



Vegetation Classification and Mapping Project Report

Chaco Culture National Historical Park

Natural Resource Technical Report NPS/SCPN/NRTR—2011/452



ON THE COVER

Fajada Butte at Chaco Culture National Historical Park
Photo courtesy of Cory Bolen

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Executive Summary

Chaco Culture National Historical Park (CHCU) encompasses 13,987 ha (34,562 ac) in west central New Mexico, and lies just south of the center of the San Juan Basin. The CHCU vegetation mapping effort was part of the National Park Service's Inventory and Monitoring Program and provides core or 'baseline' information that park managers can use to effectively manage and protect park resources. It was conducted in accordance with the protocols and standards specified by the U.S. Geological Survey/National Park Service Vegetation Mapping Program (<http://science.nature.nps.gov/im/inventory/veg/index.cfm>). Data obtained through this inventory are compatible with other efforts, allowing for synthesis and analysis at broader levels.

To effectively classify and map the wide range of vegetation at CHCU required a multi-year approach that consisted of several linked phases: (1) vegetation classification using field data and the National Vegetation Classification (NVC), (2) digital vegetation map production, and (3) map accuracy assessment. During the summer of 2005, we sampled 141 representative plots located throughout the 16,615 ha (41,057 ac) of the main unit and environs of the park. Analysis of the plot data using ordination and clustering techniques produced 18 distinct plant associations, one of which was newly described. We included four riparian and shrub types, described in previous work in the main arroyo to arrive at 22 associations for the park.

To produce the digital map, we used a combination of 1:12,000-scale true color aerial photography taken in 2004 and ground-truthing to interpret the complex patterns of vegetation and landuse at CHCU. In some areas we interpreted directly from 2001 IKONOS imagery that included 1 m panchromatic and 4 m blue, green, red, and infrared bands. A total of 28 map units were developed and directly cross-walked or matched to corresponding

plant associations and land-use classes. All of the interpreted and remotely sensed data were converted to Geographic Information System (GIS) databases using ArcInfo[®] software. Draft maps created from the vegetation classification were field-tested and revised before independent ecologists conducted an assessment of the map's accuracy during 2006.

The accuracy assessment showed an overall accuracy of 79.9 percent at fuzzy level 3 (see text for details). The field work for the accuracy assessment also revealed several previously unaccounted for vegetation associations for CHCU.

For more information on the NVC standards, please go to the FGDC National Vegetation Classification Standard website: <http://www.fgdc.gov/standards/projects/FGDC-standards-projects/vegetation>. For more information on NVC associations in the U.S., please go to NatureServe's website: <http://www.natureserve.org>. The Bureau of Reclamation has numerous services and programs and may be visited at <http://www.usbr.gov>.

Acknowledgments

Multi-faceted projects such as this one require the enthusiasm and energy of many people over several years. The dedication of all involved helped to produce a product that we, the authors, gratefully acknowledge. The combination of ecologists, geographers, botanists and natural resource professionals in all the cooperating agencies and organizations created a phenomenal work environment that greatly reduced the stresses one might expect for a project of this size.

We would specifically like to thank the following people for their efforts:

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We would be remiss if we did not also acknowledge the efforts of both Mike Story and Karl Brown, who have been stewarding these park vegetation mapping projects for so long now. Along with Karl and Mike, we acknowledge the many other scientists that produced the original protocols and those who have been applying these techniques in the field for many years. These previous efforts have raised the bar each time. We have learned much from the earlier projects and it is our distinct pleasure to have added to them. Using these new technologies and lessons learned we have, we hope, produced a finer product.

1 Introduction

1.1 Background

1.1.1 USGS-NPS Park Vegetation Mapping Program

In 1994, the U.S. Geological Survey (USGS) and National Park Service (NPS) formed a partnership to map the vegetation of the national parks in the United States. The goals of the USGS-NPS Vegetation Mapping Program (VMP) are to provide baseline ecological data for park resource managers, develop data that are useful in a regional and national context, and provide opportunities for future inventory, monitoring, and research activities (FGDC 1997, Grossman et al. 1998, <http://biology.usgs.gov/npsveg/index.html>).

Central to fulfilling the goals of this national program is the use of the National Vegetation Classification (NVC) as the standard vegetation classification. This classification

- is based upon current vegetation
- uses a systematic approach to classify vegetation communities across environmental continuums
- emphasizes natural and existing vegetation
- uses a combined physiognomic-floristic hierarchy;
- identifies vegetation units based on both qualitative and quantitative data;
- is appropriate for mapping at multiple scales

The use of standard national vegetation classification and mapping protocols (TNC and ESRI 1994b) facilitates effective resource stewardship by ensuring the compatibility and widespread use of the information throughout the NPS, as well as other federal and state agencies. These vegetation maps and the associated information support a wide variety of resource assessment, and park management and planning needs.

In addition, the associated information provides a structure for framing and answering critical scientific questions about vegetation communities and their relationship to environmental processes across the landscape.

1.2 Chaco Culture National Historical Park Vegetation Mapping Project

The specific decision to map the vegetation at CHCU was made in response to the NPS Natural Resources Inventory and Monitoring Guidelines issued in 1992 (National Park Service (NPS) 1992). Under these guidelines, CHCU was viewed as a priority park within the Southern Colorado Plateau Network (SCPN), based on its need for the program's vegetation map products. Driving this need was the park's inability to spatially analyze the vegetation at a fine enough scale to accurately address various management issues.

In 2005 the SCPN initiated this project by asking the U.S. Bureau of Reclamation's (BOR) Remote Sensing and Geographic Information Group (RSGIG) to undertake the mapping portion of this project in coordination with Lisa Floyd-Hanna of Prescott College. BOR RSGIG, Prescott College's Dave Hanna (GIS) and Lisa Floyd-Hanna (Botany), and the park ultimately formed a three-part vegetation team, each responsible for a specific portion of the project. The Prescott College team designed the field sampling scheme, stratifying the park by soil type, aspect, slope and grazing history. The team was primarily responsible for collecting standardized field samples and using them to classify CHCU's vegetation types. RSGIG was responsible for aerial photo interpretation and the creation of a digital vegetation map. BOR contracted separately with CoganTech to provide data for an accuracy assessment on the final vegetation map. Finally, CHCU staff provided logistical and technical support,

helped coordinate fieldwork, and reviewed and evaluated draft data.

Our objectives were to produce final products consistent with the USGS-NPS National Vegetation Mapping Program mandated standards:

- National Vegetation Classification Standard (FGDC 1997)
- Spatial Data Transfer Standard (FGDC 1998a)
- Content Standard for Digital Geospatial Metadata (FGDC 1998b)
- United States National Map Accuracy Standards (USGS 1999)
- Integrated Taxonomic Information System
- NPS-USGS Program-defined standards for map attribute accuracy and Minimum Mapping Unit

The products derived from the vegetation mapping efforts for CHCU include:

Spatial data

- aerial photography
- map classification/descriptions
- spatial database of vegetation communities
- hardcopy maps of vegetation communities
- metadata for spatial databases
- complete accuracy assessment of spatial data

Vegetation information

- vegetation classification
- dichotomous field key of vegetation classes
- formal description for each vegetation class
- ground photos of vegetation classes
- field data in database format

1.3 Scope of work

The Bureau of Reclamation (BOR) was contracted by the SCPN in 2005 to map approximately 18,800 ha (46,500 acres) encompassing Chaco Culture National Historical Park and a 0.5 km buffer –the park environs. We mapped and classified the vegetation using a combination of existing plot data and data collected specifically for this project, several field visits, and photo interpretation of aerial photography. We adhered to the protocols and standards for medium-sized parks, described in the NPS/BRD program documents (TNC and ESRI 1994a, section 5.1). Field reconnaissance included only the area within the main unit and Pueblo Pintado. The remaining outlier units, Kin Bineola and Kin Ya'a, were not visited due to their extreme remoteness.

1.4 Introduction to the National Vegetation Classification (NVC) and Standard (NVCS)

1.4.1 *The U.S. National Vegetation Classification and National Vegetation Classification Standard, and the US Geological Survey – National Park Service Vegetation Mapping Program*

In 1994, the USGS-NPS VMP adopted the U.S. National Vegetation Classification (NVC) (TNC and ESRI 1994a, Grossman et al. 1998) as a basis for the *a priori* definition of vegetation units to be inventoried. The Federal Geographic Data Committee (FGDC) adopted a modified version of the upper (physiognomic) levels as a federal standard (FGDC-STD-005, FGDC 1997). This standard is hereafter termed the National Vegetation Classification Standard (NVCS)¹. The NVCS established a federal standard for a complete taxonomic treatment

¹ The VMP program standards refer to the National Vegetation Classification System (also NVCS). Because of nomenclatural and acronym confusion with the federal (FGDC) National Vegetation Classification Standard, this term is no longer used by the VMP.

of vegetation in the United States at physiognomic levels (table 1). It also established conceptual taxonomic levels for the floristic units of alliance and association, that largely followed the NVC. However, the NVCS did not offer a taxonomic treatment for the floristic levels because of the immense scope of establishing robust floristic units for the entire United States. The FGDC standard requires that federally funded vegetation classification efforts collect data in a manner that enables crosswalking the data to the NVCS (ie., the physiognomic levels) and sharing between agencies. But it does not require use of that standard by agencies for internal mission needs. NatureServe maintains a treatment of floristic units (alliances and associations) which, though not a federal standard, is used for classification and mapping units by the VMP whenever feasible. In this document, the federal standard (FGDC 1997) is denoted as the National Vegetation Classification Standard (NVCS); the U.S. National Vegetation Classification (NVC) will refer exclusively to NatureServe's treatment for vegetation floristic units (alliances and associations only).

Alliances and associations are based on both the dominant species in the upper strata of a stand (greatest canopy cover), as well as on diagnostic species (those consistently found in some types but

not others). Associations are the most specific classification and are hierarchically subsumed in the alliances. Each association is included in only one alliance, while each alliance typically includes many associations. Associations, which define a distinct plant composition that repeats across the landscape, are generally named using both the dominant species in the uppermost stratum of the vegetation and one or more dominant species in the lower strata, or a diagnostic species in any stratum. Alliance names are generally based on the dominant/diagnostic species in the uppermost stratum of the vegetation, though up to four species may be used if necessary to define the type. The species nomenclature for all alliances and associations follows that of Kartesz (1999). Documentation from NatureServe (2006) describes the naming and syntax for all NVC names:

- A hyphen (“-”) separates names of species occurring in the same stratum.
- A slash (“/”) separates names of species occurring in different strata.
- Species that occur in the uppermost stratum are listed first, followed successively by those in lower strata.
- Order of species names generally reflects decreasing levels of dominance, constancy, or indicator value.
- Parentheses around a species name indicate the species is less consistently

Table 1. The National Vegetation Classification System hierarchy (Maybury 1999)

Level	Primary basis for classification	Example
Class	Structure of vegetation	Woodland
Subclass	Leaf phenology	Evergreen Woodland
Group	Leaf types, corresponding to climate	Temperate or Subpolar Needle-Leaved Evergreen Woodland
Subgroup	Relative human impact (natural/semi-natural, or cultural)	Natural/Semi-natural
Formation	Additional physiognomic and environmental factors, including hydrology	Saturated Temperate or Subpolar Needle-Leaved Evergreen Woodland
Alliance	Dominant/diagnostic species of the uppermost or dominant stratum	Longleaf Pine -- (Slash Pine, Pond Pine) Saturated Woodland Alliance
Association	Additional dominant/diagnostic species from any strata	Longleaf Pine / Little Gallberry / Carolina Wiregrass Woodland

found, either in all associations of an alliance, or in all occurrences of an association.

- Association names include the dominant species of the significant strata, followed by the class in which they are classified (e.g., “Forest,” “Woodland,” or “Herbaceous Vegetation”).
- Alliance names also include the class in which they are classified (e.g., “Forest,” “Woodland,” “Herbaceous”), but are followed by the word “Alliance” to distinguish them from associations.

Examples of alliance names from CHCU:

- *Pleuraphis jamesii* Herbaceous Alliance (James’ Galleta Herbaceous Alliance)
- *Atriplex canescens* Shrubland Alliance (Fourwing Saltbush Shrubland Alliance)
- *Pinus edulis* - (*juniperus* spp.) Woodland Alliance (Two-needle Pinyon - (Juniper species) Woodland Alliance)

Examples of association names from CHCU:

- *Pleuraphis jamesii* - *Sporobolus airoides* Herbaceous Vegetation (James’ Galleta - Alkali Sacaton Herbaceous Vegetation)
- *Atriplex canescens* - *Krascheninnikovia lanata* Shrubland (Fourwing Saltbush - Winter-fat Shrubland)
- *Pinus edulis* - *Juniperus* spp. / *Cercocarpus montanus* - Mixed Shrubs Woodland (Two-needle Pinyon - Juniper species / Mountain-mahogany - Mixed Shrubs Woodland)

For more information on the NVC see Grossman et al. 1998 and the USGS-NPS VMP standards (<http://biology.usgs.gov/npsveg/standards.html>).

In addition to the NVC, NatureServe has created a standardized Ecological Systems Classification for describing

sites based on both the vegetation and the ecological processes that drive them. Ecological systems are mid-scale biological communities that occur in similar physical environments and are influenced by similar dynamic ecological processes, such as fire or flooding. They are not conceptually a unit within the NVC and do not occupy a place in the NVC hierarchy. However, for each ecological system, a specific list of NVC associations are likely to occur. An association may occur in any number of ecological systems, limited only by the range of ecological settings in which that association occurs. Ecological systems are much like the map units used for the map legend—they are a broader scale concept that embodies the concepts of several highly specific associations that might be found in a particular setting.

1.5 Introduction to Natural Heritage Program methodology and element ranking

The Natural Heritage New Mexico Program (NHNM) is a member of the NatureServe Network of Natural Heritage Programs and Conservation Data Centers. The Natural Heritage Programs (and conservation data centers) are located in all U.S. states and Canadian provinces. Each program serves as that state’s biological diversity data center, gathering information and field observations to help develop national and statewide conservation priorities.

The multi-disciplinary team of scientists, planners, and information managers of the heritage programs uses a standardized methodology to gather information on rare, threatened, and endangered species, and significant plant communities that occur in each state. The species and plant communities for which each program maintains data are referred to as “elements of natural diversity”, or simply “elements”. Life history, status, and location data are regularly updated in a comprehensive shared data system. Sources of element data include published and unpublished

literature, museum and herbaria labels, and field surveys conducted by knowledgeable naturalists, experts, agency personnel, and our own staff of botanists, ecologists, and zoologists.

1.5.1 The Natural Heritage ranking system

The cornerstone of Natural Heritage methodology is the use of a standardized element imperilment ranking system. Ranking species and ecological communities according to their imperilment status provides guidance for where Natural Heritage Programs should focus their information-gathering activities and provides data users with a concise and meaningful tool for decision-making.

To determine the status of an element within New Mexico, NHNM gathers information on plants, animals, and plant communities. Each of these elements of natural diversity is assigned a rank that indicates its relative degree of imperilment on a five-point scale (1 = critically imperiled, 5 = demonstrably secure). The criteria used to define the element imperilment rank are (1) number of occurrences, (2) size of population, and (3) quality of population. The primary criterion is the number of occurrences (in other words, the number of known distinct localities or populations). This factor is weighted more heavily than other factors because an element found in only one place is more imperiled than something found in twenty-one places. Also of importance are the geographic range, the number of individuals, the trends in both population and distribution, identifiable threats, and the number of protected occurrences.

Element imperilment ranks are assigned both in terms of the element's degree of imperilment within New Mexico (its State-rank or S-rank) and its imperilment over its entire range (Global-rank or G-rank). Taken together, these two ranks indicate the degree of imperilment for an element.

For example, the southern redbelly dace (*Phoxinus erythrogaster*), thought to be secure in northern North America but known from only nine current locations in New Mexico, is ranked G5 S1 (globally-secure, but critically imperiled in this state). The hairless fleabane (*Erigeron subglaber*), known only in New Mexico from about four locations, is ranked a G3 S3 (vulnerable both in the state and globally, since it only occurs in New Mexico and then in small numbers). Further, the mancos milkvetch (*Astragalus humillimus*), known from only 14 locations in New Mexico, is ranked G1 S1 (critically imperiled both in the state and globally).

Plant communities can also be ranked when there is enough information. For example, *Populus fremontii* Seasonally Flooded Woodland Alliance (Fremont Cottonwood Seasonally Flooded Woodland Alliance), known to occur at CHCU as well as other places in New Mexico and Nevada, has been given a state rank of S2, because of its apparent rarity in New Mexico. NHNM actively collects, maps, and electronically processes specific occurrence information for animal and plant species considered extremely imperiled to vulnerable in the state (S1 - S3). Certain elements are "watchlisted," meaning that specific occurrence data are periodically analyzed to determine whether more active tracking is warranted. A complete description of each of the Natural Heritage imperilment ranks is provided in Table 2.

Actual locations of elements, whether they are single organisms, populations, or plant communities, are referred to as element occurrences. The element occurrence is considered the most fundamental unit of conservation interest and is at the heart of the Natural Heritage methodology. To prioritize element occurrences for a given species, an element occurrence rank (EO-Rank) is assigned, based on the size, ecological quality, and landscape context of the occurrences whenever

Table 2. Definitions of Natural Heritage Imperilment Ranks

Rank	Description
G/S1	Critically Imperiled globally/state because of rarity (5 or fewer occurrences in the world/state; or 1,000 or fewer individuals), or because some factor of its biology makes it especially vulnerable to extinction
G/S2	Imperiled globally/state because of rarity (6 to 20 occurrences, or 1,000 to 3,000 individuals), or because other factors demonstrably make it very vulnerable to extinction throughout its range
G/S3	Vulnerable through its range or found locally in a restricted range (21 to 100 occurrences, or 3,000 to 10,000 individuals)
G/S4	Apparently Secure globally/state, though it may be quite rare in parts of its range, especially at the periphery. Usually more than 100 occurrences and 10,000 individuals
G/S5	Demonstrably Secure globally/state, though it may be quite rare in parts of its range, especially at the periphery.
G/SX	Presumed Extinct globally, or extirpated within the state
G#?	Indicates uncertainty about an assigned global rank
G/SU	Unable to assign rank due to lack of available information
GQ	Indicates uncertainty about taxonomic status
G/SH	Historically known, but usually not verified for an extended period of time
G#T#	Trinomial rank (T) is used for subspecies or varieties. These taxa are ranked on the same criteria as G1-G5.
S#B	Refers to the breeding season imperilment of elements that are not residents
S#N	Refers to the non-breeding season imperilment of elements that are not permanent residents. Where no consistent location can be discerned for migrants or non-breeding populations, a rank of SZN is used.
SZ	Migrant whose occurrences are too irregular, transitory, and/or dispersed to be reliably identified, mapped, and protected
SA	Accidental in the state
SR	Reported to occur in the state but unverified
S?	Unranked. Some evidence that species may be imperiled, but awaiting formal rarity ranking.

