health attribute.

Table 5-3. Rangeland Health in Pasture 3

Ecological Site	Departure from Reference Community		
	Soil and Site Stability	Hydrological Function	Biotic Integrity
R035XY009UT Alkali Flat (Greasewood)	Slight to Moderate	Slight to Moderate	Slight to Moderate

On average, all three attributes in this site are experiencing slight to moderate departure from reference conditions. However, several of the seventeen indicators have seen a more significant shift away from their reference state. One of these, bare ground, applies to both soil/site stability and hydrological function. In the R035XY009UT site, the reference sheet indicates that bare ground should not exceed 25 percent, but at this time the transect average is 86 percent. The increased soil exposure accelerates soil loss associated with wind and water erosion and wind erosion in particular is a big factor in this pasture. In the reference state, this site should have only minor evidence of soil movement due to wind and scouring and depositional areas are seldom present. However, field observations show that areas around most of the transects do have large “blowouts” and active sand dunes. Annual production is the main biotic indicator that has had a definite departure from reference conditions. This site should be producing between 700-800 pounds per acre per year, but is currently averaging around 200-300 pounds per acre per year.

Data for the 17 indicators for the ecological site are included in the following graph.



Analysis Unit 3

Summary of Grazeable and Non-Grazeable Acres in Analysis Unit

TotalAcres		8,783.09
Non-Grazeable Acres	Developed	45.90
	Hydro	2.74
	Roads	236.71
	Slope >60	0.00
Range Acres		8,497.74

Summary of Similarity Indices, Cover, and Carrying Capacities

Similarity Indices (%)	
Minimum	3
Maximum	25
Mean	7

Cover (%)	
Foliar Cover	10.00%
Bare Ground	75.76%
Basal	0.00%

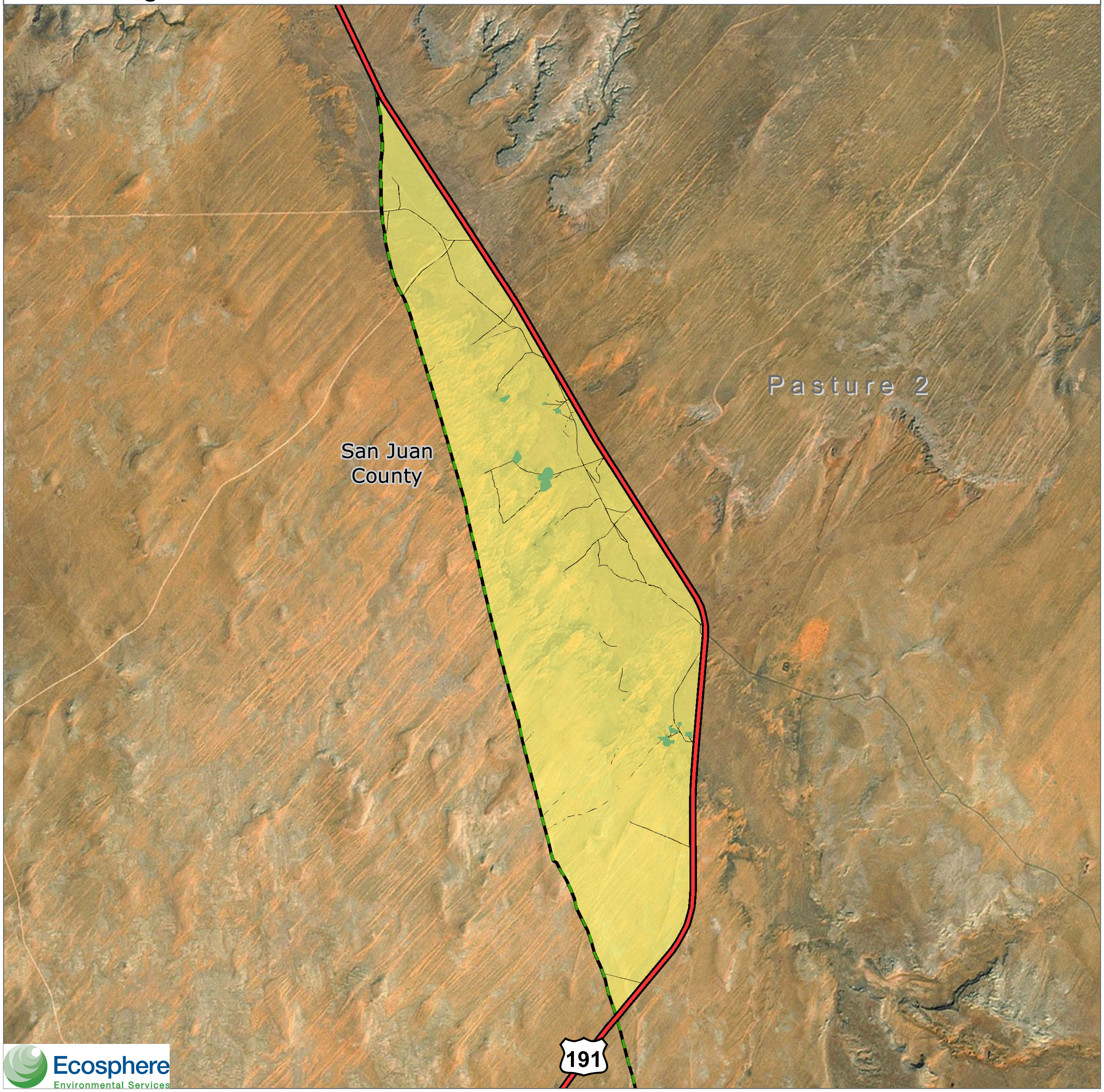
Carrying Capacity (Sheep Unit/Year)	
Initial CC	17.4
Slope Adjusted CC	17.33
Distance to Water CC	10.88

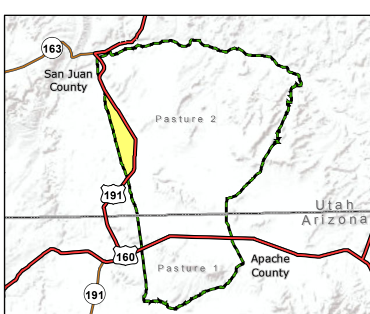
Results by Ecological Site in Sheep Units Year long

Ecological Site	Number of Transects	Percent of Analysis Unit Acres	Average Available Forage (Lbs/Acre)	Acres	Sheep Stocking Rate (Sheep Units)	Sheep Carrying Capacity (Sheep Units per Year
R035XY009UT Alkali Flat (Greasewood)	7	27	2.95	2,404.99	803.39	2.99
R035XY115UT Desert Sand (Sand Sagebrush)	6	43	8.76	3,794.64	270.55	14.03
R035XY121UT Desert Sandy Loam (Blackbrush)	4	8	1.3	685.52	1823.08	0.38
Sheppard	0	2		152.51		
Rock Outcrop	0	4		342.76		
Piute	0	<1		60.10		
Monue	0	<1		60.10		
Hummocky	0	2		152.51		
Gotho	0	<1		31.09		
Aneth	0	<1		31.09		
Alkaline Soil	0	1		96.90		
R035XY130UT Desert Shallow Sandy Loam (Shadscale)		8		685.52		