Note: Where two numbers appear in a state or global rank (for example, S2S3), the actual rank of the element is uncertain, but falls within the stated range.

sufficient information is available. This ranking system is designed to indicate which occurrences are the healthiest and ecologically the most viable, thus focusing conservation efforts where they will be most successful. The EO-Rank is based on three factors: (1) size, or a measure of the area or abundance of the element's occurrence; (2) condition/quality, or an integrated measure of the composition, structure, and biotic interactions that characterize the occurrence; and (3) landscape context, or an integrated measure of the dominant environmental regimes and processes that establish and maintain the element and connectivity.

Each of these factors is rated on a scale of A through D, with A representing an excellent rank and D representing a poor

rank. These ranks for each factor are then averaged to determine an appropriate EO-Rank for the occurrence. If not enough information is available to rank an element occurrence, an EO-Rank of E is assigned. EO-Ranks and their definitions are summarized in Table 3.

1.6 Project area

1.6.1 Location and regional setting

CHCU lies in west-central New Mexico. Four units are associated with the park and all lie within the Navajo Reservation. The main portion of the park lies almost entirely within San Juan County. The Kin Bineola Ruin lies within both San Juan and McKinley Counties however the bulk of the lands associated with the ruins are

in McKinley County. The Kin Ya'a and Pueblo Pintado Ruins are within McKinley County. The closest metropolitan areas are Farmington, Bloomfield and Aztec to the north and Cuba, Gallup and Grants to the south (fig. 1).

1.6.2 Climate and weather

CHCU is located at 1,890 m (6,200 ft) in elevation. The weather in Chaco Canyon is unpredictable and can be extreme. Summer highs are typically in the 80s to mid-90s °F. Thunderstorms can produce heavy localized downpours and sudden dramatic drops in temperatures. Hypothermia, lightning, and flash floods are real concerns. Winter temperatures drop to well below freezing most nights. The average snowfall is around 96 cm (40 in) per year. Average precipitation (snow and rain) is 20–30 cm (8–12 in) per year (fig. 2) (National Climatic Data Center [NCDC] 1991). The warmest month is July, with an average high of 84 °F and a low of 52 °F. The coldest months are typically December and January, with

Table 3. Average Element Occurrence Ranks and their definitions

Rank	Description
A	Excellent viability
B	Good viability
C	Fair viability
D	Poor viability
H	Historic: known from historical record, but not verified for an extended period of time
X	Extirpated (extinct within the state)
E	Extant: the occurrence does exist but not enough information is available to rank
F	Failed to find: the occurrence could not be relocated

average lows of 14–15 °F, and average highs of 44–45 °F (<http://www.nps.gov/CHCU/pphtml/weather.html>).

1.6.3 Physiographic setting and topography

CHCU lies within the San Juan Basin of northwestern New Mexico, on the Navajo Section of the Colorado Plateau. The Navajo Section is named for the Navajo Nation, and about half of the area of the



Figure 1. Location map for Chaco Culture National Historical Park, New Mexico

Figure 2. Pre-
cipitation (in) in west
central New Mexico
for the period 1961
- 1990. (National
Climatic Data Center
[NCDC]1991)



section is within Navajo Nation lands. The San Juan Basin occupies northeastern Arizona and northwestern New Mexico and is composed primarily of sandstone with some shale. CHCU lies in the most eastern portion of the Navajo Section. The beds are generally horizontal, and erosion in an arid climate has formed the distinctive features of mesas, cuestras, rock terraces, retreating escarpments, canyons and dry washes. In some parts, volcanic necks and buttes are abundant.

Park topography is varied, with flat to gently undulating areas within Chaco Wash and on the west side of the park. The deeply incised Chaco Wash cuts through the park and is surrounded by four prominent mesas on all sides: Chacra Mesa, North Mesa, West Mesa, and South Mesa. Figure 3 shows a three-dimensional view of the main unit of the park looking to the southwest from the northeast and Figure 4 shows a three-dimensional view of the same area looking from the southeast to the northwest. Figure 5 shows the topographic relief of west-central New Mexico, where CHCU is located.

1.6.4 Geology

The geology of the main unit of the mapping area is comprised of two major and two minor formations. Most of the area is represented by the Menefee formation, which is a combination of mud, shales and sandstones. The mesas are made up of primarily the Cliffhouse Sandstone, which is transgressive marine sandstone. The Lewis shale, a marine shale and mudstone, occurs in the north-east sections of the mapping area. The Kin-Bineoli ruins occur entirely within the Menefee formation. The Kin Ya'a ruins lie entirely within the Crevasse Canyon formation, which is an upper Cretaceous coastal plain and shallow marine stratum. The Pueblo Pintado ruins lie entirely within the Lewis Shale.

A more detailed map of the geology of the main unit is shown in Figure 6. This map shows 12 units and includes the smaller quaternary inclusions overlying the Cretaceous bedrock.

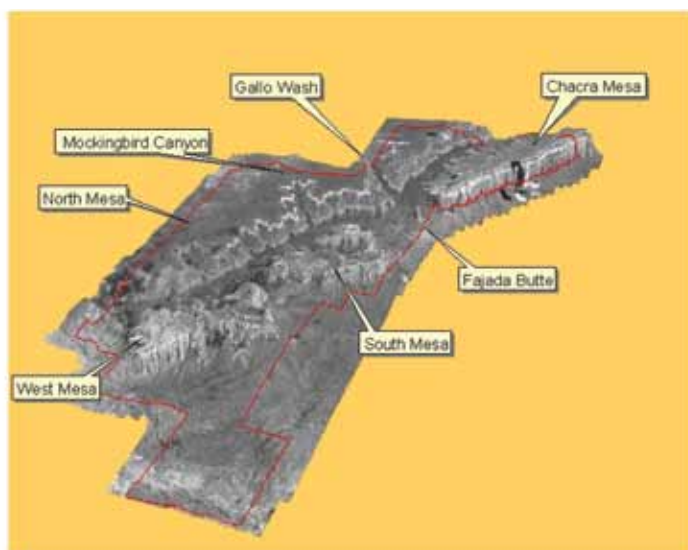


Figure 3. 3-dimensional view of Chaco Culture National Historical Park looking towards the southwest from the northeast

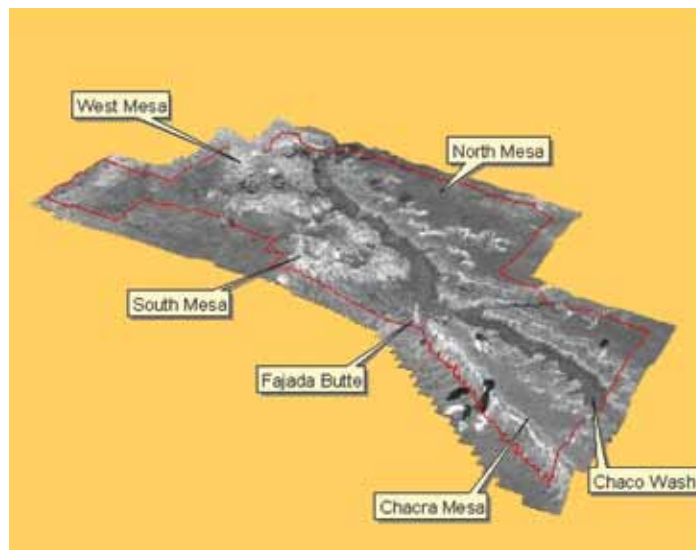


Figure 4. 3-dimensional view of Chaco Culture National Historical Park looking towards the northwest from the southeast

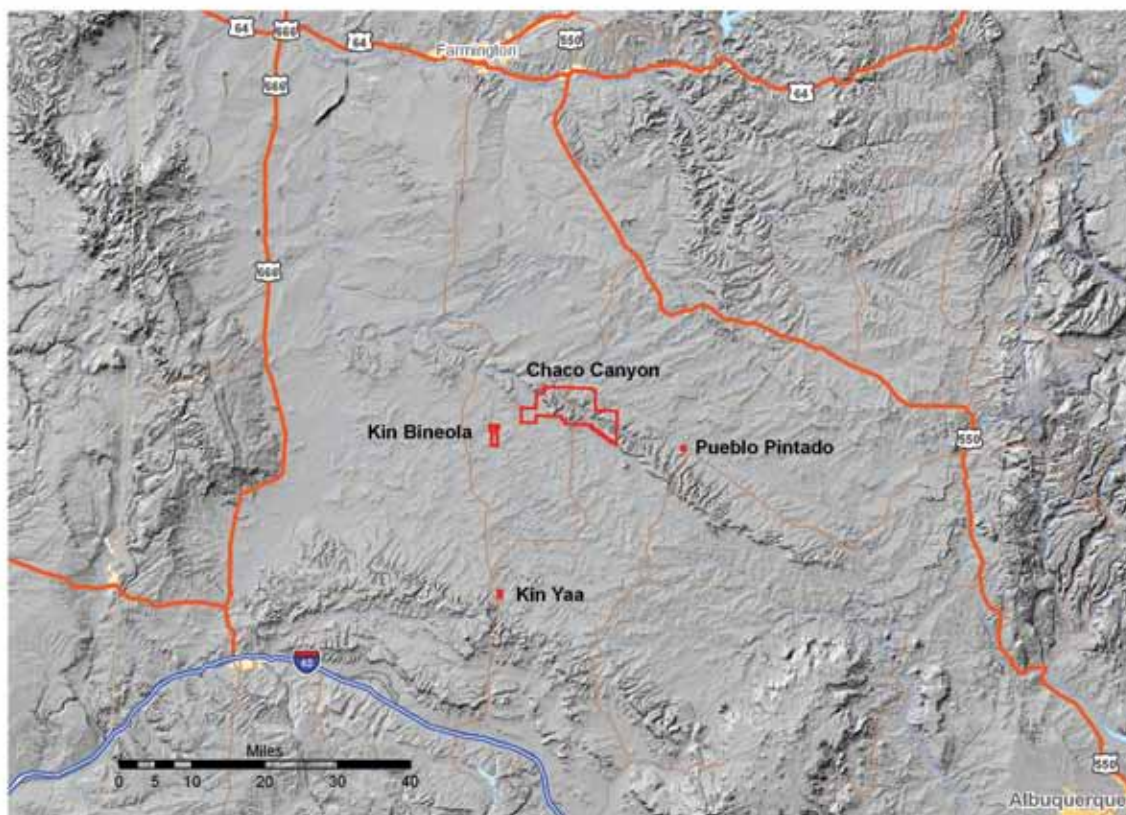


Figure 5. Topography of Chaco Culture National Historical Park and surrounding area

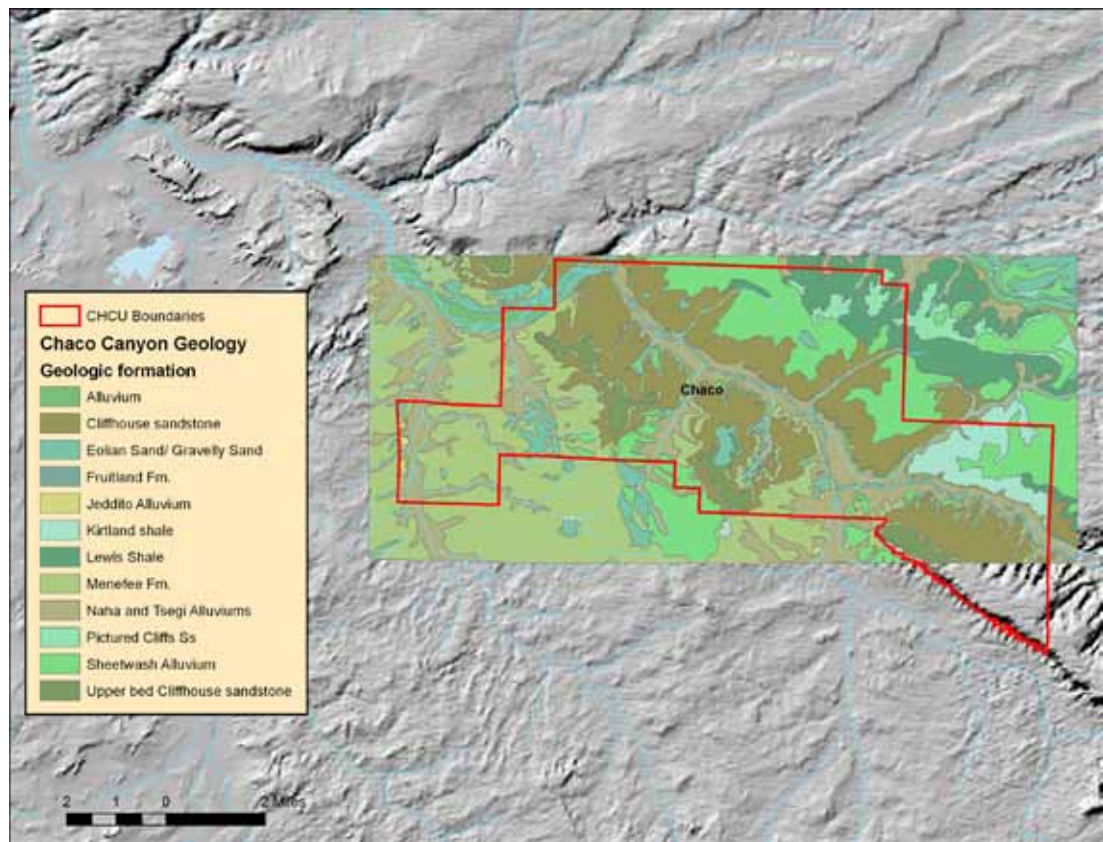


Figure 6. Geologic formations in the immediate vicinity of the main unit of Chaco Culture National Historical Park

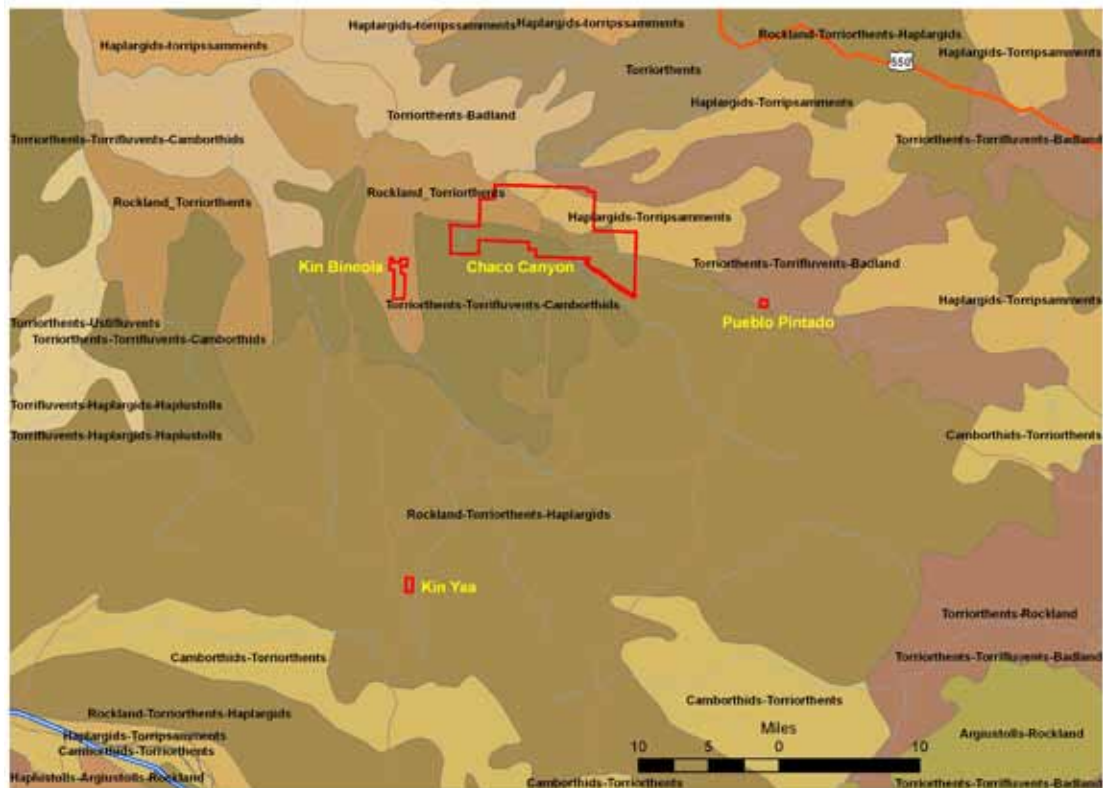


Figure 7. Regional soil map units within and adjacent to Chaco Culture National Historical Park mapping area

1.6.5 Soils

A regional view of soil types reveals five soil types intersecting the mapping area: (1) Rockland Torriothents, (2) Torriothents-Torriofluvents Badland, (3) Haplargids-Torripsamments, (4) Torriothents-Torriofluvents-Camborthids and (5) the Rockland Torriothents-Haplargids. Each of these is described in detail below.

The state overview of soils is derived from a geodatabase provided by the New Mexico Office of the State Engineer (New Mexico RGIS)(fig. 7).