2014 Range Inventory
BIA Northern Navajo Agency
Land Management District 9

Red Mesa Chapter
Pasture 3





Analysis Unit Boundary

Community Boundary

State Line

Non Grazeable Range

Developed

Hydrology

Roads

0 2.5 5

Miles

1:90,000

Date: 2/10/2015

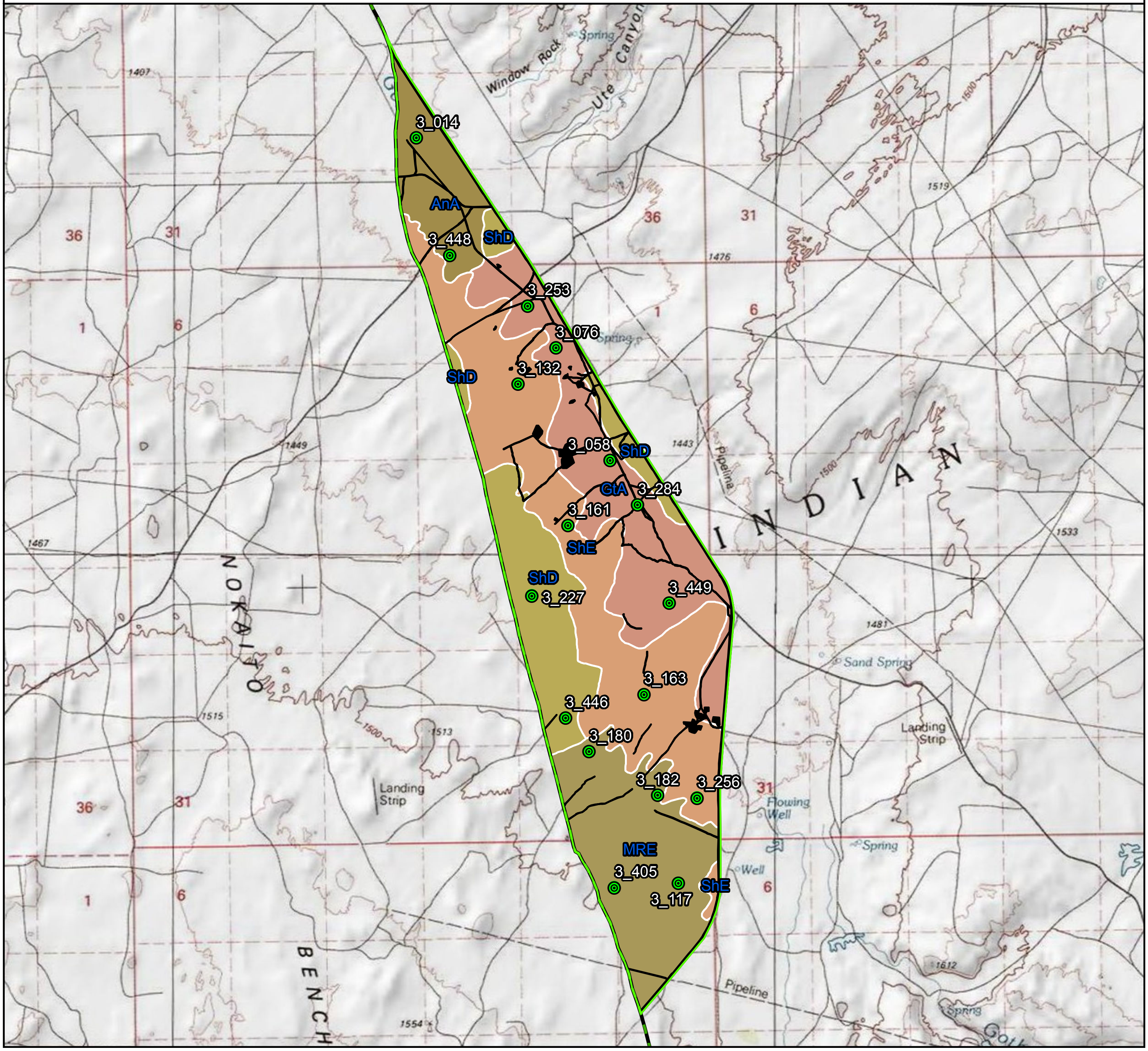
Coordinate System: NAD 1983 UTM Zone 12N

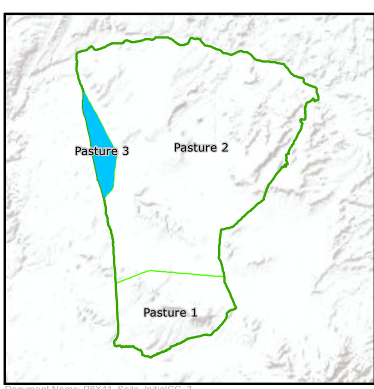
Document Name: P8X11_UNIT1

2014 Range Inventory
BIA Northern Navajo Agency
Land Management District 9
Red Mesa Chapter, Pasture 3

Total Acres: 8,783
Grazeable Acres*: 8,498
*Total acres minus non grazeable areas and areas with > 60% slope.

Initial Annual Carrying Capacity: 17 Sheep





Transect Location
Non Grazeable Range
Unit Boundary
Soil Map Unit
Community Boundary