The local detailed soils data was extracted from the SSURGO (Soil Survey Geographic Database) on line database (Soil Survey Staff, NRCS). These data do not include San Juan County where the bulk of CHCU lands occur.

A soils map was recently completed for the park (Zschetzsche and Clark 2004) and contains detailed information for 20 soil map units. These 20 units are subdivided into 4 general soil types:

- **Soils on flood plains and stream terraces.** The soils in this group make up about 13 percent of the survey area. These soils are very deep and level. They are sandy to clayey in texture and moderately well drained to well drained. They are subject to periods of flooding that range from rare to frequent. The native vegetation is *Sarcobatus vermiculatus* (black greasewood) and *Sporobolus airoides* (alkali sacaton) on the stream terraces, and *Populus* (cottonwood), *Salix* (wil-lows), and *Sporobolus cryptandrus* (sand dropseed) on the flood plains of Chaco Wash and the Chaco River.
- **Soils on alluvial fans and fan remnants.** The soils in this group make up about 19 percent of the survey area. These soils are very deep and gently to moderately sloping. They are moderately coarse to moderately fine textured and well drained. The native vegetation is *Atriplex canescens* (fourwing saltbush), *Pleuraphis jamesii* (galleta grass), *Sporobolus giganteus* (giant dropseed), and sand dropseed.

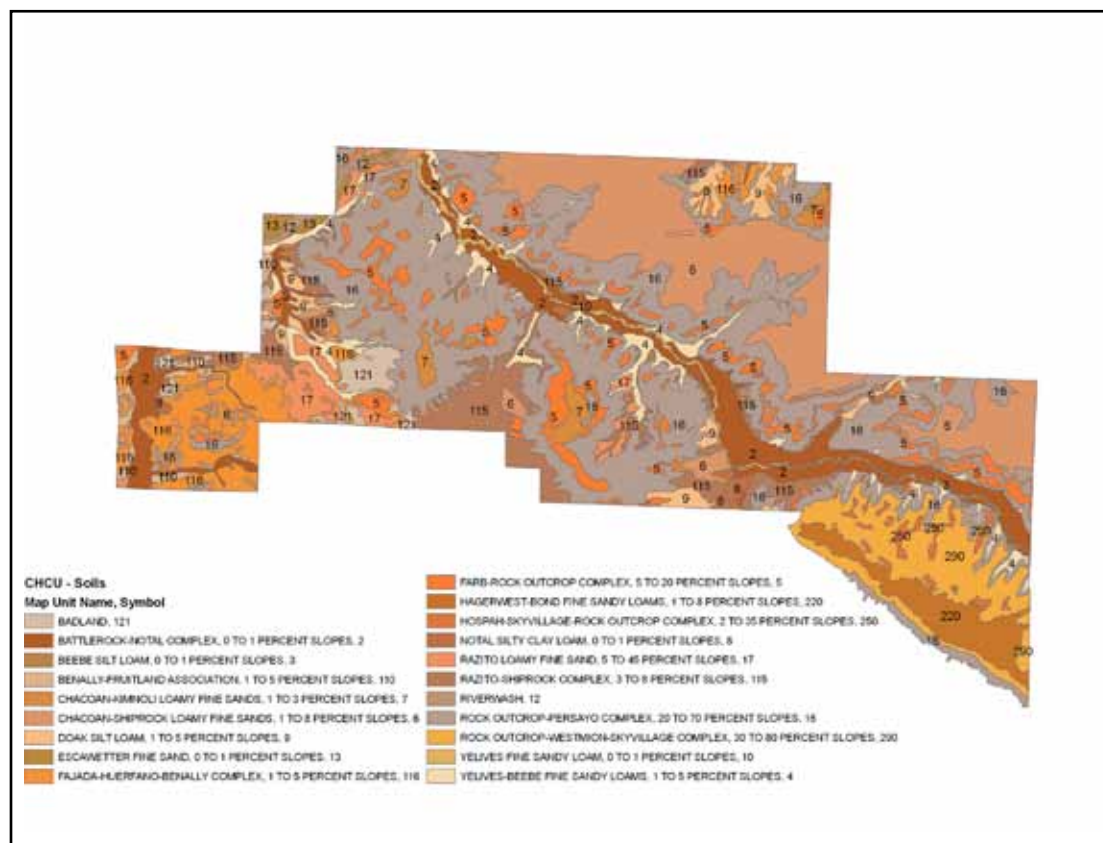
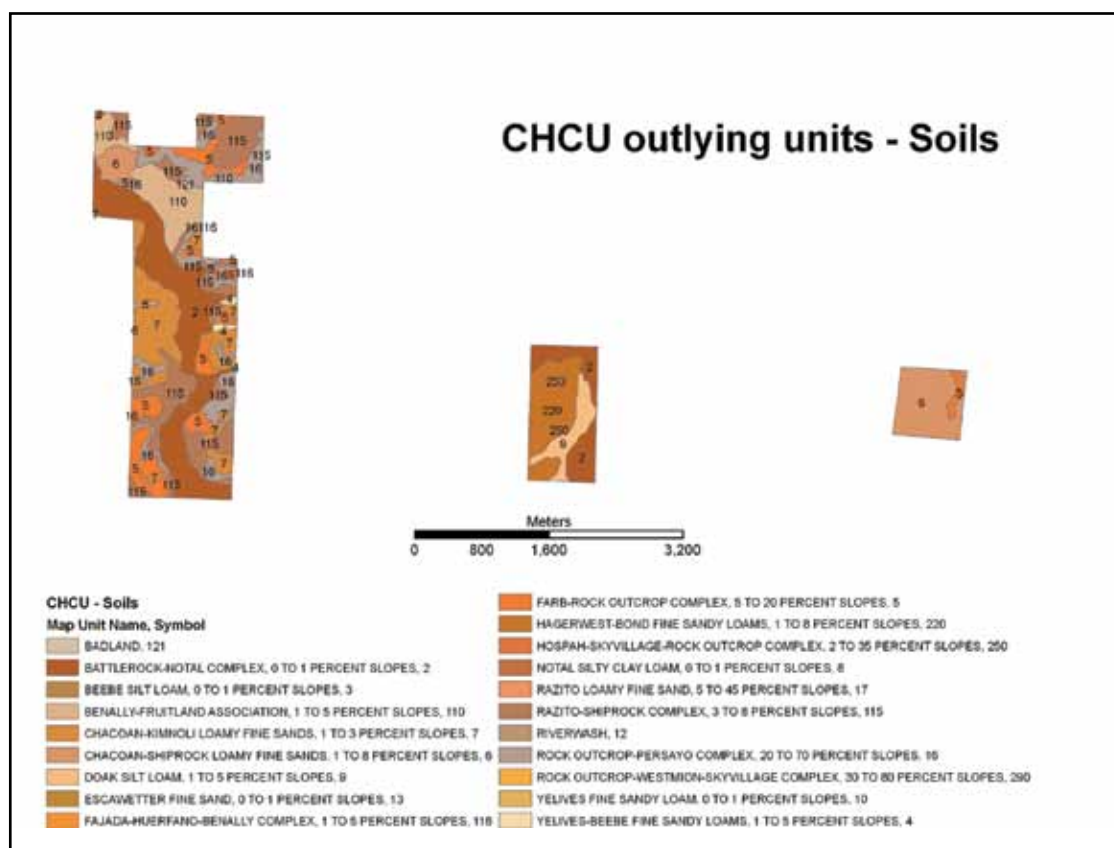


Figure 8. Chaco Culture National Historical Park soils map – main unit

Figure 9. Soils map for outlying units of Chaco Culture National Historical Park



- **Soils on erosional terraces that are sodium-affected.** The soils in this group make up about 8 percent of the survey area. These soils are very shallow to very deep and nearly level. They are medium to moderately fine textured and well drained. These soils have high sodium content. The native vegetation is *Atriplex obovata* (mound saltbush) and alkali sacaton. Badland and Rock outcrop are minor components.
- **Soils of escarpments.** The soils in this group make up about 41 percent of the survey area. These soils are generally very shallow to shallow and nearly level to very steep on the structural benches. They are moderately coarse to fine textured and well drained.
- **Soils in areas of mesa summits and cuesta dipslopes.**

This soil map also includes information about each of the individual park units. Figure 8 shows the soil distribution for the main park unit. Figure 9 shows the

soil distribution for the outlying units. For a more in depth discussion of each soil type, please refer to Zschetzsche and Clark (2004).

1.6.6 Wildlife

The following descriptions of wildlife are taken from Bailey 1995. The park is described by two regions, northern and southern. The northern region lies within the Colorado Plateau Semi-Desert Province and the southern region within the Arizona-New Mexico Mountains Semidesert - Open Woodland - Coniferous Forest--Alpine Meadow Province. The following are general descriptions, but local variations are certain to exist.

Northern Park Units (Chaco, Kin Bineola and Pueblo Pintado) - Colorado Plateau Semi-Desert Province

Major mammals are the mule deer, mountain lion, coyote, and bobcat; elk are locally important. Pronghorn antelope are the primary large mammal in the arid grasslands. Smaller species

include the blacktail jackrabbit, Colorado chipmunk, rock squirrel, wood rat, white-footed mouse, cliff chipmunk, cottontail, porcupine, and gray fox. The ringtail cat and spotted skunk occur rarely.

The most abundant resident birds are the bushtit, pinyon jay, plain titmouse, black-chinned hummingbird, Woodhouse's jay, red-tailed hawk, golden eagle, red-shafted flicker, and rock wren. Summer residents include the chipping sparrow, nighthawk, black-throated gray warbler, northern cliff swallow, lark sparrow, and mourning dove. Common winter residents are the pink-sided junco, Shufeldt's junco, gray-headed junco, red-backed junco, Rocky Mountain nuthatch, mountain bluebird, robin, and Steller's jay. Turkeys are locally abundant during winter.

Reptiles include the horned lizard, collared lizard, and rattlesnake (USDA Forest Service 2005).

**Southern Park Unit (Kin Ya'a) -
Arizona-New Mexico Mountains
Semidesert - Open Woodland -
Coniferous Forest--Alpine Meadow
Province**

The most common large mammal is the mule deer. Mammalian predators include mountain lions, coyotes, and bobcats. Small mammals are the deer mouse, longtail weasel, porcupine, golden-mantled ground squirrel, Colorado chipmunk, red squirrel, wood rat, pocket gopher, longtail vole, Kaibab (Abert) squirrel, and cottontail.

Some of the more common birds are the northern pygmy-owl, olive warbler, red-faced warbler, hepatic tanager, mountain bluebird, pygmy nuthatch, white-breasted nuthatch, Mexican junco, Steller's jay, red-shafted flicker and the Rocky Mountain sapsucker. Goshawks and red-tailed hawks are present.

The only widely found reptile is the short-horned lizard (USDA Forest Service 2005).

Recent biological inventories documented 33 species of mammals for Chaco Canyon (Bogan et al. 2007), including one insectivore, Crawford's desert shrew (*Notiosorex crawfordi*); 15 species of bat, notably the spotted bat (*Euderma maculatum*) and big free-tailed bat (*Nyctinomys macrotis*); 2 species of rabbits, desert cottontail (*Sylvilagus audubonii*) and black-tailed jackrabbit (*Lepus californicus*); 21 species of rodents, including Colorado chipmunk (*Eutamias quadrivittatus*), Gunnison's prairie dog (*Cynomys gunnisoni*), and deer mouse (*Peromyscus maniculatus*); 9 species of carnivores, including coyote (*Canis latrans*), American badger (*Taxidea taxus*), and mountain lion (*Puma concolor*); and 3 species of ungulates, including the recently arrived elk (*Cervus elaphus*).

Fourteen species of amphibians and reptiles have been documented for Chaco Canyon, including tiger salamander (*Ambystoma tigrinum*), eastern collared lizard (*Crotaphytus collaris*), and western rattlesnake (*Crotalus viridis*). The eastern fence lizard (*Sclerophorus undulates*) was the most abundant lizard throughout the study (Persons and Nowak 2008).

1.6.7 Vegetation

CHCU lies within ecoregion 22 sensu Omernik (1987) (fig. 10) and two ecoregions sensu Bailey (1995) (fig. 11). The park falls entirely within Omernik's Arizona / New Mexico Plateau. The northern units of the park fall into Bailey's Colorado Plateau Semi-Desert Province, Navajo Canyonlands Section while the southern unit, Kin Ya'a, into the White Mountain-San Francisco Peaks Section (fig. 12). Table 4 describes in more detail information about both the Omernik and Bailey descriptions (<http://www.nationalatlas.com/natlas>). Bailey's map was created at a scale of 1:7,500,000, therefore the boundaries of the ecoregions at the scale of this project must be considered as estimates.

Other regional data (1:1,000,000 scale paper map by Dr. William Dick-Peddie, 1993) shows the park within both Great

Basin Desert Scrub and Desert Grassland (Ecotone) (fig. 12).