0 0.5 1 2 3 4 5
Miles

Ecosphere Environmental Services

1:90,000

Date: 2/10/2015

Coordinate System: NAD 1983 UTM Zone 12N

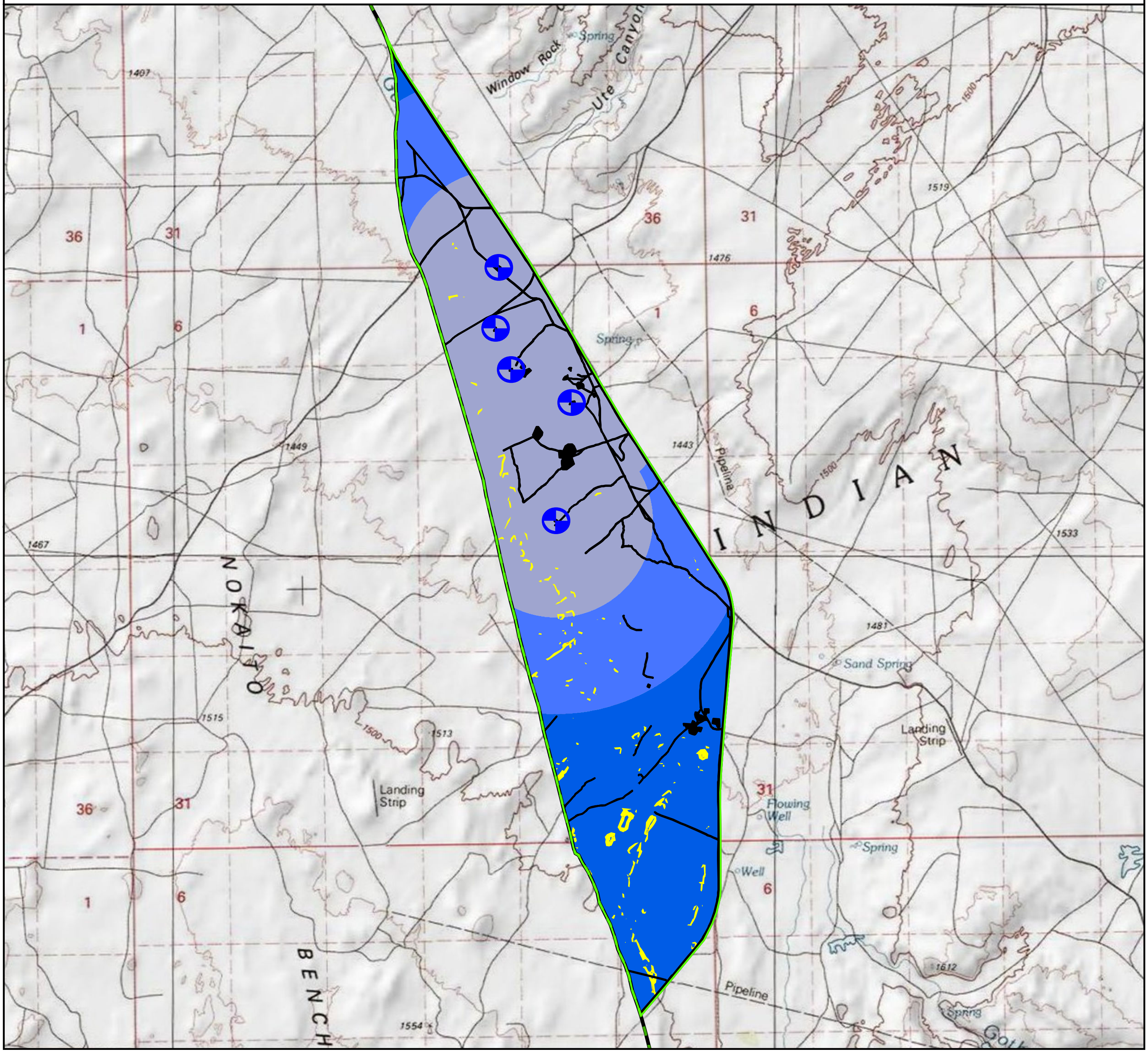
Document Name: P8X11_Soils_InitialCC_3

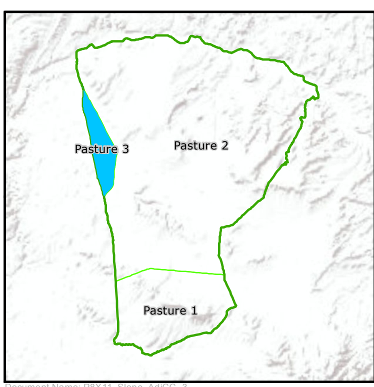
2014 Range Inventory
BIA Northern Navajo Agency
Land Management District 9

Red Mesa Chapter, Pasture 3

Total Acres: 8,783
Grazeable Acres*: 8,498
*Total acres minus non grazeable areas and areas with > 60% slope.

Adjusted Annual Carrying Capacity: 11 Sheep





Water Source
Pasture Boundary
Community Boundary
Non Grazeable Range

Distance to Water
0-1 Mile
1-2 Miles
> 2 Miles

Slope
10 - 30%
30 - 60%
> 60%

0 0.5 1 2 3 4 5
Miles

1:90,000

Ecosphere Environmental Services

Date: 2/10/2015

Coordinate System: NAD 1983 UTM Zone 12N

Document Name: P8X11_Slope_AdjCC_3

6. Conclusions and Recommendations

The study area is composed of sandy grasslands, sand dunes, and occasional badland areas near the San Juan River. Pinyon-juniper woodlands can be found on top of low mesas and large areas of sandstone outcrops occur in various locations throughout the study area. Production in the all three pastures is quite low, and the amount of bare ground and wind erosion is high. A common theme in each pasture is the lack of perennial grasses. In many cases, former grassland sites have converted to shrublands. This is not a desired shift, but shrubs at least help protect the soil and can be thinned out with various treatments. Other sites have degraded to the point where either very little vegetation remains, or the dominant plants are annual forbs and grasses, often non-native. These changes are largely due to a combination of unmanaged grazing and sustained drought conditions. Another commonality among the pastures is the encroachment of sand dunes. Many of the transects were placed within soil map units composed of badland sites and other, non-sandy soil types. However, during the field survey, it was clear that up to several feet of sand have since been deposited onto these areas. This is problematic because in many cases, the associated ecological site description can no longer be used as a reliable measure of comparison as soils and plant communities are drastically different from the reference state, but not necessarily due to onsite disturbances. Although wind erosion is a problem in the study area, a lot of this sand is being blown in from off-site locations. In the future, it will likely be necessary to develop new site descriptions to better accommodate these changes. For the purposes of this study, transects in these locations were classified as located within a “minor component” because their data would not accurately reflect the major component soil and ecological site descriptions.

Increases in shrubs are notable with rubber rabbitbrush (*Ericameria nauseosa*) and Greene’s rabbitbrush (*Chrysothamnus greenei*) in Pasture 1, rubber rabbitbrush, Rusby’s goldenbush (*Isocoma rusbyi*), black greasewood (*Sarcobatus vermiculatus*), and fourwing saltbush (*Atriplex canescens*) in Pasture 2, and rubber rabbitbrush, mound saltbush (*Atriplex obovata*), and black greasewood in Pasture 3. The most commonly encountered invasive species were prickly Russian thistle (*Salsola tragus*), saltlover (*Halogeton glomeratus*), and cheatgrass (*Bromus tectorum*). Prickly Russian thistle is widespread throughout the study area with some areas containing only small amounts, while others have this species as a dominant species in the plant community. Cheatgrass was found in Pastures 1 and 2, but only as a minimal constituent of the current plant community. Saltlover was only encountered on three transects: two in the breaks near the San Juan River and one at the north end of Pasture 3. Given the toxic and invasive nature of this species, efforts should be made to map the total extent and implement control measures before it becomes more widespread.

The following sections provide some recommendations regarding drought and grazing management, shrub reduction, weed control, and data analysis and monitoring.

6.1 Drought

Precipitation is one of the greatest obstacles to overcome when managing and restoring rangeland. Local precipitation monitoring stations recorded lower than average precipitation throughout the growing season in 2014. Indeed, precipitation levels throughout the southwest indicate ongoing long-term drought conditions (National Drought Mitigation Center [NDMC] 2014). 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. Due to the high percentage of bare ground in the study area, many areas are at risk of accelerated water erosion during this type of storm event. This increases soil loss while decreasing water retention. The potential for soil loss due to wind erosion is also very high, as much of the study area contains unstable sandy soils. Sandy soils require a lot of plant cover to become stable. It may be necessary to encourage growth of less palatable, stabilizing species initially. Grasses such as sandhill muhly (*Muhlenbergia pungens*) and James' galleta (*Pleuraphis jamesii*) are excellent cover plants that do well in loose soils.

It also is very important to collect accurate precipitation data. Calculations for annual production (and resulting stocking rates) incorporate average precipitation for a given water year. Location-specific precipitation gauges allow managers to more closely monitor precipitation, giving them the opportunity to proactively implement drought management plans. Plants demonstrate rapid growth during a certain portion of the growing season; cool-season plants tend to experience this between March and the beginning of June, with a smaller growth surge in the fall, while warm-season plants grow more quickly during mid-summer. These are critical time periods for forage species and a lack of adequate moisture will compromise growth for the duration of the growing season. Moisture that arrives outside of these windows of rapid growth will help plants, but will be much less effective. Semiarid regions generally are considered to be experiencing drought conditions when the cumulative growing season precipitation is 20 to 25 percent below average during these periods of rapid growth (NDMC 2014). 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 in the study area as the majority of forage plants are warm-season grasses like James's galleta and alkali sacaton (*Sporobolus airoides*). Monsoonal moisture arriving in mid to late July corresponds well with the period of rapid growth for these grasses. However, in years where the monsoons are delayed or largely absent, it will be necessary to adjust grazing plans. 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. Stabilizing active sand dunes is probably the most important step that needs to be taken in the Red Mesa Community.

A lack of precipitation and vegetation has led to an increase in the number and size of dunes and caused previously stabilized sand to "reactivate" and begin moving again. One recent approach to this problem is to utilize seed cakes and sand sausages. The cakes are a mix of compost, clay, and native grass seed. The clay material is more resistant to wind than sand and helps keep the seed in place while the compost provides a nutrient-rich medium in which the seedlings can develop. Sand sausages refer to bio-degradable tubes. These tubes are filled with sand taken directly from a dune and then laid out in a grid formation. The seed cakes are placed within each square of the dune. The sausages act to both protect the seedlings and slow down dune growth. The idea is that by the time the tubes decompose, enough vegetation will have become established to stabilize the dune (NAU EEOP 2012).

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 mostly in the northeastern corner of the study area which contains 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 much of the study area. For example, all pastures have some amount of the following forage species: James' galleta, Indian ricegrass (*Achnatherum hymenoides*), tall dropseed (*Sporobolus contractus*), alkali sacaton, fourwing saltbush, and Cutler's jointfir (*Ephedra cutleri*).This indicates that with careful and proactive management, native species production and frequency should increase naturally without much intervention. In areas that are more deteriorated, seeding with local, drought-tolerant species that can germinate early, such as scarlet globemallow (*Sphaeralcea coccinea*) and sand dropseed (*Sporobolus cryptandrus*), may speed up revegetation, and increase the likelihood of success.

The lack of native herbaceous diversity is due, in large part, to unmanaged continuous grazing systems. Determining forage production based upon a normal precipitation year allows managers to establish a "ceiling" or carrying capacity for their land. Stocking rates developed for a normal precipitation year should not be used 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 forage 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 the key to reaping these benefits. Many of the ESDs available for the study 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

Many of the ecological sites in the study area have transitioned from grassland to shrubland. For example, dense stands of blackbrush (*Coleogyne ramosissima*) occur on about 25 percent of all transect locations, and black greasewood is common in low-lying areas, especially those within the R035XY009UT ecological site. This site’s reference state does often have greasewood as a dominant part of the plant community, but in the pastures, these sites typically have a mix of bare ground and non-native species in the shrub interspaces instead of native, perennial grasses and forbs. Rubber rabbitbrush, broom snakeweed (*Gutierrezia sarothrae*), and Green’s rabbitbrush (*Chrysothamnus greenei*) frequently occur in sandy locations, but stand density is usually low.

Shrubs help protect the soil surface and many species provide browse for livestock, but it is more desirable from an ecological and grazing management standpoint to have a more balanced mix of grasses and shrubs. In some cases, employing proper grazing management should be sufficient to encourage the re-establishment of native forbs and grasses. As the herbaceous component begins to flourish, woody species will cease to dominate, and a more balanced plant community will develop. However, it may become necessary to reduce shrub populations either by mechanical or chemical means. A number of mechanical methods have been used to control shrubs on rangelands including roller chopping, root plowing, shredding, chaining, and bulldozing. These practices require relatively gentle terrain and the cost of operating the equipment can be expensive, which limits their practicality in the 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 (DiTomaso 2000; Olsen et al. 1994). Tebuthiuron (Spike®, Scrubmaster®, Perflan®) and Picloram (Tordon®, Grazon®) have proven effective in controlling broom snakeweed. 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 (Gesink et al. 1973; McDaniel and Duncan 1987; Schmutz and Little 1970; Sosebee et al. 1979). 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; Evans and Young 1978; Tueller and Evans 1969). Before implementing shrub control measures, consultation with experts is recommended to determine the best rates and timing for herbicide applications, minimize impacts to non-target plant and wildlife species, and explore alternate control methods.

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

Given the prevalence of non-native species and bare ground in the black greasewood communities, and its value as a browse species for livestock and wildlife, full-scale removal or heavy thinning will likely not have a desirable effect. Using herbicides to achieve light to moderate amount of thinning would be a better approach and would need to be coordinated with a seeding program in order to populate the understory with native, herbaceous species. Combined applications of triclopyr (Garlon®, Pathfinder®) and benazolin (Asset®, Benazalox®) or 2,4-D and picloram have yielded results in previous studies (Cluff et al. 1984; Ferrell and Whitson 1987). The best effects are achieved when plants are treated during periods of accelerated growth experienced between late May and late June (Roundy et al. 1981; Roundy et al. 1983).

6.4 Invasive Species

Prickly Russian thistle (*Salsola tragus*)

Prickly Russian thistle is a drought tolerant, disturbance-loving species that does well in sandy soils. 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). However, 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.

Prickly Russian thistle also can accelerate revegetation of disturbed areas by supporting the growth of soil mycorrhizae. 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 mycorrhizae invade the roots of Russian thistle and do not form an association with this plant, but rather kill the infected roots and move on to the roots of neighboring plants. In this manner, the fungi population increases while prickly 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, prickly Russian thistle will persist on a site for about 2 years and then will be replaced by annual and biennial mustards like tall tumblemustard (*Sisymbrium altissimum*) and various tansymustard (*Descurainia* spp.) (Chapman et al. 1969). The mustard species continue to build up the soil substrate by maintaining soil mycorrhiza populations and adding organic matter to the soil as the plants die. However, it is important to note that this process can only occur in sites where disturbance factors, such as grazing, are removed or at least minimized. In most parts of the study area, continuous, year-round grazing effectively causes this plant to persist in the plant community as native species are consumed before they have the chance to become established and seeds from thistle plants are free to sprout and establish additional populations.

Prickly Russian thistle also helps prepare a site by releasing oxalates into the soil. These chemicals work to change inorganic phosphorous into a soluble form that can be taken up by plants (Cannon et al. 1995). Phosphorus often is a limiting nutrient in the soil and by increasing its availability, favorable forage plants can become established more quickly. Prickly Russian thistle can be controlled or even eradicated through various mechanical and chemical treatments (Burrill et al. 1989; Young and Whitesides 1987); 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.

Cheatgrass (*Bromus tectorum*)

Cheatgrass is not abundant in the study area, but it was encountered fairly frequently in Pastures 1 and 2. Cheatgrass is difficult to control due to its ability to produce large quantities of seed, which either germinate in the fall or carry over in the seed bank to germinate in the following spring (Smith et al. 2008).

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

Saltlover (*Halogeton glomeratus*)

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 (Duda et al. 2003; Eckert and Kinsinger 1960; Lancaster et al. 1987). In the study area, saltlover was only encountered on a few transects in the northern regions of Pasture 2.

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 (USDA Agricultural Research Service 2006; Whitson et al. 2002).

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 et al. 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 (Blaisdell and Holmgren 1984; Keller 1979; West 1983; Whisenant and Wagstaff 1991).