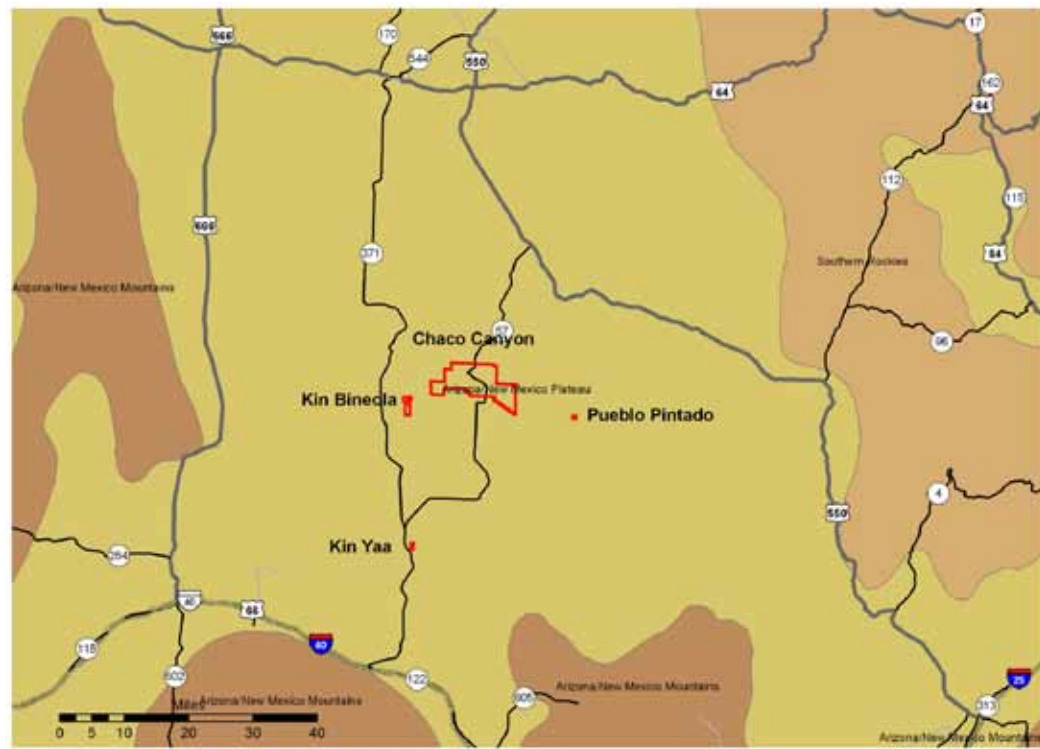


Figure 10. Regional view of Omernik's (1987) ecoregions

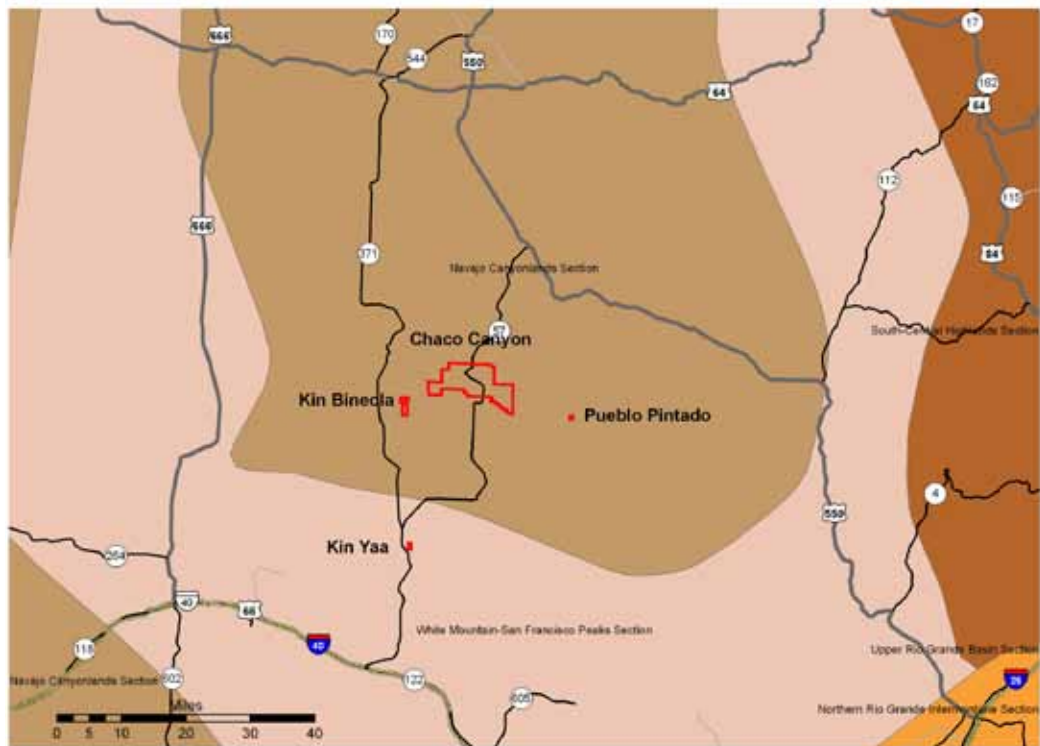


Figure 11. Regional view of Bailey's (1995) ecoregions

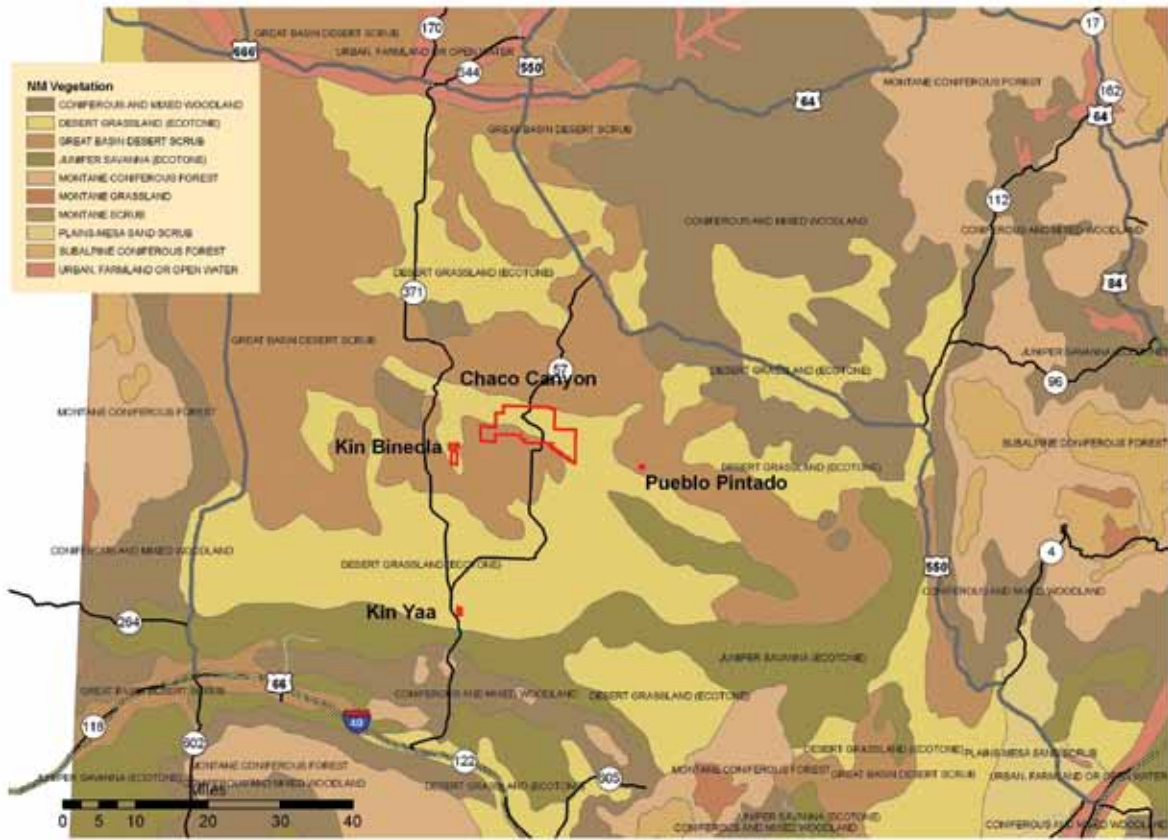


Figure 12. 1:1,000,000 Vegetation map of New Mexico (Dick-Peddie - no date)

Table 4. Omernik's and Bailey's descriptions of the ecosystems of Chaco Culture National Historical Park.

Ecoregions - Omernik (1987)

Ecoregion Code: 22

Name: Arizona/New Mexico Plateau

Description: The Arizona/New Mexico Plateau represents a large transitional region between the semiarid grasslands and low relief tablelands of the Southwestern Tablelands ecoregion in the east, the drier shrublands and woodland covered higher relief tablelands of the Colorado Plateau in the north, and the lower, hotter, less vegetated Mojave Basin and Range in the west and Chihuahuan Deserts in the south. Higher, more forest covered, mountainous ecoregions border the region on the northeast and southwest. Local relief in the region varies from a few meters on plains and mesa tops to well over 300 m along tableland side slopes.

Ecoregions – Bailey (1995)

Northern Units

Domain: Dry Domain

Division: Tropical/Subtropical Steppe Division

Province: Colorado Plateau Semi-Desert Province

Section: Navajo Canyonlands Section

Southern Units

Domain: Dry Domain

Division: Tropical/Subtropical Regime Mountains

Province: Arizona-New Mexico Mountains Semi-Desert-Open Woodland-Coniferous Forest-Alpine Meadow Province

Section: White Mountain-San Francisco Peaks Section

2 Methods

The methods used to produce a vegetation map for parks the size of CHCU are described in detail in USGS – NPS Vegetation Mapping Program Documents and Standards (<http://biology.usgs.gov/npsveg/standards.html>) and summarized here. The general tasks include planning meetings, collecting and analyzing existing data, development of the classification, development of the sampling strategy, field work, data input and analysis, photo interpretation, cartography, and map validation and accuracy assessment. These tasks necessarily interact with one another throughout the entire process.

2.1 Responsibilities and deliverables

BOR assumed the primary responsibility for all the tasks for this project. Products will include a full report, metadata, and distribution of the data and information to the appropriate NPS offices and websites. The data will ultimately be made available through the USGS website (<http://biology.usgs.gov/npsveg/>). Data and report have been reviewed by the staff of the Southern Colorado Plateau Network; Brad Shattuck, CHCU Chief of Resources; internal BOR peer review; and external peer review (Dan Cogan, Cogantech).

2.2 Planning and scoping

A general planning and scoping meeting was held at Chaco Culture National Historical Park to discuss the vegetation mapping needs March 16–17, 2005. Topics discussed included

- project background – National Program Standards
- unit overviews
- task overviews
 - compilation and preparation of existing data
 - preliminary classification and data review

- data collection
 - map classification
 - available photographs
 - database for information
 - local descriptions
 - metadata
 - map production
- field season

2.3 Preliminary data collection and review of existing information

2.3.1 Vegetation studies

Previous vegetation studies at Chaco Canyon during the past three decades involved 1) a vegetation mapping project, 2) a riparian vegetation inventory, 3) a grazing effects study, and 4) a weed survey.

Loren Potter, University of New Mexico, and colleagues began the CHCU vegetation mapping project in the early 1970s (Kelly and Potter 1974). As new acquisitions expanded the park boundaries considerably, Floyd-Hanna et al. (1993) added vegetation mapping of Chacra Mesa to the earlier 1974 map. This combined map covered the entire park area, although the methods and the spatial data used to produce the component maps varied considerably.

In conjunction with studies carried out by the USGS, Hanna and Floyd-Hanna also assessed the riparian vegetation at CHCU. Using high resolution IKONOS satellite imagery, they mapped the spatial extent of woody vegetation communities throughout Chaco, Gallo, and Fajada Washes (Hanna and Floyd-Hanna 2003). Hanna and Floyd-Hanna found that *Populus* stands occupied 10.5 ha (25.8 acres), or 4.8% of the total area of Chaco Wash. *Salix* stands occupied 2.8 ha (6.9 acres) or 1% of the total area, mixed woody shrubs occupied 121 ha, or 56% of the total area, and the invasive *Tamarix*

(salt cedar) occupied 12 ha (29.7 acres) or 6% of Chaco Wash. They sampled 2,065 *Populus* trees in 25 transects scattered among 7 strata. Although two of the seven reaches exhibited recruitment of saplings, they did not detect any recruitment by seed germination. Most of the vegetative recruitment was in hybrid stands (cross between two established species, in this case *Populus angustifolia* X *P. fremontii*). The populations characterized by larger trees were found on high floodplain.

The third study focused on post-grazing recovery by vegetation. In 1936 the National Park Service began fencing the boundaries of what was at that time a national monument (8,600 ha, ~21,251 acres), and completed the task in 1948 (NPS 1995, 1998). In 1980, the monument was expanded and converted into Chaco Culture National Historical Park. Fencing of the four new parcels (amounting to 5,000 ha; 12,355 acres) was completed from 1995 to the present. Consequently, Chaco currently has one of the largest grazing exclosures in western North America—one of the few that meets the size criterion of a proposal from Bock et al. (1993) that defined size parameters for grazing exclosures. There are 8,600 ha (~21,251 acres) that have been protected from grazing for 50+ years, including the entire riparian area; and an additional 5,000 ha (12,335 acres) that have been protected for 5 years or less, including upland sagebrush and pinyon-juniper woodlands. The entire 13,600 ha (33,606 acres) exclosure is surrounded by lands that continue to be grazed by Navajo ranchers. This study is summarized in Floyd et al. (2003).

Finally, Hanna and Floyd-Hanna (2004) developed a spatial model to predict invadable habitats in CHCU. In addition to this project, a survey of invasive species was conducted at CHCU, which identified four species of concern out of a potential list of 17 invasive species known from this geographic area. *Salsola kali* (Russian-thistle) is the most pervasive invasive

species, occurring throughout much of the bottomland adjacent to Chaco Wash—the area also most heavily impacted by visitation. *Halogeton glomeratus* (Halogeton) is abundant in limited areas, especially on Razito-Shiprock soils. *Bassia scoparia* (burningbush syn. *Kochia scoparia*) is common, although rarely in high densities. *Bromus tectorum* (cheatgrass) occurs throughout the lower elevations of Chaco Canyon and is most common along roadsides. Although this limited study did not look exhaustively at factors that might facilitate invasions of these habitats, pilot data suggest strongly that soil type and texture is important in determining which sites in the bottomland of CHCU will be susceptible to invasions of exotics. Two soils—Notal Silty Clay Loam and the Battlerock-notal complexes—are the most susceptible. Also, the presence of moderate or well developed microbial crusts correlated with lower invasive densities. The constant disturbance that is inherent with roads (and the visitation of archeological sites that those roads facilitate) in the canyon bottomland contributes to invasions.

2.3.2 Digital data

Although Chaco Canyon has been imaged by a variety of agencies for decades now (Brad Shattuck, pers. comm.) only recently has digital data and the accompanying metadata that makes it useful to future researchers been archived. For this project we had recent large scale digital soils, geology, and airborne imagery available, in addition to a very recent detailed digital map of the riparian vegetation in the main park unit (Hanna and Floyd-Hanna 2003). Regional soils and vegetation maps are also available although these are somewhat limited for this project.

2.4 Field survey

The field sampling design for the CHCU Vegetation Mapping Project was based on unique landscape features called

biophysical units (BPUs). We used these BPUs to stratify the landscape for relevé allocation, based on the grazing history (greater than 60 year protection and less than 10 year protection, soil class (from the NRCS general soil map units; flood plain and river terrace, alluvial fan and fan remnants, erosional terraces, escarpments, mesa summits/cuesta dip slopes, and riverwash), and aspect (north, south, east, and west facing). The BPU strategy is based on the assumption that environmental characteristics drive vegetation patterns at CHCU. The number of BPUs sampled for each defined BPU class was proportional to the total area and frequency of occurrence of each BPU type in the park.

At each location, one 20×20 m square plot was established with one side due north. Field data, consisting of a variety of environmental and vegetation characteristics as defined by protocols established by SCPN were collected within each plot; plant species were recorded and a Braun-Blanquet cover/abundance value was assigned. A copy of the datasheet and

all cover/abundance values are included in the DVD accompanying this report. Data were entered into an Access 2000 database. Locations were recorded with GPS; uncorrected UTM's were recorded in the field on data sheets and entered into the Access Database. Later, points were differentially corrected and the corrected points are provided in an attached PLOTS database. Plot sample locations are shown in Figure 13. Two digital photos were taken at each plot, one facing due north from the middle of the south plot boundary, and the other facing due south from the middle of the north plot boundary. These photographs are included with the digital database. We examined the field data periodically to determine if adequate numbers of relevés were sampled for each expected and observed community type.

2.5 Aerial photography

Truecolor aerial photography at a scale of 1:12,000 was collected on July 1, 2004. The aerial photography collected for CHCU was part of a region-wide U.S. Department of Agriculture-NPS agreement for a

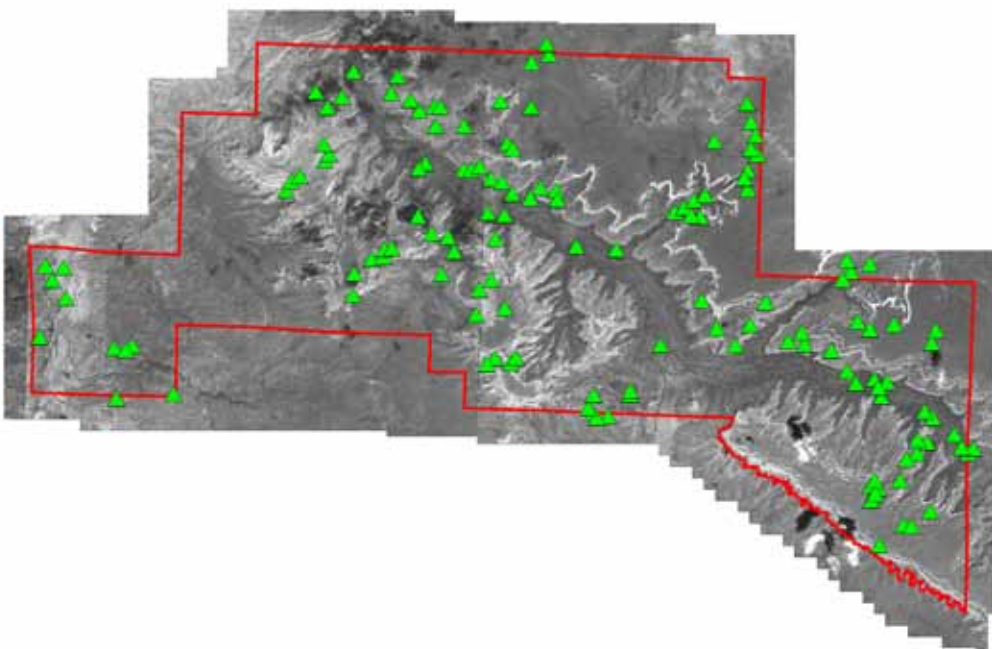


Figure 13. Vegetation plot locations for CHCU (two plots at Pueblo Pintado not shown)

number of other park units within the SCPN.

2.6 Photo interpretation

Photo interpretation was done using the the 9×9 in, 1:12,000-scale true color photographs. Mylar overlays placed on each aerial photo allowed us to make notes and delineate polygons. At this stage of interpretation we used a stereoscope to help recognize complex photo signatures and topographic features on the 9×9 in aerial photos. We then manually transferred these to the orthophoto basemap. Finally, in order to insure completeness and accuracy, digital transfer specialists reviewed all of the interpreted orthophotos for consistency and recommended changes where necessary. Once all the obvious vegetation and land-use classes were delineated we proceeded into the second stage.

The GPS-located vegetation plots collected by the field crew were instrumental to the photo interpretive effort. These plots gave us a good idea

of what the signatures of the individual map units represented. In addition to the tabular data associated with each vegetation plot, the two photographs collected at each plot helped not only to identify the immediate area, but also provided us with a “look” at the areas surrounding the vegetation plot, which might have been a different map unit. In addition to the vegetation plots, we made use of a number of different sources that had ground-referenced information.

2.7 Map units

The map units delineated on the aerial photos were derived from the NVC classification as constrained by the limitations of the photography. After an initial map unit meeting with all parties to this mapping effort, we arrived at an initial list of map units we thought reasonable. With one exception, each NVC association corresponded to one map unit. We also separated one NVC association into two map units due to different soil types which led to obvious differences in image interpretation (Map Unit 26). For data compilation purposes this map unit was kept as one NVC association. With the initial determination of preliminary map units made, the photo interpreters started their work. After an additional field visit in April 2006, one additional map unit was added without supporting plots. A map unit and vegetation association key is presented in Appendix A.

The photo interpretation also covered vegetation context and structure. Four attributes were included: map unit, height, density and coverage pattern. The structural categories and codes are listed in Table 5. A lookup table for the map unit names is provided with the geodatabase and in Appendix B.

2.7.1 Incorporating the Hanna and Floyd-Hanna (2003) map

Of particular interest to this project was the Hanna and Floyd-Hanna riparian

Table 5. Structural categories for vegetation photo interpretation

Code	Height (m)
1	<1
2	1–5
3	5–15
4	15–30
5	>30
Coverage density	
1	Closed canopy / continuous, 75–100 %
2	Discontinuous, 50–75%
3	Dispersed, 25–50%
4	Sparse, <25%
Coverage patterns	
1	Evenly dispersed
2	Clumped / bunched
3	Gradational / transitional
4	Alternating

Table 6. Conversion of Hanna-Floyd-Hanna (H-F) map units to the current effort

H-F map class	CHCU Vegetation Map map class
<i>Salix</i>	<i>Salix exigua</i> Temporarily Flooded Shrubland
<i>Populus</i>	<i>Populus fremontii</i> Temporarily Flooded Woodland Alliance
<i>Chrysothamnus</i>	<i>Ericameria nauseosa</i> Shrubland Alliance
<i>Artemisia</i> / <i>Atriplex</i> – grass, <i>Tamarix</i> , bare soil class	<i>Tamarix</i> spp. Semi-natural Temporarily Flooded Shrubland Alliance

vegetation map (H-F map) that was produced in 2003 (Hanna and Floyd-Hanna 2003). This very detailed map has been blended into this effort, eliminating the need to photo interpret the riparian corridor. The H-F map included the following map classes: *Salix*, *Populus*, *Chrysothamnus*-grass (rabbitbrush-grass), *Artemisia* / *Atriplex* – grass (sagebrush/saltbush – grass), *Tamarix*, and a bare soil class (table 6). We combined the *Artemisia* / *Atriplex* – grass, *Tamarix*, and bare soil classes into the *Tamarix* spp. Semi-

natural Temporarily Flooded Shrubland Alliance. All other classes fit into existing NVC types. Because the H-F map was produced by on-the-ground mapping, it was assumed to be 100% accurate, and therefore these map units were not included in the accuracy assessment.