Russian knapweed (*Acroptilon repens*)

Large populations of Russian knapweed were encountered at sites along the San Juan River riparian corridor. This species has the potential to quickly spread once it has been introduced into a system and it has allelopathic properties that inhibit growth in native plants (Beck and Hanson 1989; Whitson 1999). This feature is particularly problematic in this region as seed can easily be transported downstream to new locations via the river. Similarly, even if current infestations are eradicated, upstream seed sources can easily reestablish new populations. Livestock generally avoid consuming this weed, but if eaten in sufficient quantity, it can be toxic, especially to horses (Panter 1991; Robles et al. 1997).

The elements necessary to control Russian knapweed include stressing plants enough to induce them use up nutrient reserves in the roots, eliminating seed sources, and controlling vegetative spread by either isolating populations during treatments (i.e. uprooting plants) to insure that root fragments are not spread to adjacent areas or by planting competitive species (Beck 2001). Mechanical control, such as cutting or pulling plants by hand can help contain populations, but these methods need to be repeated 2-3 times a year. This species is fairly resistant to herbicide, but decent results have been achieved using a combination of clopyralid (Curtail®, Confront®) and 2,4-D (Benz et al. 1999). In general, integrated weed management that employs some combination of chemical, biological, and mechanical treatments seems to be the best approach to controlling this species (Mullin 1992).

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, James' galleta, alkali sacaton, tall dropseed, and fourwing saltbush. The next step is to use this data to identify specific locations that would benefit most from improvement measures and then organize field visits to gain an "on-the-ground" perspective. Groups of transects that yielded low production and high counts of bare ground may be in severely eroded areas and great effort would be necessary to improve these sites. On the other hand, these groups of transects may just have a high potential for erosion and simple improvements could greatly enhance the soil and plant community. Using the data to pinpoint areas with the highest densities of shrubs would serve as a starting point for assessing whether chemical control measures are necessary. In some cases, it may be better to focus on grazing strategies and let natural succession run its course. Identifying places with high forage production can be helpful for implementing rotational grazing schemes. These areas would be able to withstand higher grazing pressures, while more fragile locations are rested. Visits to these areas would allow managers to determine the feasibility of adding water sources if none are present. If data from certain transects show that native forage species are not present, it may be necessary to implement reseeding programs. Agriculture extension offices and the NRCS are good resources to help determine appropriate seed mixes and find seed sources.

Grazing programs should make use of available tools. When it is possible to erect fences, they should be designed to ease movement and exclusion of livestock, as dictated by the condition of the vegetation. Designating pastures where fences already exist, such as the highway fences that bisect grazing units, also would be useful for monitoring forage in those pastures. Currently, the forage on one of side the highway is applied to the carrying capacity on both sides of the highway. Separating the grazing units into pastures would allow for more site-specific data collection and monitoring, as well as livestock management. Water sources and salt blocks can also 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 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 again. 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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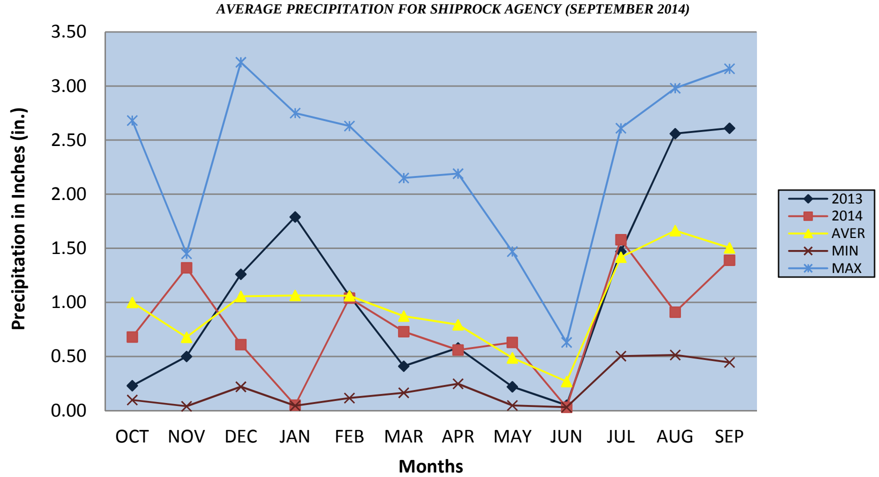
Appendix A – Precipitation Data

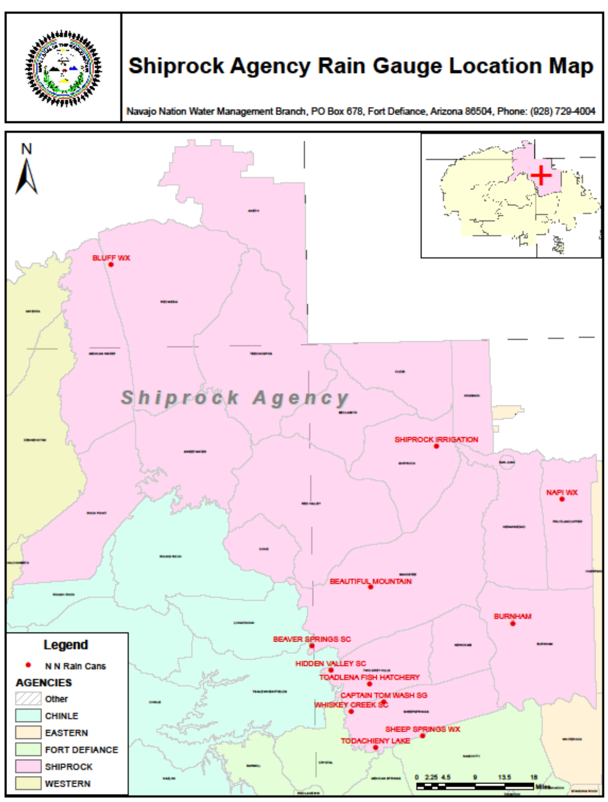
Navajo Nation Precipitation Report
Department of Water Resources * Water Management Branch
PO Box 678 * Fort Defiance, Arizona 86504 * Phone: (928) 729-4004 * Fax: (928) 729-4126

MONTHLY AVERAGES (INCHES) FOR ALL RAINCANS IN SHIPROCK AGENCY

WATER YEAR	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	WY Monthly AVG
2000	0.10	0.09	0.52	1.49	0.73	2.15	0.75	0.31	0.63	0.96	2.04	0.48	0.85
2001	2.68	0.61	0.44	1.22	0.98	1.01	0.91	0.86	0.27	1.61	2.07	0.65	1.11
2002	0.33	0.71	0.82	0.27	0.17	0.40	0.67	0.10	0.12	0.99	1.24	3.16	0.75
2003	1.32	1.07	0.76	0.43	1.86	1.60	0.43	0.42	0.28	1.16	1.40	1.67	1.03
2004	1.20	1.43	0.71	0.85	1.02	0.82	2.19	0.05	0.33	1.13	0.63	2.13	1.04
2005	1.45	1.18	1.25	1.75	2.63	1.06	1.63	0.47	0.31	0.78	2.98	1.17	1.39
2006	0.85	0.04	0.22	0.62	0.12	1.25	0.52	0.19	0.36	1.64	1.54	1.74	0.76
2007	2.36	0.17	0.90	0.65	1.24	0.97	1.00	1.47	0.51	0.79	2.28	1.43	1.15
2008	0.24	0.04	3.22	2.75	2.02	0.16	0.25	0.47	0.37	1.37	1.56	0.45	1.07
2009	0.54	0.67	2.32	0.60	0.74	0.48	0.66	0.92	0.49	0.50	0.51	1.16	0.80
2010	0.51	0.41	0.96	2.70	0.95	0.87	0.51	0.21	0.16	2.43	2.36	1.45	1.13
2011	1.32	0.47	1.14	0.32	0.55	0.51	0.95	0.90	0.03	2.24	1.36	2.25	1.00
2012	1.26	1.45	0.72	0.48	0.81	0.65	0.28	0.11	0.09	2.61	1.52	0.84	0.90
2013	0.23	0.50	1.26	1.79	1.06	0.41	0.58	0.22	0.05	1.47	2.56	2.61	1.06
2014	0.68	1.32	0.61	0.05	1.04	0.73	0.56	0.63	0.03	1.58	0.91	1.39	0.79
	Summary for SHIPROCK AGENCY (15 detail records)												
Average	*1.00*	*0.68*	*1.06*	*1.06*	*1.06*	*0.87*	*0.79*	*0.49*	*0.27*	*1.42*	*1.66*	*1.50*	
Minimum	*0.10*	*0.04*	*0.22*	*0.05*	*0.12*	*0.16*	*0.25*	*0.05*	*0.03*	*0.50*	*0.51*	*0.45*	
Maximum	*2.68*	*1.45*	*3.22*	*2.75*	*2.63*	*2.15*	*2.19*	*1.47*	*0.63*	*2.61*	*2.98*	*3.16*	

AVERAGE PRECIPITATION FOR SHIPROCK AGENCY (SEPTEMBER 2014)





Appendix B – Plant List

GenusSpecies	Code	Growth	Family	Duration	Sheep	Goat	Cattle
Abronia fragrans	ABFR2	Forb	Nyctaginaceae	Perennial	Not Consumed	Not Consumed	Not Consumed
Abronia sp.	ABRON	Forb	Nyctaginaceae	Perennial	Not Consumed	Not Consumed	Not Consumed
Achnatherum hymenoides	ACHY	Graminoid	Poaceae	Perennial	Desirable	Emergency	Preferred
Ambrosia acanthicarpa	AMAC2	Forb	Asteraceae	Annual	Not Consumed	Not Consumed	Not Consumed
Amelanchier utahensis	AMUT	Shrub	Rosaceae	Perennial	Desirable	Desirable	Desirable
Androsace septentrionalis	ANSE4	Forb	Primulaceae	Annual/Perennial	Not Consumed	Not Consumed	Not Consumed
Arenaria sp.	ARENA	Forb	Caryophyllaceae	Perennial	Not Consumed	Not Consumed	Not Consumed
Aristida purpurea	ARPU9	Graminoid	Poaceae	Perennial	Not Consumed	Not Consumed	Not Consumed
Artemisia bigelovii	ARBI3	Shrub	Asteraceae	Perennial	Emergency	Emergency	Not Consumed
Artemisia campestris	ARCA12	Forb	Asteraceae	Perennial	Not Consumed	Not Consumed	Not Consumed
Artemisia dracunculus	ARDR4	Forb/Subshrub	Asteraceae	Perennial	Desirable	Desirable	Desirable
Artemisia filifolia	ARFI2	Shrub	Asteraceae	Perennial	Emergency	Emergency	Not Consumed
Artemisia nova	ARNO4	Shrub	Asteraceae	Perennial	Desirable	Emergency	Emergency
Artemisia tridentata	ARTR2	Shrub	Asteraceae	Perennial	Emergency	Emergency	Not Consumed
Asclepias sp.	ASCLE	Forb	Asclepiadaceae	Perennial	Emergency T	Emergency I	Emergency T
Asclepias subverticellata	ASSU2	Forb	Asclepiadaceae	Perennial	Emergency T	Emergency I	Emergency T
Astragalus mollissimus	ASMOT	Forb	Fabaceae	Perennial	Not Consumed T	Not Consumed T	Not Consumed T
Astragalus sp.	ASTRA	Forb	Fabaceae	Perennial	Emergency T	Emergency T	Emergency T
Astragalus sp.	ASTRA	Forb	Fabaceae	Annual	Emergency T	Emergency T	Emergency T
Atriplex canescens	ATCA2	Shrub	Chenopodiaceae	Perennial	Desirable	Desirable	Desirable
Atriplex confertifolia	ATCO	Shrub	Chenopodiaceae	Perennial	Not Consumed I	Not Consumed I	Not Consumed I
Atriplex obovata	ATOB	Subshrub	Chenopodiaceae	Perennial	Emergency	Emergency	Emergency
Bassia scoparia	BASC5	Forb	Chenopodiaceae	Annual	Desirable T	Emergency T	Desirable T
Bouteloua barbata	BOBA2	Graminoid	Poaceae	Annual	Not Consumed	Not Consumed	Not Consumed
Bouteloua gracilis	BOGR2	Graminoid	Poaceae	Perennial	Emergency	Not Consumed	Desirable
Bromus rubens	BRRU2	Graminoid	Poaceae	Annual	Desirable I	Emergency I	Desirable I
Bromus tectorum	BRTE	Graminoid	Poaceae	Annual	Desirable I	Emergency I	Desirable I
Cercocarpus montanus	CEMO2	Shrub	Rosaceae	Perennial	Desirable	Desirable	Emergency
Chaetopappa ericoides	CHER2	Forb	Asteraceae	Perennial	Not Consumed	Not Consumed	Not Consumed
Chamaesyce fendleri	CHFE3	Forb	Euphorbiaceae	Perennial	Not Consumed	Not Consumed	Not Consumed
Chamaesyce parryi	CHPA28	Forb	Euphorbiaceae	Annual	Not Consumed	Not Consumed	Not Consumed
Chamaesyce sp.	CHAMA15	Forb	Euphorbiaceae	Annual	Not Consumed	Not Consumed	Not Consumed
Chrysothamnus greenei	CHGR6	Shrub	Asteraceae	Perennial	Emergency	Emergency	Emergency