2.7.2 Polygon attribution

Each polygon has a number of attributes that are stored in the associated table within the GIS database (table 7). Many

Table 7. Polygon attribute items and descriptions used in the spatial database of Chaco Culture National Historical Park

Attribute	Description
AREA*	Surface area of the polygon in m ²
PERIMETER*	Perimeter of the polygon in m
CHCU_VEG#*	Unique internal polygon coding
CHCU_VEG-ID*	Unique internal polygon coding
VEGCODE	Final Map Unit Codes - BOR derived, project specific.
HEIGHT	Height range of the dominant vegetation layer. (Height classes: <1 m, 1–5 m, 5–15 m, 15–30 m, >30 m)
DENSITY	Density of the tallest strata. (Density classes: <25%, 25–50%, 50–75%, >75%)
PATTERN	Vegetation pattern within the polygon. (Vegetation pattern classes: Evenly dispersed, Clumped/bunched, Gradational, Alternating)
SLOPE	Slope of label point within polygon (degrees).
ASPECT	Aspect of label point within polygon.
AND_LEV1	Land Use and Land Cover Classification System (USGS, Anderson et al. 1976) Level 1.
AND_LEV11	Land Use and Land Cover Classification System (USGS, Anderson et al. 1976) Level 2.
HECTARES	Area in hectares
ACRES	Area in acres
ELEV_M	Elevation in meters for label point
ELEV_FT	Elevation in feet for label point
EL_CODE	Ecological Systems Classification Code - NatureServe Ecological Classification.

*ArcMap© default items

of these attributes were derived from the photo interpretation and others were calculated or crosswalked from other classifications. Table 7 shows all the attributes and their sources. Anderson Level 1 and 2 codes are also included. These codes, which are also ecological system codes (E1_Code), should allow for a more regional perspective on the vegetation types. Look-up tables for both the Anderson codes and ecological system names are also included in the geodatabase. Also, there are three E1_codes in the database. These reflect the one to many relationships that may exist when cross walking the Map Unit to ecological systems. Finally, acres and hectares are calculated using XTools Pro for ArcGis Desktop (www.xtoolspro.com).

In addition to the standard polygon attributes discussed above, we include an attribute that reflects the total vegetation density per polygon. Vegetation densities may be determined by any number of established and accepted vegetation indices applied to aerial imagery that includes a near infrared band. For this project we were fortunate enough to have a multi-band IKONOS image available. Density attributes were added using the IKONOS imagery and image manipulation. Arid environments are noted for having a high soil reflectivity component that makes the use of other vegetation indices such as the NDVI (Normalized difference vegetation index) difficult.

Two indices have since been developed for use in arid environments and have received widespread acceptance: the SAVI (soil adjusted vegetation index) (Huete 1988) and, subsequently, the MSAVI (modified soil adjusted vegetation index) (Qi et al. 1994). We opted to use the MSAVI for this mapping effort because it takes into account the normally high component of soil reflectance typical in more arid environments. Areas of high bare ground or bare rock will have a lower MSAVI index than those of high vegetation cover, such as the greasewood flats along

Chaco Wash. The values for the derived MSAVI image are nominal data with values ranging from 1 (low vegetation density) to 5 (high vegetation density). In addition to the MSAVI value, we also include the standard deviation for the MSAVI image for each polygon. This item gives the user an idea of how varied the data are for each polygon. Polygons with a low standard deviation for the MSAVI values have a higher uniformity of vegetation density than those with a high standard deviation.

After polygons were photointerpreted and assigned a vegetation type, we further subdivided them based upon the MSAVI values. That is, should one polygon be labeled vegetation type X, but have different vegetation densities as shown by the MSAVI image, we divided the polygon to reflect the vegetation cover. Therefore, one will find polygons with the same vegetation attribution adjacent to one another, but with a different vegetation cover (MSAVI value). The development of the MSAVI image from the IKONOS data is detailed in Appendix C.

2.8 Digital transfer

The transfer process for the CHCU vegetation mapping project involved taking the interpreted line work and rendering it into a comprehensive digital network of attributed polygons. To accomplish this, we created an ArcInfo® GIS database using in-house protocols. The protocols consist of a shell (master file) of Arc Macro Language (AML) scripts and menus (nearly 100 files) that automate the transfer process, thus insuring that all spatial and attribute data are consistent and stored properly. The actual transfer of information from the interpreted orthophotos to a digital, geo-referenced format involved scanning, rasterizing, vectorizing, cleaning, building topology, and labeling each polygon.

The scanning technique involved a multi-step process whereby the mylar overlay sheets produced by the photo interpreters

were first marked with recognizable features on the IKONOS imagery base map. These mylars were subsequently scanned into a digital form. The digital image file (tagged image format .tif) created from the scanned sheet was then converted from a raster image to a vector file using routines within ArcMap. Using the reference marks on the mylars, we were then able to geo-reference the scanned mylar to the IKONOS imagery.

Once the mylar overlay sheets were scanned and registered, we removed all erroneous information, such as dangling lines. After this cleaning, we joined the lines into polygons by building topology in the GIS program. We then matched the edges of the resulting polygons with those from adjacent orthophotos. Finally, we created labels for each polygon and added the attribute information. Using this process we created one final coverage or spatial database for the entire project.

Attribution for all the polygons at CHCU included information pertaining to map units, NVC associations, Anderson land-use classes, and other relevant data. All of the attribute items are listed in Table 7 and are referenced in the CHCU vegetation look-up table included on the DVD that accompanies this report. Attribute data were taken directly from the interpreted photos or were added later using the IKONOS imagery as a guide.

2.9 Plot data management and classification analysis

2.9.1 Plot data management

We imported the data collected in 2005 from the Access database into Excel spreadsheets for specific formatting alterations prior to importing the species percent cover values into the multi-variate statistical analysis program PC-Ord (McCune and Medford 1999). Descriptive statistics were derived for the cover/abundance values and, because a high beta-diversity (≥ 2) was represented, we

stratified the data into three physiognomic classes: woody vegetation, herbaceous vegetation, and shrub vegetation. Non-metric multi-dimensional scaling (NMS) was used to test the strength of this stratification. The three new matrices were then analyzed separately. We deleted the rare species (with only one occurrence) in order to reduce noise in the dataset. In addition, we used NMS ordination to help us organize the vegetation communities and compare our results with the clustering analyses.

2.9.2 Vegetation classification

Cluster analysis (a hierarchical agglomerative classification of objects) was conducted for each matrix using the “Cluster” algorithms in PC-Ord. We made adjustments to the resulting clusters if the indicator species were exotic species or rare species that, from our field work, did not define the vegetation sufficiently. We also ran TWINSPLAN (a hierarchical, divisive clustering algorithm) in PC-Ord, which assigns the grouped relevés and indicator species that belong to each cluster. The resulting 17 clusters were further grouped or aggregated if 1) doing so would assist in defining the vegetation within an existing NVC association, or 2) doing so would allow greater clarity in creating map units.

Finally, we visually inspected the potential groups to cross-check them with established NVC associations. During this analysis we assigned each relevé an association according to the NatureServe Explorer (<http://www.natureserve.org/explorer/servlet/NatureServe?init=Ecol>) database, when available, and developed new potential associations when needed. After association names were classified for each physiognomic class, we compared the results for each physiognomic class and determined if there was overlap between classes, and if so, made adjustments. The physiognomic classes were aggregated in the final tally of associations and alliances.

The vegetation of Chaco Wash was

analyzed in detail in a recent project by Hanna and Floyd-Hanna (2003); therefore these communities were not re-visited with the protocols above. All of the pixels representing these classes were spatially joined. We then smoothed the lines so that they would match the line work of the current effort. Both the Hanna and Floyd-Hanna map and this one were then joined together to produce a seamless map.

2.10 Map verification

As we completed the photo interpretation and digital transfer for sections of the park, we printed draft 1:12,000-scale hard copy vegetation maps for review. In all cases, we checked these draft maps against the interpreted photographs to ensure that the polygons were labeled properly and to locate any extra or missing lines. We also compared the map labels to the plot data if they fell in the same location. Copies of the revised draft map were then ground truthed in the field by the photo interpreters. During the ground-truthing process, we verified aerial photograph signatures using landmarks and GPS waypoints. The map and map units were then modified to correct any mistakes.

2.11 Accuracy assessment sample design

The process of selecting accuracy assessment (AA) sample points followed that described by the NVMP; Accuracy Assessment Procedures manual (ESRI et al. 1994). The design attempts to adhere to scientific principles that govern sampling and statistical analysis, but also be practical. The consideration of map accuracy typically can have two components: thematic map accuracy and positional accuracy. The accuracy assessment that follows reflects only thematic map accuracy. Positional accuracy is not considered. Given that polygon boundaries are only occasionally “hard” and subject to interpretation, it makes little sense to spend the effort to quantify a subjective boundary.

2.11.1 Sample method

The accuracy assessment protocol takes into consideration maximum and minimum sample sizes, statistical as well as cost constraints, and each map class abundance and frequency. The sample selection is a stratified random sample, stratified by map units. Five scenarios are based on class abundance and frequency and are defined in Table 8.

2.11.2 Sample site selection

These parameters were coded into in-house software programs that allows for repeat sample selection using a variety of sample choices, such as cost weighting and distance from polygon boundary. Cost weighting allows one to eliminate sample points that have extremely arduous access (distance/difficulty = cost) or are in dangerous locations. Because of the reasonable access to most of the park, cost adjustments were not applied here. Being able to choose minimum distance to polygon boundaries helped to eliminate ecotonal boundaries that can cause confusion and loss of effort. A minimum distance of 10 m was chosen for this effort. The distribution of sample points is shown in Figure 14. Accuracy assessment sample points were collected for areas inside the main park unit. The outlying units of Pueblo Pintado, Kin Ya'a, and Kin Bineola were not sampled.

Field crews were provided with two sets of samples. The primary set included the preferred target for the sample selection (i.e., A list). If a target was inaccessible for any reason, the crews were free to substitute from a secondary set of points (i.e., B list). The effect of this arbitrary reselection reduces somewhat the randomness of the stratified random selection of points. The positive effect of this is to take advantage of the cost of sending a crew to a particular location.

2.11.3 Data collection: Accuracy assessment points

Table 8. Recommended number of map accuracy samples per class by frequency and area

Scenario	Description	Polygons in class	Area occupied by class (ha)	Recommended # of samples in class
Scenario A	The class is abundant. It covers more than 50 hectares of the total area and consists of at least 30 polygons. In this case, the recommended sample size is 30.	>30	>50	30
Scenario B	The class is relatively abundant. It covers more than 50 hectares of the total area but consists of fewer than 30 polygons. In this case, the recommended sample size is 20. The rationale for reducing the sample size for this type of class is that sample sites are more difficult to find because of the lower frequency of the class.	<30	>50	20
Scenario C	The class is relatively rare. It covers less than 50 hectares of the total area but consists of more than 30 polygons. In this case, the recommended sample size is 20. The rationale for reducing the sample size is that the class occupies a small area. At the same time, however, the class consists of a considerable number of distinct polygons that are possibly widely distributed. The number of samples therefore remains relatively high because of the high frequency of the class.	>30	<50	20
Scenario D	The class is rare. It has more than 5 but fewer than 30 polygons and covers less than 50 hectares of the area. In this case, the recommended number of samples is 5. The rationale for reducing the sample size is that the class consists of small polygons and the frequency of the polygons is low. Specifying more than 5 sample sites will therefore probably result in multiple sample sites within the same (small) polygon. Collecting 5 sample sites will allow an accuracy estimate to be computed, although it will not be very precise.	5–30	<50	5
Scenario E	The class is very rare. It has fewer than 5 polygons and occupies less than 50 hectares of the total area. In this case, it is recommended that the existence of the class be confirmed by a visit to each sample site. The rationale for the recommendation is that with fewer than 5 sample sites (assuming 1 site per polygon), no estimate of level of confidence can be established for the sample (the existence of the class can only be confirmed through field checking).	<5	<50	Visit all and confirm

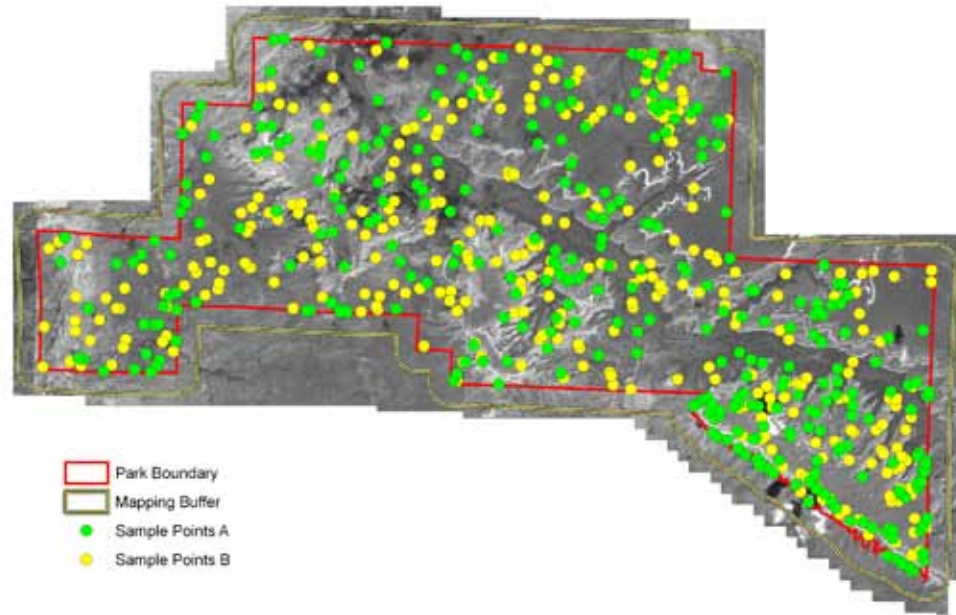
Field maps were produced that showed the sample points and polygon boundaries. The addition of the polygon boundary to the field map aided in navigation to the point and provided the field crews with some contextual information. Field crews navigated to each point using the field maps produced for this effort in addition to a GPS with a known target location.

To help control cost and logistic issues, only those map units that had a vegetative component received an accuracy assessment. In addition, the arroyo polygons mapped by Hanna and Floyd-Hanna (2003) were not tested as these are assumed to be 100% correct. This resulted

in the removal of 1,465 polygons from consideration, or 56% of the total number of polygons. This translates into 5% of the project area not being assessed through a formal accuracy assessment. The disparity between frequency (56%) and abundance (5%) is a result of the high number of very small polygons in the arroyo that were removed from accuracy assessment consideration. The result of this is that the reported overall accuracies are most probably higher than the actual overall map accuracy.

In August of 2006, the accuracy assessment field crews were given printouts of satellite imagery overlaid with the map

Figure 14. Initial accuracy assessment sample point distribution



unit polygons. These maps contained 337 randomly-selected locations to be used as AA points. The field crews were instructed to navigate to these points and complete an AA datasheet (included in the digital files that accompany this report). As explained above, a secondary set of possible AA points was included on the maps as replacements for those primary points which might be inaccessible or otherwise unusable.

Between August 21 and 25, 2006, the field crews collected 201 AA points. Field days were planned around collecting as many primary points as possible; however, when secondary points occurred along a planned route for the day, they were surveyed in anticipation of future points which might be missed. Because of inclement weather on the first trip a second trip in October was planned in order to pick up the remaining points missed on the first trip, primarily located on Chacra Mesa. An additional 114 points were collected on the second trip for a total of 315 AA points. Figures 14 and 42 through 44 show the locations of the collected AA points. Appendix D summarizes the field crew's notes for each trip.

Upon arrival at a point, crews would begin with a broad visual survey of the area to determine whether vegetation at the point was representative of the map unit polygon (ecotone or inclusions). If vegetation was not representative, the crew would move the point to a more representative location within the polygon and record the distance and bearing to the new point. The crew would then visually determine the boundaries of the point to be sampled. The minimum mapping unit is 0.5 ha and this was used as the sample plot area. Crews would then begin collecting data on species composition, vegetation structure, geology, and topography of the area. After filling out the AA Point form, the crew would use the Field Key (Appendix A) to assign an NVC association or map unit to the plot (most, but not all map units are a one-to-one relationship with associations). If no association seemed to fit, the crew would assign an association name to the plot based on the NVC naming conventions for associations (dominant species of the primary strata). At each plot, pictures were taken in each of the cardinal directions from the plot center, when possible. At some plots, no pictures were taken due to technical camera problems. Crews were instructed to document what

they observed at the plots by recording extensive field notes. The pictures and the notes that crews collected in the field proved very useful in resolving classification questions later during the AA. All photographs are included with the digital data set for this project.

While all fields on the AA form were checked for accuracy, particular attention was given to checking the UTMs and plot numbers, and to comparing the assigned association name with species data. All AA point data were then entered into the PLOTS database. Following the data entry, the AA data in the database was subjected to another round of QC to catch data entry errors. A map unit column was added to the database and filled using a Microsoft Access query. Those points which did not fit well into an existing NVC association were keyed to a map unit by hand.

2.12 Accuracy assessment metrics

Once all the AA data had been entered and compiled, the accuracy analysis portion of the project was started. This involved a number of steps including an initial binary accuracy assessment, calculation of confidence intervals, a fuzzy evaluation of the AA data, hypotheses testing and the construction of fuzzy error distribution maps.

2.12.1 Initial data processing

While in the field, the crew came across numerous instances of vegetation types that were not seen during the original census. These points were labeled as the crew thought fit during sampling. They were then removed from binary accuracy assessment as there was no reference type to compare them against — i.e., there was no map unit that would correspond to the field designation. This is discussed in greater detail under the discussion section of this report. Adjustments were also made to compensate for renaming map unit 28 (*Tetradymia canescens* – *Atriplex canescens* Shrubland or Gray Horsebrush

– Fourwing Saltbush Shrubland), which was redesignated after field data collection to *Atriplex canescens* - *Krascheninnikovia lanata* Shrubland (Fourwing Saltbush - Winter-fat Shrubland). Some plots were redesignated as a woody type rather than an herbaceous or shrubby type using the imagery as a guide. For example, extreme low density juniper or pinyon (< 5%) is difficult to quantify using the limited area under consideration for AA points. All data were entered into the USGS-NPS PLOTS database. Finally, a table containing just the map unit codes, the initial, first alternate, and second alternate map unit designations was created for subsequent AA analysis by the GIS software.

2.12.2 Binary accuracy assessment

All AA plots and their respective map unit classification (reference layer) were compared to the digital vegetation polygon data (predictive layer). This provides an initial overall accuracy assessment and omission and commission errors (user's and producer's accuracy respectively). [Unless otherwise noted all subsequent formulas are described from Accuracy Assessment Procedures (ESRI et al., 1994)]. The following formulas are used for all fuzzy level AA metrics.

User's accuracy

User's accuracy was calculated as:

$$\frac{n_{ii}}{n_{i+}}$$

where i is the landcover type, n_{ii} is the number of matches between map and reference data, and n_{i+} is the total number of samples of i in the map. This formula is the number of “correct” observations divided by the sum of the column.

Producer's accuracy

Producer's accuracy was calculated as:

$$\frac{n_{ii}}{n_{+i}}$$

where n_{+i} = total number of samples of i in the reference data. This formula is the number of “correct” observations divided by the sum of the row.

Overall map accuracy

Overall accuracy for the map was calculated as:

$$\frac{\sum_{i=1}^k n_{ii}}{n}$$

where k = number of land cover types and n = total number of reference points. This formula is simply the sum of the diagonal entries divided by the total number of AA points.

2.12.3 Confidence interval

The 90% confidence interval for a binomial distribution is obtained from the following equation:

$$\hat{p} \pm \left\{ z_{\alpha} \sqrt{\frac{\hat{p}(1 - \hat{p})}{n}} + \frac{1}{(2n)} \right\}$$

where $z = 1.645$ (this comes from a table of the z -distribution at the significance level for a two-sided limit with a 90% confidence interval),

$\hat{p}$ = sample accuracy (0 to 1.0), and n = number of sites sampled. The term $1/(2n)$ is the correction for continuity. The correction should be applied to account for the fact the binomial distribution describes discrete populations.

A kappa statistic (k) is calculated for overall accuracy of each fuzzy level evaluated as follows:

$$k = \frac{N \sum_{i=1}^r x_{ii} - \sum_{i=1}^r (x_{i+} \times x_{+i})}{N^2 - \sum_{i=1}^r (x_{i+} \times x_{+i})}$$

Kappa can be used as a measure of agreement between model predictions and reality (Congalton 1991), or to determine if the values contained in an error matrix represent a result significantly better than random (Jensen 1996). Kappa is computed where N is the total number of sites in the matrix, r is the number of rows in the matrix, x_{ii} is the number in row i and column i , x_{+i} is the total for row i , and x_{i+} is the total for column i (Jensen 1996). Existing ArcView scripts made this onerous process easy and repeatable [kappa_stats.avx by Jenness and Wynne (2004) or kappa.avx developed by the RS/GIS Laboratories at Utah State University (2003) and available at <http://www.gis.usu.edu/~chrisg/avext/>].

2.12.4 Fuzzy accuracy assessment

The need for an alternative to the standard binary approach of accuracy assessment was recognized some time ago. Gopal and Woodcock (1994) described the first fuzzy accuracy assessment approach that is commonly used today. This type of analysis allows for degrees of membership to a particular class—we are allowed to recognize that a particular class may be considered wrong using a strict binary

Table 9. Fuzzy set accuracy ranks (Gopal and Woodcock 1994)

Fuzzy class	Description
1	Absolutely wrong. This answer is absolutely unacceptable. Very wrong.
2	Understandable but wrong. Not a good answer. There is something about the site that makes the answer understandable but there is clearly a better answer. This answer would pose a problem for the users of the map.
3	Reasonable or acceptable answer. Maybe not the best possible answer but it is acceptable; this answer does not pose a problem to the user if it is seen on the map. Correct.
4	Good answer: Would be happy to find this answer given on the map. Very correct.
5	Absolutely right. No doubt about the match. Perfect.

approach, but with the fuzzy analysis that class may be mostly correct. This does provide a much better representation of the continuity present in the real world and still allows us to map using discrete classes.

The standard approach to assigning fuzzy membership to a class is to review each of the AA points and assign a fuzzy level to that plot. Fuzzy level designations are shown in Table 9. This approach allowed us to evaluate each fuzzy level using the standard binary approach. That is, we developed a contingency table for fuzzy levels 5, 4 and 3. Because we are only interested in the fuzzy levels that allow for varying degrees of membership and still be considered correct we ignored fuzzy levels 2 and 1.

All points that received a “correct” designation during the initial binary assessment were assigned fuzzy membership 5. To insure that this “correct” designation was carried through subsequent fuzzy analysis, both fuzzy levels 4 and 3 were automatically calculated using the “correct” value, regardless of the alternate designations designated in the field. All other plots were then selected for other fuzzy membership designations. The contingency tables are presented in the “Results” section of this report.

2.12.5 Hypothesis testing

The hypothesis test for this accuracy assessment determines whether or not the accuracy estimate exceeds 80% (program standard). For the purposes of this accuracy assessment we use the following hypothesis (Accuracy Assessment Procedures 1994):

“The hypothesis that 80% accuracy has been met will be accepted unless the sample map accuracy is low enough so that the conclusion that rejection is appropriate can be drawn with some predetermined degree of certainty.”

We used the confidence interval to determine whether to accept or reject this hypothesis. There is an extremely close relationship between confidence intervals and hypothesis testing. When a 90% confidence interval is constructed, all values in the interval are considered plausible values for the parameter being estimated. Values outside the interval are rejected as implausible. If the value of the parameter specified by the null hypothesis is contained in the 90% interval then the null hypothesis cannot be rejected at the 0.1 level. If the value specified by the null hypothesis is not in the interval then the null hypothesis can be rejected at the 0.1 level.

3 Results

3.1 Field data collection

Field data were collected during the summer of 2005 when a total of 141 vegetation plots were established in the park. During the fall of 2006, a total of 315 accuracy assessment points were established. These data were used to develop the classification of the vegetation of CHCU, as well as verify the accuracy of the completed map. The accuracy assessment points served to alert the park to the presence of additional types that had not been identified during the vegetation plot sampling in 2005.

3.2 Vegetation classification

A total of 22 vegetation types are described for the park using a combination of previous riparian studies (Hanna and Floyd-Hanna 2003) and this current effort. All of these types, with the exception of the *Lycium pallidum* - *Atriplex canescens* / *Tetradymia canescens* Shrubland (Pale Desert-thorn - Fourwing saltbush / Spineless Horsebrush Shrubland) are recognized NVC types. The vegetation plot data collected in 2005 were classified into 18 distinct vegetation types based on species composition, structure, and environmental characteristics. Analysis techniques included a combination of Cluster and Twinspan—grouping similar plant associations based on species cover/abundance values. A summary list of the vegetation associations is shown in Table 10.

Assignment of all the accuracy assessment sampling points to either a classified NVC type, or an “other/unclassified” category identified six additional types as potentially occurring (Appendix D) and six non-vegetated types. These “other” types have not been included in the classification because they are based only on AA sample points and were not used to create the classification. After review, the potential types were fit into logical NVC types; a list of the resulting five potential additional types along with brief local

description is included later in the results section. With additional sampling and classification work, these additional types may represent possible future extensions of the classification, or may be recognized as variants of existing classified types. The dichotomous key to the vegetation types of CHCU is located in Appendix A. Local and global descriptions for each NVC type follow below. All global descriptions are provided by the NatureServe website.

The vegetation described from CHCU has only limited diversity and is dominated by shrub types. Of the 23 described types, 14 are shrubland or shrub herbaceous types and these comprise 14,687 ha (36,290 acres), or about 78% of the mapping area. Wooded types are limited and exceedingly low density in most areas, with perhaps the exception of Chacra Mesa where densities are somewhat greater, albeit, still low. Total wooded area within the mapping area is 1,311 ha (3,240 acres) or about 7%. A total of 3 herbaceous community types were classified for the park. An additional grazed forbland class was created for a small portion of the mapping area that is heavily grazed. These herbaceous types are dominated by *Pleuraphis jamesii* (James’ galleta), *Sporobolus airoides* in most areas, with occasional occurrences of *Hesperostipa comata* (needle and thread), *Bouteloua gracilis* (blue grama), and *Achnatherum hymenoides* (Indian ricegrass). Outside the park one finds greater occurrence of *Bouteloua gracilis* (blue grama) due to the grazing impacts. Other mapped units not included within the NVC are bare ground, rock, arroyos, talus slopes, roads and parking lots, archaeological sites and NPS developments. These areas comprise 786 ha (1,942 acres), or about 4% of the mapped area.

Table 10. NVCS associations and alliances found at Chaco Culture National Historical Park

Alliance	Association	Common or translated name	Code	Global status	Rounded global status	Plots
Proposed Type - No Alliance Designation	<i>Lycium pallidum</i> - <i>Atriplex canescens</i> / <i>Tetradymia canescens</i> Shrubland	Pale Desert-thorn – (Four-wing saltbush / Gray horsebrush) Shrubland	CEGL00XXX			139, 157, 195, 545, 903, 104
<i>Pleuraphis jamesii</i> Herbaceous Alliance	<i>Pleuraphis jamesii</i> - <i>Sporobolus airoides</i> Herbaceous Vegetation	James' Galleta - Alkali Sacaton Herbaceous Vegetation	CEGL001778	G2G3	G2 - Imperiled	123, 874, 163, 31, 76
<i>Sporobolus airoides</i> - (<i>Pleuraphis jamesii</i>) Shrub Herbaceous Alliance	<i>Gutierrezia sarothrae</i> / <i>Sporobolus airoides</i> - <i>Pleuraphis jamesii</i> Shrub Herbaceous Vegetation	Broom Snakeweed / Alkali Sacaton - James' Galleta Shrub Herbaceous Vegetation	CEGL001776	GU	GU - Unrankable	329, 1017, 447, 196, 181, 162
<i>Bouteloua gracilis</i> Herbaceous Alliance	<i>Bouteloua gracilis</i> Herbaceous Vegetation	Blue Grama Shortgrass Prairie	CEGL001760	G4Q	G4 - Apparently Secure	303
<i>Hesperostipa comata</i> Bunch Herbaceous Alliance	<i>Hesperostipa comata</i> - <i>Achnatherum hymenoides</i> Herbaceous Vegetation	Needle-and-Thread - Indian Ricegrass Mixedgrass Prairie	CEGL001703	G2?	G2 - Imperiled	164, 149
<i>Artemisia nova</i> Shrubland Alliance	<i>Artemisia nova</i> - <i>Atriplex canescens</i> Shrubland	Black Sagebrush – Fourwing saltbush Shrubland	CEGL00XXX			449, 677, 1022, 1020, 1021, 1019, 97, 372, 87, 152, 16, 160, 90, 4
<i>Ephedra torreyana</i> Sparsely Vegetated Alliance	<i>Ephedra torreyana</i> - (<i>Atriplex canescens</i> , <i>Atriplex confertifolia</i>) Sparse Vegetation	Torrey's Joint-fir - (Fourwing Saltbush, Shadscale) Sparse Vegetation	CEGL005801	GNR	GNR - Not Yet Ranked	199, 38, 51, 52, 36, 2, 1023, 119, 148, 37, 60
<i>Purshia (stansburiana, mexicana)</i> Shrubland Alliance	<i>Purshia stansburiana</i> - <i>Ephedra torreyana</i> Shrubland	Stansbury Cliffrose - Torrey's Joint-fir Shrubland	CEGL00XXX			54, 109, 25, 103, 58, 151, 158
<i>Atriplex canescens</i> Shrubland Alliance	<i>Atriplex canescens</i> Shrubland	Fourwing Saltbush Shrubland	CEGL001281	G5	G5 - Secure	359, 334, 45, 116, 161, 172, 27, 117, 190, 201, 1016, 1018, 191, 866, 713, 184
<i>Sarcobatus vermiculatus</i> Shrubland Alliance	<i>Sarcobatus vermiculatus</i> - <i>Atriplex canescens</i> Shrubland	Black Greasewood – Fourwing Saltbush Shrubland	CEGL00XXX			1011, 1010, 153, 11, 1026, 984, 458, 227, 17, 1001, 549, 1024, 761, 193, 939, 1014, 446, 660
<i>Forestiera pubescens</i> Temporarily Flooded Shrubland Alliance	<i>Forestiera pubescens</i> Shrubland	Stretchberry Shrubland	CEGL001168	G1G2	G1 - Critically Imperiled	168
<i>Sporobolus airoides</i> - (<i>Pleuraphis jamesii</i>) Shrub Herbaceous Alliance	<i>Atriplex obovata</i> / <i>Sporobolus airoides</i> - <i>Pleuraphis jamesii</i> Shrub Herbaceous Vegetation	Mound Saltbush / Alkali Sacaton - James' Galleta Shrub Herbaceous Vegetation	CEGL001775	GU	GU - Unrankable	178, 125, 182, 176, 940, 89, 79, 173, 175, 177

Table 10, continued. NVCS associations and alliances found at Chaco Culture National Historical Park

Alliance	Association	Common or translated name	Code	Global status	Rounded global status	Plots
<i>Atriplex canescens</i> Shrubland Alliance	<i>Atriplex canescens</i> - <i>Krascheninnikovia lanata</i> Shrubland	Fourwing Saltbush - Winterfat Shrubland	CEGL001285	G5	G5 - Secure	61, 841, 154, 174, 180, 194, 165, 156, 1025, 18, 15, 9, 141, 1030, 14
<i>Artemisia tridentata</i> (ssp. <i>tridentata</i> , ssp. <i>xericensis</i>) Shrubland Alliance	<i>Artemisia tridentata</i> ssp. <i>tridentata</i> / <i>Pleuraphis jamesii</i> Shrubland	Basin Big Sagebrush / James' Galleta Shrubland	CEGL001015	G2G4	G3 - Vulnerable	1031
<i>Atriplex canescens</i> Shrubland Alliance	<i>Artemisia tridentata</i> - <i>Atriplex canescens</i> - <i>Sarcobatus vermiculatus</i> / (<i>Achnatherum hymenoides</i>) Shrubland	Big Sagebrush - Fourwing Saltbrush - Greasewood / (Indian Ricegrass) Shrubland	CEGL001355	G1	G1 - Critically Imperiled	Chaco Wash
<i>Ericameria nauseosa</i> Shrubland Alliance		Rubber Rabbitbrush Shrubland Alliance	A.835			Chaco Wash
<i>Atriplex confertifolia</i> Shrubland Alliance	<i>Atriplex confertifolia</i> / <i>Pleuraphis jamesii</i> Shrubland	Shadscale / James' Galleta Shrubland	CEGL001304	G3G5	G4 - Apparently Secure	
<i>Salix (exigua, interior)</i> Temporarily Flooded Shrubland Alliance	<i>Salix exigua</i> Temporarily Flooded Shrubland	Coyote Willow Temporarily Flooded Shrubland	CEGL001197	G5	G5 - Secure	Chaco Wash
<i>Tamarix</i> spp. Semi-natural Temporarily Flooded Shrubland Alliance	<i>Tamarix</i> spp. Semi-natural Temporarily Flooded Shrubland Alliance	Salt-cedar species Semi-natural Temporarily Flooded Shrubland Alliance	A.842			Chaco Wash
<i>Juniperus monosperma</i> Woodland Alliance	<i>Juniperus monosperma</i> / <i>Cercocarpus montanus</i> Woodland	One-seed Juniper / Alderleaf Mountain-mahogany Woodland	CEGL000713			147, 111,155,92,167,80,102,19, 105,7,101,33, 188
<i>Pinus edulis</i> - (<i>Juniperus</i> spp.) Woodland Alliance	<i>Pinus edulis</i> - <i>Juniperus</i> spp. / <i>Cercocarpus montanus</i> - Mixed Shrubs Woodland	Two-needle Pinyon - Juniper species / Alderleaf Mountain-mahogany - Mixed Shrubs Woodland	CEGL000780	G5	G5 - Secure	166, 171, 169, 170, 197, 1027, 1028, 108
<i>Populus fremontii</i> Temporarily Flooded Woodland Alliance	<i>Populus fremontii</i> <i>Salix exigua</i> Forest	Fremont Cottonwood / Coyote Willow Forest	CEGL000666			Chaco Wash

3.3 Vegetation alliances and associations

The following descriptions of vegetation types are derived from two sources. These include the NatureServe Ecological Communities web site and a previous report by Hanna and Floyd-Hanna (2003). Most of each description represents global descriptions for each type derived from the NatureServe Ecological Communities website (www.natureserve.org/explorer). These descriptions have been edited to reduce repetitiveness. Each described association is preceded by the name of its parent alliance. Some of the associations are called “provisional” by NatureServe. These are associations for which NatureServe does not have enough information to determine global range at the present time. When associations are provisional, the alliance-level global descriptions are provided. Included within each of the descriptions are local descriptions that have been written in association with the data collected during this project. These descriptions describe the condition for each type at CHCU, which may or may not match exactly with the global description. In most cases the vegetation type is described to the association level, however, if the data and the sites are difficult to assign unequivocally to an association, only the alliance level is described. Additional information about the definition of the many categories for each vegetation type (e.g. classification confidence, classification approach, etc.) can be found at the NatureServe web site (see above). Finally, all riparian alliance and associations mapped and described by Hanna and Floyd-Hanna (2003) have been adopted for this report.