Abronia fragrans	ABFR2	Forb	Nyctaginaceae	Perennial	Not Consumed	Not Consumed	Not Consumed
Chrysothamnus pulchellus	CHPU4	Shrub	Asteraceae	Perennial	Not Consumed T	Not Consumed T	Not Consumed T
Chrysothamnus viscidiflorus	CHVI8	Shrub	Asteraceae	Perennial	Emergency	Emergency	Emergency
Coleogyne ramosissima	CORA	Shrub	Rosaceae	Perennial	Not Consumed	Emergency	Not Consumed
Commandra umbellata	COUM	Subshrub	Santalaceae	Perennial	Not Consumed	Not Consumed	Not Consumed
Cordylanthus wrightii	COWR2	Forb	Scrophulariaceae	Annual	Not Consumed	Not Consumed	Not Consumed
Cryptantha cineria	CRCI3	Forb	Boraginaceae	Perennial	Not Consumed	Not Consumed	Not Consumed
Cryptantha circumcissa	CRCI2	Forb	Boraginaceae	Annual	Not Consumed	Not Consumed	Not Consumed
Cryptantha crassisepala	CRCR3	Forb	Boraginaceae	Annual	Not Consumed	Not Consumed	Not Consumed
Cryptantha sp.	CRYPT	Forb/Subshrub	Boraginaceae	Annual	Not Consumed	Not Consumed	Not Consumed
Cryptantha sp.	CRYPT	Forb/Subshrub	Boraginaceae	Annual	Not Consumed	Not Consumed	Not Consumed
Cryptantha sp.	CRYPT	Forb/Subshrub	Boraginaceae	Perennial	Not Consumed	Not Consumed	Not Consumed
Descurainia pinnata	DEPI	Forb	Brassicaceae	Annual	Not Consumed	Not Consumed	Not Consumed
Descurainia sp.	DESCU	Forb	Brassicaceae	Annual	Not Consumed	Not Consumed	Not Consumed
Dicoria canescens	DICA4	Forb	Asteraceae	Annual	Not Consumed	Not Consumed	Not Consumed
Dimorphocarpa wislizeni	DIWI2	Forb	Brassicaceae	Ann./Bienn./Perenn.	Emergency	Emergency	Emergency
Distichlis spicata	DISP	Graminoid	Poaceae	Perennial	Not Consumed	Not Consumed	Not Consumed
Elymus elymoides	ELEL5	Graminoid	Poaceae	Perennial	Emergency	Emergency	Emergency
Elymus sp.	ELYMU	Graminoid	Poaceae	Perennial	Emergency	Emergency	Emergency
Ephedra cutleri	EPCU	Shrub	Ephedraceae	Perennial	Desirable	Desirable	Desirable
Ephedra sp.	EPHED	Shrub	Ephedraceae	Perennial	Desirable	Desirable	Desirable
Ephedra torreyana	EPTO	Shrub	Ephedraceae	Perennial	Desirable	Desirable	Desirable
Ephedra viridis	EPVI	Shrub	Ephedraceae	Perennial	Desirable	Desirable	Desirable
Eremopyrum triticeum	ERTR13	Graminoid	Poaceae	Annual	Not Consumed	Not Consumed	Not Consumed
Ericameria nauseosa	ERNA10	Shrub	Asteraceae	Perennial	Emergency	Emergency	Emergency
Ericameria parryi	ERPA30	Shrub	Asteraceae	Perennial	Not Consumed	Emergency	Not Consumed
Erigeron flagellaris	ERFL	Forb	Asteraceae	Biennial/Perennial	Not Consumed	Not Consumed	Not Consumed
Erigeron sp.	ERIGE2	Forb	Asteraceae	Annual	Not Consumed	Not Consumed	Not Consumed
Eriogonum cernuum	ERCE2	Forb	Polygonaceae	Annual	Emergency	Desirable	Emergency
Eriogonum corymbosum	ERCO14	Shrub	Polygonaceae	Perennial	Not Consumed	Not Consumed	Not Consumed
Eriogonum inflatum	ERIN4	Forb	Polygonaceae	Annual/Perennial	Emergency	Desirable	Emergency
Eriogonum leptocladon	ERLE9	Shrub	Polygonaceae	Perennial	Emergency	Emergency	Emergency
Eriogonum microthecum	ERMI4	Shrub	Polygonaceae	Perennial	Emergency	Desirable	Emergency
Eriogonum sp.	ERIOG	Forb	Polygonaceae	Annual	Not Consumed	Not Consumed	Not Consumed

Abronia fragrans	ABFR2	Forb	Nyctaginaceae	Perennial	Not Consumed	Not Consumed	Not Consumed
Eriogonum sp.	ERIOG	Forb	Polygonaceae	Perennial	Not Consumed	Not Consumed	Not Consumed
Eriogonum umbellatum	ERUM	Subshrub	Polygonaceae	Perennial	Emergency	Desirable	Emergency
Eriogonum wetherillii	ERWE	Forb	Polygonaceae	Annual	Not Consumed	Not Consumed	Not Consumed
Euphorbia sp.	EUPHO	Forb	Euphorbiaceae	Perennial	Not Consumed	Not Consumed	Not Consumed
Fraxinus anomala	FRAN2	Shrub/Tree	Oleaceae	Perennial	Emergency	Emergency	Not Consumed
Gilia sinuata	GISI	Forb	Polemoniaceae	Annual	Not Consumed	Not Consumed	Not Consumed
Gilia sp.	GILIA	Forb	Polemoniaceae	Annual	Not Consumed	Not Consumed	Not Consumed
Grindelia squarrosa	GRSQ	Forb	Asteraceae	Ann./Bienn./Perenn.	Not Consumed	Not Consumed	Not Consumed
Gutierrezia microcephala	GUMI	Subshrub	Asteraceae	Perennial	Emergency T	Emergency T	Emergency T
Gutierrezia sarothrae	GUSA2	Subshrub	Asteraceae	Perennial	Emergency T	Emergency T	Emergency T
Halogeton glomeratus	HAGL	Forb	Chenopodiaceae	Annual	Not Consumed T	Not Consumed T	Not Consumed T
Hymenopappus filifolius	HYFI	Forb	Asteraceae	Perennial	Not Consumed	Not Consumed	Not Consumed
Ipomopsis gunnisonii	IPGU	Forb	Polemoniaceae	Annual	Not Consumed	Not Consumed	Not Consumed
Ipomopsis sp.	IPOMO	Forb	Polemoniaceae	Annual	Not Consumed	Not Consumed	Not Consumed
Isocoma rusbyi	ISRU2	Subshrub	Asteraceae	Perennial	Not Consumed T	Not Consumed T	Not Consumed T
Krascheninnikovia lanata	KRLA2	Subshrub	Chenopodiaceae	Perennial	Preferred	Desirable	Desirable
Lappula occidentalis	LAOC3	Forb	Boraginaceae	Annual	Not Consumed	Not Consumed	Not Consumed
Lepidium montanum	LEMO2	Subshrub	Brassicaceae	Ann./Bienn./Perenn.	Not Consumed	Not Consumed	Not Consumed
Lepidium sp.	LEPID	Forb	Brassicaceae	Annual	Not Consumed	Not Consumed	Not Consumed
Lesquerella sp.	LESQU	Forb	Brassicaceae	Annual	Not Consumed	Not Consumed	Not Consumed
Leymus salinus	LESA4	Graminoid	Poaceae	Perennial	Emergency	Emergency	Emergency
Linanthus pungens	LIPU11	Subshrub	Polemoniaceae	Perennial	Not Consumed	Not Consumed	Not Consumed
Linum aristatum	LIAR3	Forb	Linaceae	Annual/Perennial	Not Consumed	Not Consumed	Not Consumed
Linum sp.	LINUM	Forb	Linaceae	Perennial	Not Consumed	Not Consumed	Not Consumed
Linum sp.	LINUM	Forb	Linaceae	Annual	Not Consumed	Not Consumed	Not Consumed
Lupinus pusillus	LUPU	Forb	Fabaceae	Annual	Not Consumed T	Not Consumed T	Not Consumed T
Lycium pallidum	LYPA	Shrub	Solanaceae	Perennial	Emergency	Desirable	Emergency
Machaeranthera canescens	MACA2	Forb	Asteraceae	Ann./Bienn./Perenn.	Not Consumed	Not Consumed	Not Consumed
Mentha sp.	MENTH	Forb	Lamiaceae	Perennial	Emergency	Emergency	Emergency
Mentzelia albicaulis	MEAL6	Forb	Loasaceae	Annual	Not Consumed	Not Consumed	Not Consumed
Mentzelia multiflora	MEMU3	Forb	Loasaceae	Perennial	Not Consumed	Not Consumed	Not Consumed
Mentzelia pumila	MEPU3	Forb	Loasaceae	Biennial	Not Consumed	Not Consumed	Not Consumed
Mentzelia sp.	MENTZ	Forb	Loasaceae	Annual	Not Consumed	Not Consumed	Not Consumed