Herbaceous vegetation

<i>Bouteloua gracilis</i> Herbaceous Alliance	29
<i>Bouteloua gracilis</i> Herbaceous Vegetation	29
Grazed Forb Grassland (NON-NVC)	32
<i>Hesperostipa comata</i> Bunch Herbaceous Alliance	32
<i>Hesperostipa comata</i> - <i>Achnatherum hymenoides</i> Herbaceous Vegetation	32
<i>Pleuraphis jamesii</i> Herbaceous Alliance	34
<i>Pleuraphis jamesii</i> - <i>Sporobolus airoides</i> Herbaceous Vegetation	34

Shrub herbaceous vegetation

<i>Sporobolus airoides</i> - (<i>Pleuraphis jamesii</i>) Shrub Herbaceous Alliance	36
<i>Atriplex obovata</i> / <i>Sporobolus airoides</i> - <i>Pleuraphis jamesii</i> Shrub Herbaceous Vegetation	36
<i>Gutierrezia sarothrae</i> / <i>Sporobolus airoides</i> - <i>Pleuraphis jamesii</i> Shrub Herbaceous Vegetation	37

Shrubland

<i>Artemisia nova</i> Shrubland Alliance	39
<i>Artemisia nova</i> - <i>Atriplex canescens</i> Shrubland	39
<i>Artemisia tridentata</i> (ssp. <i>tridentata</i> , ssp. <i>xericensis</i>) Shrubland Alliance	41
<i>Artemisia tridentata</i> ssp. <i>tridentata</i> / <i>Pleuraphis jamesii</i> Shrubland	41
<i>Atriplex canescens</i> Shrubland Alliance	43
<i>Atriplex canescens</i> Shrubland	43
<i>Atriplex canescens</i> - <i>Krascheninnikovia lanata</i> Shrubland	44

<i>Atriplex confertifolia</i> Shrubland Alliance	45
<i>Atriplex confertifolia</i> / <i>Pleuraphis jamesii</i> Shrubland	46
<i>Ephedra torreyana</i> Sparsely Vegetated Alliance	47
<i>Ephedra torreyana</i> - (<i>Atriplex canescens</i> , <i>Atriplex confertifolia</i>) Sparse Vegetation	47
<i>Forestiera pubescens</i> Temporarily Flooded Shrubland Alliance	48
<i>Forestiera pubescens</i> Shrubland	48
<i>Lycium pallidum</i> - (<i>Atriplex canescens</i> / <i>Tetradymia canescens</i>) Shrubland	50
<i>Purshia (stansburiana, mexicana)</i> Shrubland Alliance	51
<i>Purshia stansburiana</i> - <i>Ephedra torreyana</i> Shrubland	51
<i>Sarcobatus vermiculatus</i> Shrubland Alliance	52
<i>Sarcobatus vermiculatus</i> - <i>Atriplex canescens</i> Shrubland	52
Woodland	
<i>Juniperus monosperma</i> Woodland Alliance	56
<i>Juniperus monosperma</i> / <i>Cercocarpus montanus</i> Woodland	56
<i>Pinus edulis</i> - (<i>Juniperus</i> spp.) Woodland Alliance	57
<i>Pinus edulis</i> - <i>Juniperus</i> spp. / <i>Cercocarpus montanus</i> - Mixed Shrub Woodland	57
Riparian and temporarily flooded associations (Chaco Wash)	
<i>Atriplex canescens</i> Shrubland Alliance	60
<i>Artemisia tridentata</i> - <i>Atriplex canescens</i> - <i>Sarcobatus vermiculatus</i> / (<i>Achnatherum hymenoides</i>) Shrubland	60
<i>Ericameria nauseosa</i> Shrubland Alliance	61
<i>Salix (exigua, interior)</i> Temporarily Flooded Shrubland Alliance	63
<i>Salix exigua</i> Temporarily Flooded Shrubland	63
<i>Tamarix</i> spp. Semi-natural Temporarily Flooded Shrubland Alliance	66
<i>Populus fremontii</i> Seasonally Flooded Woodland Alliance	67
<i>Artemisia filifolia</i> Shrubland Alliance	69
<i>Cercocarpus montanus</i> Shrubland Alliance	69
<i>Purshia (stansburiana, mexicana)</i> Shrubland Alliance	71
<i>Pinus edulis</i> - (<i>Juniperus</i> spp.) Woodland Alliance	71
Weedy forbs (Non-NVC) Alliance	72

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3.3.1 Herbaceous vegetation

ALLIANCE: *Bouteloua gracilis* Herbaceous Alliance (fig. 15)

Translated name: Blue Grama Herbaceous Alliance
 Unique identifier: A.1282
 Classification approach: International Vegetation Classification (IVC)



Figure 15. Plot CHCU – 0303. *Bouteloua gracilis* Herbaceous Alliance.

ASSOCIATION: *Bouteloua gracilis* Herbaceous Vegetation

Translated name: Blue Grama Herbaceous Vegetation
 Common name: Blue Grama Shortgrass Prairie
 Unique identifier: CEGLO01760
 Classification approach: International Vegetation Classification (IVC)

SUMMARY

This minor plant association is reported from Arizona, Colorado, New Mexico and Wyoming. Sites are flat to gently sloping and include plains, plateaus and montane meadows. Substrates are variable and range from coarse-textured soils derived from sand, gravel, granite or cinder to silty clay loam prairie soils. The vegetation is characterized by a moderate to dense (25-80% cover) herbaceous layer that is strongly dominated by the warm-season, perennial shortgrass *Bouteloua gracilis*. Associated grasses are *Bouteloua curtipendula* (sideoats grama), *Elymus elymoides* (squirreltail), *Muhlenbergia* spp. (muhly), *Pascopyrum smithii* (western wheatgrass), *Pleuraphis jamesii* (= *Hilaria jamesii*) (James' galleta), *Sporobolus cryptandrus* (sand dropseed), and the introduced annual grass *Bromus tectorum*. Forb cover is sparse. Associated forbs include *Artemisia carruthii* (Carruth's sagewort), *Artemisia dracunculus* (tarragon), *Eriogonum* spp. (buckwheat), and *Sphaeralcea coccinea* (scarlet globemallow). Scattered *Ericameria nauseosa* (rubber rabbitbrush) shrubs and an occasional *Pinus edulis*, *Juniperus* spp., or *Pinus ponderosa* tree (in montane stands) may be present.

CLASSIFICATION CONFIDENCE: 3 - Weak

CLASSIFICATION COMMENTS:

This is a low-confidence association. There are many other associations in the *Bouteloua gracilis* Herbaceous Alli

ance (A.1282). This association often represents degraded montane grasslands and *Bouteloua gracilis*-dominated grasslands that lack other diagnostic species. *Bouteloua gracilis* is often able to persist after other species are eliminated because it is an extremely drought- and grazing-tolerant species.

VEGETATION HIERARCHY:

Formation Class	V - Herbaceous Vegetation
Formation Subclass	V.A - Perennial graminoid vegetation
Formation Group	V.A.5 - Temperate or subpolar grassland
Formation Subgroup	V.A.5.N - Natural/Semi-natural temperate or subpolar grassland
Formation Name	V.A.5.N.e - Short sod temperate or subpolar grassland
Alliance Name	<i>Bouteloua gracilis</i> Herbaceous Alliance

ECOLOGICAL SYSTEMS PLACEMENT:

Ecological system ID	Ecological system name
CES303.672	Western Great Plains Shortgrass Prairie
CES303.817	Western Great Plains Foothill and Piedmont Grassland
CES304.787	Inter-Mountain Basins Semi-Desert Grassland

GLOBAL STATUS: G4Q (23Feb1994)

ROUNDED GLOBAL STATUS: G4 - Apparently Secure

UNITED STATES DISTRIBUTION: AZ, CO, NM? UT, WY

GLOBAL DISTRIBUTION: United States

GLOBAL RANGE: This minor plant association occurs in Arizona, Colorado, New Mexico and Wyoming

ENVIRONMENTAL SUMMARY:

This minor plant association is reported from Arizona, Colorado, New Mexico and Wyoming. Elevation ranges from 1,830-2,705 m (6,000-8,875 ft.). Sites are flat to moderately sloping and include plains, plateaus and montane meadows and parks. Substrates are variable and range from coarse-textured soils derived from sand, gravel, granite or cinder to silty clay loam prairie soils. Montane *Bouteloua gracilis*-dominated grasslands included in this association are typically the result of heavy grazing use by wildlife and/or livestock that select out less grazing-tolerant mid grasses.

DYNAMICS:

Bouteloua gracilis is an extremely drought- and grazing-tolerant shortgrass species. It is one of the most widely distributed grasses in the interior western U.S. and is present in many different grassland, shrubland and woodland communities. It evolved with grazing by large herbivores and generally forms a short sod. However, in some stands ungrazed plants develop the upright physiognomy of a bunchgrass. *Bouteloua gracilis* is a warm-season grass and relatively unaffected by spring grazing while it is dormant. Montane *Bouteloua gracilis*-dominated stands are often seral to midgrass associations dominated by species of *Achnatherum* (needlegrass), *Danthonia* (oatgrass), *Festuca* (fescue), *Hesperostipa* (needle and thread), or *Muhlenbergia* and are the result of inappropriate stocking rates or season of use by large herbivores.

LOCAL DESCRIPTION:

This association was on the Navajo Reservation and was heavily grazed. The dominant grasses were *Bouteloua gracilis* and *Pleuraphis jamesii*. Forbs were few, including *Cryptantha micrantha* (redroot cryptantha) and *Chaetopappa ericoides* syn. *Leucelene ericoides* (rose heath). *Gutierrezia sarothrae* (threadleaf snakeweed) was present.

PLOT NUMBERS: 303

ASSOCIATION: Grazed Forb Grassland (NON-NVC)

Unique identifier: cegl00xxx (temporary – probably not classifiable)

LOCAL DESCRIPTION:

This unnatural association is found in Gallo Wash north of the Chaco Canyon NHP boundary on the Navajo Reservation. Active, intense, grazing retains a low cover of weedy vegetation including *Bassia scoparia* (burningbush), *Lappula occidentalis* syn. *L. redowski* (flatspine stickseed), and *Mentzelia albicaulis* (whitestem blazingstar). Grasses, when identifiable, included *Bouteloua gracilis*.

PLOT NUMBERS: 485

ALLIANCE: *Hesperostipa comata* Bunch Herbaceous Alliance (fig. 16)

Translated name:	Needle-and-Thread Bunch Herbaceous Alliance
Unique identifier:	A.1270
Classification approach:	International Vegetation Classification (IVC)



Figure 16. Plot CHCU – 149. *Hesperostipa comata* Bunch Herbaceous Alliance.

ASSOCIATION: *Hesperostipa comata* - *Achnatherum hymenoides* Herbaceous Vegetation

Translated name:	Needle-and-Thread - Indian Ricegrass Herbaceous Vegetation
Common name:	Needle-and-Thread - Indian Ricegrass Mixedgrass Prairie
Unique identifier:	CEGL001703
Classification approach:	International Vegetation Classification (IVC)

SUMMARY:

This grassland association has been described from western Colorado and south-central Wyoming. Stands develop on benches, plateaus and ridges ranging in elevation from 1,550 to 2,560 m (5,085-8,400 ft.). The stands recorded in northwestern Colorado resulted from burning sagebrush shrublands on sandy soils. Slopes are gentle to moderately steep and may be oriented to any aspect. Soils tend to be well-drained, deep and sandy, although they may be derived from a variety of sources. The unvegetated ground surface is mostly covered by litter and bare ground. This grassland occurs in small to medium-sized patches, often in sagebrush shrublands that have burned. Total vegetation cover often does not exceed 40% and may be as low as 20%. *Hesperostipa comata* and *Achnatherum hymenoides* codominate the vegetation, and *Pascopyrum smithii* and *Elymus elymoides* are common secondary species. Forbs have moderate diversity but are inconsistent among sites; common species include *Phlox hoodii* (spiny phlox),

Eriogonum flavum (alpine golden buckwheat), and *Sphaeralcea coccinea*. Scattered shrubs are often present, including *Artemisia tridentata* ssp. *wyomingensis*, *Krascheninnikovia lanata* (winterfat), *Gutierrezia sarothrae* (broom snakeweed), and *Ericameria nauseosa*. Other species sometimes present with low cover include *Cerastium arvense* (field chickweed), *Carex* spp., *Symphyotrichum laeve* (= *Aster laevis*) (smooth blue aster), *Achillea millefolium* (common yarrow), *Equisetum laevigatum* (smooth horsetail), *Iva axillaris* (povertyweed), *Taraxacum officinale* (common dandelion), *Poa palustris* (fowl bluegrass), and *Penstemon confertus* (yellow penstemon).

CLASSIFICATION CONFIDENCE: 2 - Moderate

CLASSIFICATION COMMENTS:

This grassland needs to be rechecked against the *Oryzopsis hymenoides* - *Stipa comata* (Indian ricegrass - needle and thread) montane grassland in Baker (1984), and a thorough comparison is needed between the information on this association and the descriptions of other grassland types in the region. Sparse stands or those with significant *Bouteloua gracilis* may be difficult to separate from *Artemisia frigida* - (*Bouteloua gracilis*, *Achnatherum hymenoides*, *Poa secunda*) - Lichens Rocky Mesa Dwarf-shrubland (CEGL002344). Codominance by *Achnatherum hymenoides* distinguishes this association from *Hesperostipa comata* Great Basin Herbaceous Vegetation (CEGL001705) that is widespread in the Great Basin and Colorado Plateau.

VEGETATION HIERARCHY

Formation Class	V - Herbaceous Vegetation
Formation Subclass	V.A - Perennial graminoid vegetation
Formation Group	V.A.5 - Temperate or subpolar grassland
Formation Subgroup	V.A.5.N - Natural/Semi-natural temperate or subpolar grassland
Formation Name	V.A.5.N.d - Medium-tall bunch temperate or subpolar grassland
Alliance Name	<i>Hesperostipa comata</i> Bunch Herbaceous Alliance

ECOLOGICAL SYSTEMS PLACEMENT:

Ecological system ID	Ecological system name
CES303.817	Western Great Plains Foothill and Piedmont Grassland
CES304.787	Inter-Mountain Basins Semi-Desert Grassland

GLOBAL STATUS: G2? (30Nov1998)

ROUNDED GLOBAL STATUS: G2 - Imperiled

UNITED STATES DISTRIBUTION: CO, UT, WY

GLOBAL DISTRIBUTION: United States

GLOBAL RANGE:

This type has been described from western Colorado and the Great Divide Basin of south-central Wyoming. Other basins in south-central and southwestern Wyoming are similar in climate and geology, and this association may well extend over a wide area of the two states.

DYNAMICS:

The stands recorded in northwestern Colorado resulted from burning sagebrush shrublands on sandy soils.

LOCAL DESCRIPTION:

This grass association formed patches within the low shrubland on the upper, southern, end of Chacra Mesa. Elevations were 2,035 m (6,624 ft) and 2,082 m (6,777 ft) on Cliffhouse sandstone. The association was dominated by grasses *Hesperostipa comata*, *Achnatherum hymenoides*, and *Bouteloua gracilis*. Scattered shrubs included *Krascheninnikovia lanata* and *Gutierrezia sarothrae*. Forbs included *Opuntia polyacantha* (plains pricklypear),

Stephanomeria pauciflora (brownplume wirelettuce), *Cryptantha micrantha*, and *Phacelia crenulata* (cleftleaf wildheliotrope.)

PLOT NUMBERS: 164, 149

ALLIANCE: *Pleuraphis jamesii* Herbaceous Alliance (fig. 17)

Translated name: James' Galleta Herbaceous Alliance
 Unique identifier: A.1287
 Classification approach: International Vegetation Classification (IVC)



Figure 17. Plot CHCU – 0123. *Pleuraphis jamesii* Herbaceous Alliance

ASSOCIATION: *Pleuraphis jamesii* - *Sporobolus airoides* Herbaceous Vegetation (fig. 18)

Translated name: James' Galleta - Alkali Sacaton Herbaceous Vegetation
 Unique identifier: CEGLO01778
 Classification approach: International Vegetation Classification (IVC)

SUMMARY:

This once-extensive grassland of the northern Chihuahuan Desert, Colorado Plateau and Great Basin has been described in New Mexico from White Sands Missile Range and the upper Rio Puerco watershed, as well as in north-central Arizona and southeastern Utah. It has, however, experienced significant declines throughout its range. It primarily occurs in swales within open valley bottoms and alluvial flats, although sandsheets and dunes also can support the association. Sites are on level to gentle slopes (<15%) at elevations between 1,300-2,075 m (4,260-6,800 ft.). Soils are generally deep, with surface textures ranging from loamy sands, fine loams to silty clay loams and clays, derived from substrates that include lava flows, cinders, eolian sands, alluvium and relict Pleistocene river cobbles. The vegetation is characterized by a sparse to moderately dense perennial herbaceous layer that is dominated by *Pleuraphis jamesii* (= *Hilaria jamesii*) with *Sporobolus airoides* as a subdominant. Total vegetation cover in grazed sites generally does not exceed 20% but may be as high as 50% in protected areas. Occasionally, *Sporobolus airoides* may be codominant or dominant over *Pleuraphis jamesii*. This association usually has a sparse but diverse shrub layer that may include scattered *Atriplex canescens*, *Atriplex confertifolia*, *Atriplex obovata*, *Ephedra torreyana* (Torrey's jointfir), *Ericameria nauseosa*, *Gutierrezia sarothrae*, *Krascheninnikovia lanata*, *Opuntia imbricate* (tree cholla), *Opuntia macrorhiza* (twistspine pricklypear), *Opuntia phaeacantha* (tulip pricklypear), *Sarcobatus vermiculatus* (greasewood), and *Yucca angustissima* (narrowleaf *Yucca*). The key graminoid species dominate the herbaceous layer and account for more than 80% of the total plant cover. Associated herbaceous species, such as *Achnatherum hymenoides*, *Bouteloua gracilis*, *Muhlenbergia porteri* (bush muhly), *Muhlenbergia pungens* (sandhill muhly),

Muhlenbergia torreyi (ring muhly), *Pascopyrum smithii*, *Scleropogon brevifolius* (burrograss), *Sphaeralcea coccinea*, and *Sporobolus cryptandrus*, may be present with low cover (Francis 1986, Muldavin et al. 2000b). Biological soil crusts may be extensive in undisturbed examples of this association.



Figure 18. Plot CHCU AA-98_North. *Pleuraphis jamesii* – *Sporobolus airoides* Herbaceous Vegetation

CLASSIFICATION CONFIDENCE: 2 - Moderate

CLASSIFICATION COMMENTS:

In the classification of the plant communities of the upper Rio Puerco watershed, Francis (1986) described two plant communities codominated by *Pleuraphis jamesii* - *Sporobolus airoides* that were separated by the relative dominance of the key species. Both plant communities were combined into this association.