Abronia fragrans	ABFR2	Forb	Nyctaginaceae	Perennial	Not Consumed	Not Consumed	Not Consumed
Mentzelia sp.	MENTZ	Forb	Loasaceae	Perennial	Not Consumed	Not Consumed	Not Consumed
Monroa squarrosa	MOSQ	Graminoid	Poaceae	Annual	Not Consumed	Not Consumed	Not Consumed
Muhlenbergia pungens	MUPU2	Graminoid	Poaceae	Perennial	Not Consumed	Not Consumed	Not Consumed
Oenothera sp.	OENOT	Forb	Onagraceae	Annual	Not Consumed	Not Consumed	Not Consumed
Oenothera sp.	OENOT	Forb	Onagraceae	Perennial	Not Consumed	Not Consumed	Not Consumed
Opuntia macrorhiza	OPMA2	Cactus	Cactaceae	Perennial	Emergency I	Emergency I	Emergency I
Opuntia phaeacantha	OPPH	Cactus	Cactaceae	Perennial	Emergency I	Emergency I	Emergency I
Opuntia polyacantha	OPPO	Cactus	Cactaceae	Perennial	Emergency I	Emergency I	Emergency I
Opuntia sp.	OPUNT	Cactus	Cactaceae	Perennial	Not Consumed	Not Consumed	Not Consumed
Pascopyrum smithii	PASM	Graminoid	Poaceae	Perennial	Desirable	Desirable	Desirable
Penstemon ambigua	PEAM	Subshrub	Scrophulariaceae	Perennial	Not Consumed	Not Consumed	Not Consumed
Perennial Forb	PF#	Forb	x	Perennial	x	x	x
Perennial Graminoid	PG#	Graminoid	x	Perennial	x	x	x
Phacelia crenulata	PHCR	Forb	Hydrophyllaceae	Annual	Not Consumed	Not Consumed	Not Consumed
Phacelia sp.	PHACE	Forb	Hydrophyllaceae	Annual	Not Consumed	Not Consumed	Not Consumed
Phlox hoodii	PHHO	Forb	Polemoniaceae	Perennial	Emergency	Not Consumed	Emergency
Plantago patagonica	PLPA2	Forb	Plantaginaceae	Annual	Not Consumed	Not consumed	Not Consumed
Plantago sp.	PLANT	Forb	Plantaginaceae	Annual	Not Consumed	Not consumed	Not Consumed
Pleuraphis jamesii	PLJA	Graminoid	Poaceae	Perennial	Emergency	Not Consumed	Emergency
Poa fendleriana	POFE	Graminoid	Poaceae	Perennial	Desirable	Desirable	Preferred
Poliomintha incana	POIN3	Shrub	Lamiaceae	Perennial	Not Consumed	Not consumed	Not Consumed
Portulaca oleracea	POOL	Forb	Portulacaceae	Annual	Not Consumed	Not consumed	Not Consumed
Purshia stansburiana	PUST	Shrub	Rosaceae	Perennial	Desirable	Desirable	Desirable
Quercus turbinella	QUTU2	Shrub	Fagaceae	Perennial	Emergency	Desirable	Emergency
Rhus trilobata	RHTR	Shrub	Anacardiaceae	Perennial	Not Consumed	Emergency	Not Consumed
Rumex hymenosepalus	RUHY	Forb	Polygonaceae	Perennial	Not Consumed	Not consumed	Not Consumed
Salsola tragus	SATR12	Forb	Chenopodiaceae	Annual	Emergency I	Emergency I	Emergency I
Sarcobatus vermiculatus	SAVE4	Shrub	Chenopodiaceae	Perennial	Not Consumed	Not Consumed	Not Consumed
Schismus barbatus	SCBA	Graminoid	Poaceae	Annual	Not Consumed	Not Consumed	Not Consumed
Sclerocactus sp.	SCLER10	Cactus	Cactaceae	Perennial	Not Consumed I	Not Consumed I	Not Consumed I
Sphaeralcea coccinea	SPCO	Forb	Malvaceae	Perennial	Not Consumed	Not Consumed	Not Consumed
Sphaeralcea grossulariifolia	SPGR2	Forb	Malvaceae	Perennial	Not Consumed	Not Consumed	Not Consumed
Sphaeralcea parvifolia	SPPA2	Forb	Malvaceae	Perennial	Not Consumed	Not Consumed	Not Consumed

Abronia fragrans	ABFR2	Forb	Nyctaginaceae	Perennial	Not Consumed	Not Consumed	Not Consumed
Sphaeralcea sp.	SPHAE	Forb	Malvaceae	Perennial	Not Consumed	Not Consumed	Not Consumed
Sporobolus airoides	SPAI	Graminoid	Poaceae	Perennial	Emergency	Emergency	Emergency
Sporobolus contractus	SPCO4	Graminoid	Poaceae	Perennial	Emergency	Not Consumed	Emergency
Sporobolus cryptandrus	SPCR	Graminoid	Poaceae	Perennial	Not Consumed	Not Consumed	Desirable
Sporobolus flexuosus	SPFL2	Graminoid	Poaceae	Perennial	Emergency	Emergency	Emergency
Sporobolus pyramidatus	SPPY2	Graminoid	Poaceae	Annual/Perennial	Not Consumed	Not Consumed	Not Consumed
Sporobolus sp.	SPORO	Graminoid	Poaceae	Perennial	Emergency	Emergency	Emergency
Stanleya pinnata	STPI	Forb	Brassicaceae	Perennial	Not Consumed	Not Consumed	Not Consumed
Stephanomeria exigua	STEX	Forb	Asteraceae	Annual	Not consumed	Not consumed	Not consumed
Streptanthella longirostris	STLO4	Forb	Brassicaceae	Annual	Not Consumed	Not Consumed	Not Consumed
Streptanthus sp.	STREP2	Forb	Brassicaceae	Annual	Not Consumed	Not Consumed	Not Consumed
Suaeda moquinii	SUMO	Subshrub	Chenopodiaceae	Perennial	Not Consumed	Not Consumed	Not Consumed
Townsendia annua	TOAN	Forb	Asteraceae	Annual	Not Consumed	Not Consumed	Not Consumed
Tribulus terrestris	TRTE	Forb	Zygophyllaceae	Perennial	Not Consumed T	Not Consumed I	Not Consumed T
Vancleavia stylosa	VAST3	Subshrub	Asteraceae	Perennial	Not Consumed T	Not Consumed T	Not Consumed T
Vanclevea stylosa	VAST3	Shrub	Asteraceae	Perennial	Not Consumed	Not Consumed	Not Consumed
Vulpia octoflora	VUOC	Graminoid	Poaceae	Annual	Not Consumed	Not Consumed	Not Consumed
Yucca angustissima	YUAN2	Shrub	Liliaceae	Perennial	Not Consumed I	Not Consumed I	Not Consumed I
Yucca baileyi	YUBA2	Shrub	Liliaceae	Perennial	Not Consumed I	Not Consumed I	Not Consumed I
Yucca sp.	YUCCA	Shrub	Liliaceae	Perennial	Not Consumed I	Not Consumed I	Not Consumed I