VEGETATION HIERARCHY:

Formation Class	V - Herbaceous Vegetation
Formation Subclass	V.A - Perennial graminoid vegetation
Formation Group	V.A.5 - Temperate or subpolar grassland
Formation Subgroup	V.A.5.N - Natural/Semi-natural temperate or subpolar grassland
Formation Name	V.A.5.N.e - Short sod temperate or subpolar grassland
Alliance Name	<i>Pleuraphis jamesii</i> Herbaceous Alliance

ECOLOGICAL SYSTEMS PLACEMENT:

Ecological system ID	Ecological system name
CES302.735	Apacherian-Chihuahuan Semi-Desert Grassland and Steppe

GLOBAL STATUS: G2G3 (14Nov2005)

ROUNDED GLOBAL STATUS: G2 - Imperiled.

This once-extensive grassland of the Great Basin and Chihuahuan Desert ecoregions has been described in New Mexico from the Upper Rio Puerco watershed and White Sands Missile Range, as well as isolated areas in north-central Arizona and southeastern Utah. It has experienced significant declines throughout its range. Remaining examples that have not been negatively impacted by grazing and/or invaded by shrubs are rare. However, this grassland is probably more widespread than is documented and hence the rank of G2G3.

STATE STATUS: S? (Jan2008)

UNITED STATES DISTRIBUTION: AZ, CO, NM, UT

GLOBAL DISTRIBUTION: United States

GLOBAL RANGE:

This once-extensive grassland of the northern Chihuahuan Desert, Colorado Plateau and Great Basin is reported in New Mexico from White Sands Missile Range and the upper Rio Puerco watershed. More recently, it has been documented in north-central Arizona and southeastern Utah. It has experienced significant declines throughout its range.

DYNAMICS:

Many stands are on sandy, alkaline bottomlands that could easily support *Atriplex* spp. or *Sarcobatus vermiculatus* shrublands. Soil texture, moisture-holding capacity and depth to water table may determine which of these communities occurs in a valley bottom.

LOCAL DESCRIPTION:

This association was dominated by grasses *Sporobolus airoides*, *Pleuraphis jamesii*, and *Bouteloua gracilis*. It may also have supported scattered, low density *Atriplex canescens*, *Atriplex confertifolia* (shadscale saltbush), and other shrubs. The association was found in open mesa tops and canyon bottoms on several different substrates including Menefee and Lewis Shales and occasionally Cliffhouse sandstone. Forbs included *Mentzelia albicaulis* (whitestem blazingstar), *Hackelia floribunda* (manyflower stickseed), *Asclepias macrotis* (longhood milkweed), *Corydalis aureus* (golden smoke), *Eriogonum compositum* syn. *E. umbellatum* (arrowleaf buckwheat), *Gilia acerosum* syn. *G. rigidula* (bluebowls), and *Sphaeralcea parvifolia* (smallflower globemallow). All but one site was currently grazed or afforded short term protection. This association often included weedy species, especially if the area was currently grazed, with abundant *Lappula redowski*, *Bassia scoparia* and *Salsola kali*.

PLOT NUMBERS: 123, 874, 163, 31, 76

3.3.2 Shrub herbaceous vegetation

ALLIANCE: *Sporobolus airoides* - (*Pleuraphis jamesii*) Shrub Herbaceous Alliance (fig. 19)

Translated name:	Alkali Sacaton - (James' Galleta) Shrub Herbaceous Alliance
Unique identifier:	A.1523
Classification approach:	International Vegetation Classification (IVC)



Figure 19. Plot CHCU – 0176. *Sporobolus airoides* - (*Pleuraphis jamesii*) Shrub Herbaceous Alliance

ASSOCIATION: *Atriplex obovata* / *Sporobolus airoides* - *Pleuraphis jamesii* Shrub Herbaceous Vegetation

Translated name:	New Mexico Saltbush / Alkali Sacaton - James' Galleta Shrub Herbaceous Vegetation
Unique identifier:	CEGL001775
Classification approach:	International Vegetation Classification (IVC)
Classification confidence:	3 - Weak

VEGETATION HIERARCHY:

Formation Class	V - Herbaceous Vegetation
Formation Subclass	V.A - Perennial graminoid vegetation
Formation Group	V.A.5 - Temperate or subpolar grassland
Formation Subgroup	V.A.5.N - Natural/Semi-natural temperate or subpolar grassland
Formation Name	V.A.7.N.e - Medium-tall temperate or subpolar grassland with a sparse needle-leaved or microphyllous evergreen shrub layer
Alliance Name	<i>Sporobolus airoides</i> - (<i>Pleuraphis jamesii</i>) Shrub Herbaceous Alliance

ECOLOGICAL SYSTEM(S):

Ecological system ID	Ecological system name
CES304.784	Inter-Mountain Basins Mixed Salt Desert Scrub
CES304.787	Inter-Mountain Basins Semi-Desert Grassland
CES304.788	Inter-Mountain Basins Semi-Desert Shrub-Steppe

GLOBAL STATUS: GU (23Feb1994)

ROUNDED GLOBAL STATUS: GU - Unrankable

STATE STATUS: SU (20Jan2008)

LOCAL DESCRIPTION:

This shrubland association was confined to Menefee Shales near Kin Klizhen and on lower slopes facing south on South Mesa. Elevations range from 1,837-1,952 m (6,027 – 6,404 ft.). The association was dominated by *Atriplex obovata* (mound saltbush), and included *Artemisia nova* (black sagebrush) and *Ephedra torreyana* (Torrey's jointfir). Grasses included *Elymus elymoides* (squirreltail), *Hesperostipa comata*, *Achnatherum hymenoides*, *Pleuraphis jamesii* and *Sporobolus airoides*. Forbs included *Cryptantha micrantha* and *Townsendia incana* (hoary Townsend daisy). Biotic crusts were well-developed, often with black crust (nitrogen-fixing) components.

PLOT NUMBERS: 79, 89, 125, 173, 175, 176, 177, 178, 182, 940

ASSOCIATION: *Gutierrezia sarothrae* / *Sporobolus airoides* - *Pleuraphis jamesii* Shrub Herbaceous Vegetation

Translated name:	Broom Snakeweed / Alkali Sacaton - James' Galleta Shrub Herbaceous Vegetation
Common name:	Kindlingweed / Alkali Sacaton - James' Galleta
Unique identifier:	CEGL001776
Classification approach:	International Vegetation Classification (IVC)

SUMMARY:

This Colorado Plateau desert grassland has been documented from the upper Rio Puerco watershed in northwestern New Mexico and the Painted Desert of northern Arizona on alluvial flats and mesas. Sites are level to gently sloping, and substrates are variable. Stands typically have been disturbed by improper grazing of livestock, frequent sheet flow, or wind. The vegetation is characterized by an open (10-25% cover) woody layer dominated by *Gutierrezia sarothrae* with a moderately dense perennial graminoid layer typically codominated by *Pleuraphis jamesii*. (= *Hilaria jamesii*) and *Sporobolus airoides*, although either may dominate or *Sporobolus airoides* may be absent. The herbaceous layer has greater cover than the shrub layer that may include other scattered shrubs and dwarfshrubs such as *Artemisia tridentata*, *Atriplex canescens*, *Ephedra viridis* (Cutler's jointfir), *Eriogonum corymbosum* (crispleaf buckwheat), *Ericameria nauseosa*, *Fallugia paradoxa*, *Isocoma drummondii* (Drummond's goldenbush), *Opuntia* spp., or *Juniperus monosperma*. Associated herbaceous species such as *Achnatherum hymenoides*, *Aristida purpurea*, *Bouteloua* spp., *Hesperostipa comata*, *Muhlenbergia porteri*, *Sphaeralcea coccinea*, and *Sporobolus cryptandrus* may be present with low cover (Francis 1986). Diagnostic of this *Pleuraphis jamesii*- and *Sporobolus airoides*-codominated shrub steppe association is the dominance of *Gutierrezia sarothrae* in the open short shrub layer (10-25% cover).

CLASSIFICATION CONFIDENCE: 3 - Weak

CLASSIFICATION COMMENTS:

Stands dominated by *Sporobolus airoides* are included in this association and alliance. There is no *Sporobolus airoides* Shrub Herbaceous Alliance in the USNVC.

VEGETATION HIERARCHY:

Formation Class	V - Herbaceous Vegetation
Formation Subclass	V.A - Perennial graminoid vegetation
Formation Group	V.A.5 - Temperate or subpolar grassland
Formation Subgroup	V.A.5.N - Natural/Semi-natural temperate or subpolar grassland
Formation Name	V.A.7.N.e - Medium-tall temperate or subpolar grassland with a sparse needle-leaved or microphyllous evergreen shrub layer
Alliance Name	<i>Sporobolus airoides</i> - (<i>Pleuraphis jamesii</i>) Shrub Herbaceous Alliance

ECOLOGICAL SYSTEMS PLACEMENT:

Ecological system ID	Ecological system name
CES304.788	Inter-Mountain Basins Semi-Desert Shrub-Steppe

GLOBAL STATUS: GU (23Feb1994)

ROUNDED GLOBAL STATUS: GU - Unrankable

STATE STATUS: S? (20JAN2008)

UNITED STATES DISTRIBUTION: AZ, NM

GLOBAL DISTRIBUTION: United States

GLOBAL RANGE:

This shrub steppe association occurs in the Colorado Plateau from the upper Rio Puerco watershed in north-western New Mexico to north-central Arizona.

LOCAL DESCRIPTION:

This association was a mix of low densities of various shrubs including *Atriplex canescens*, *Tetradymia canescens*, *Gutierrezia sarothrae*, *Artemisia nova* and abundant grasses including *Pleuraphis jamesii*, *Achnatherum hymenoides*, *Agropyron smithii* (western wheatgrass), *Muhlenbergia pungens* (sandhill muhly), and *Bouteloua gracilis*. Forbs include *Phacelia crenulata* (clefthead wildheliotrope), *Mirabilis multiflora* (Colorado four o'clock), several *Cryptantha* species, *Descurainia paradise* syn. *D. pinnata* (paradise tansymustard), *Oligosporus dracunculus* (tarragon) and *Erysimum capitatum* (sanddune wallflower). Most of the plots occurred on Cliffhouse sandstone, but one occurred on Menefee shale and one on Pictured Cliff sandstone. Others occurred on Aeolian sand/gravelly sand. The topography was defined as high or low level with low slopes.

PLOT NUMBERS: 329, 1017, 447, 196, 181, 162

3.3.3 Shrubland

ALLIANCE: *Artemisia nova* Shrubland Alliance (fig. 20)

Translated name: Black Sagebrush Shrubland Alliance

Unique identifier: A.1105



Figure 20. Plot CHCU-0097. *Artemisia nova* Shrubland Alliance

ASSOCIATION: *Artemisia nova* - *Atriplex canescens* Shrubland

Translated name: Black Sagebrush – Fourwing saltbush Shrubland

Unique identifier: CEGLO0XXX (Provisional)

Classification approach: International Vegetation Classification (IVC)

SUMMARY:

Associations within this alliance occur at intermediate elevations (1,400-2,500 m) in the Intermountain and Rocky Mountain West, a region of semi-arid, continental climate regime. Soils are typically young, shallow, coarse-textured, and often derived from calcareous parent materials. *Artemisia nova* associations occur on well-drained slopes and ridges and often grow with other *Artemisia* associations on deeper soils. In the Columbia River Basin, the vegetation in this alliance occupies the driest habitats of all the *Artemisia*-dominated alliances. This alliance is characterized by the dominance of the dwarf-shrub *Artemisia nova*, which must contribute at least 40% of the total shrub cover in any stand, and by cover of perennial graminoids that is typically less than 20%. Associated shrub species that occur in stands of this alliance include *Chrysothamnus viscidiflorus*, *Atriplex confertifolia*, *Artemisia tridentata*, *Artemisia arbuscula* (little sagebrush), *Artemisia cana*, *Symphoricarpos oreophilus* (mountain snowberry), *Grayia spinosa* (spiny hopsage), *Purshia tridentata*, and *Gutierrezia sarothrae*. The ground layer is dominated by perennial bunch grasses which may exceed the height of the shrubs but typically have <20% total cover. Recurrent species include *Pseudoroegneria spicata* (bluebunch wheatgrass), *Achnatherum hymenoides* (= *Oryzopsis hymenoides*), *Achnatherum speciosum* (= *Stipa speciosa*) (desert needlegrass), *Achnatherum thurberianum* (= *Stipa thurberiana*) (Thurber's needlegrass), *Hesperostipa comata* (= *Stipa comata*), *Elymus elymoides*, *Poa secunda*, and *Koeleria macrantha* (prairie Junegrass). In southern stands, *Bouteloua gracilis* and *Pleuraphis jamesii* (= *Hilaria jamesii*) may also be important. Common forbs include *Balsamorhiza sagittata* (arrowleaf balsamroot), *Senecio integerrimus* (lambstongue ragwort), *Packera multilobata* (= *Senecio multilobatus*) (lobeleaf groundsel), *Stenotus armerioides* (thrift mock goldenweed), *Heterotheca villosa* (hairy false goldenaster), *Phlox hoodii*, *Sphaeralcea coccinea*, and *Castilleja angustifolia* (northwestern Indian paintbrush). At the edges of intermountain basins, this alliance is usually contiguous with *Atriplex confertifolia* shrublands.

VEGETATION HIERARCHY

Formation Class	III - Shrubland
Formation Subclass	III.A - Evergreen shrubland
Formation Group	III.A.4 - Microphyllous evergreen shrubland
Formation Subgroup	III.A.4.N - Natural/Semi-natural microphyllous evergreen shrubland
Formation Name	III.A.4.N.a - Lowland microphyllous evergreen shrubland
Alliance Name	<i>Artemisia nova</i> Shrubland Alliance

UNITED STATES DISTRIBUTION: CA, CO, ID, MT, NM, NV, OR, UT, WY

GLOBAL DISTRIBUTION: United States

GLOBAL RANGE:

Associations in this alliance occur in the mountains of the Mojave Desert, throughout the Great Basin, and east into western and central Wyoming, Montana, Colorado, Utah, and northwestern New Mexico. It also occurs in the upper Columbia River Basin of southeastern Idaho.

VEGETATION STRUCTURE:

This shrubland alliance is characterized by sparse to moderate (20-60%) cover of a low-stature, microphyllous evergreen shrub, and a sparse to well-developed graminoid layer. The graminoids often exceed the shrubs in height, and ungrazed stands may have the appearance of perennial grasslands (Baker and Kennedy 1985). The shrubs may be pruned by livestock and native ungulate browsing into low, spreading cushion-like shrubs. Prostrate and, occasionally, upright forbs are present, but with very low cover.

ENVIRONMENTAL SUMMARY

Associations within this alliance occur at intermediate elevations (1,400-2,500 m) in the Intermountain and Rocky Mountain West. The climate is semi-arid with 20-30 cm of annual precipitation. The temperature regime is continental, with cold winters, warm summers, a large diurnal temperature range, and a short frost-free season. Soils are typically young, shallow, coarse-textured, and often derived from calcareous parent materials. *Artemisia nova* associations occur on well-drained slopes and ridges and often grow with other *Artemisia* associations on deeper soils. In the Columbia River Basin, the vegetation in this alliance occupies the driest habitats of all the *Artemisia*-dominated alliances. At the edges of intermountain basins, this alliance is usually contiguous with *Atriplex confertifolia* shrublands (Hironaka 1978).

DYNAMICS:

This shrubland alliance is associated with shallow, rocky soils which experience extreme drought in summer. The plants are low and widely spaced, which tends to decrease the risk of fire (Chappell et al. 1997). Barbour and Major (1977) report that *Artemisia nova* is utilized by livestock to a much greater degree than other species of *Artemisia*, resulting in low, pruned plants. *Artemisia nova* dwarf-shrublands grow in more xeric sites than other *Artemisia* shrublands. Blackburn and Tueller (1970) noted rapid invasion of these communities by *Juniperus osteosperma* and *Pinus monophylla* in Nevada, citing overgrazing coupled with fire suppression, and possibly climate change as causative variables.

LOCAL DESCRIPTION:

This common low shrub and forb association was usually associated with benches of Cliffhouse Sandstone or Menefee shale. *Artemisia nova* and *Atriplex canescens* dominated. Other shrubs included *Ephedra torreyana*, *Rhus trilobata* (skunkbush), *Cercocarpus montanus* (mountain mahogany), *Gutierrezia sarothrae*, *Chrysothamnus Greenei* (Greene's rabbitbrush), and *Brickellia microphylla* (littleleaf brickellbush). Grasses included *Pleuraphis jamesii*, *Achnatherum hymenoides* (Indian ricegrass) and occasionally *Poa fendleriana* (muttongrass) and *Elymus elymoides* (squirreltail). Occasionally, *Juniperus monosperma* was scattered in this association.

PLOT NUMBERS: 4, 16, 87, 90, 97, 152, 160, 372, 449, 677, 1022, 1020, 1021, 1019

ALLIANCE: *Artemisia tridentata* (ssp. *tridentata*, ssp. *xericensis*) Shrubland Alliance (fig. 21)

Translated name: (Basin Big Sagebrush, Foothill Big Sagebrush) Shrubland Alliance
 Unique identifier: A.830
 Classification approach: International Vegetation Classification (IVC)



Figure 21. Plot CHCU-1031. *Artemisia tridentata* (ssp. *tridentata*, ssp. *xericensis*) Shrubland Alliance

ASSOCIATION: *Artemisia tridentata* ssp. *tridentata* / *Pleuraphis jamesii* Shrubland

Translated name: Basin Big Sagebrush / James' Galleta Shrubland
 Unique identifier: CEGLO01015
 Classification approach: International Vegetation Classification (IVC)

SUMMARY:

This association has been described from the Colorado Plateau in southeastern Utah and may occur in parts of Colorado, New Mexico and Arizona. Most stands occur on valley floors, alluvial flats and on the terraces of intermittent drainages. A few stands have been reported from mesas. Sites are located between 1,866 and 2,200 m (6,122-7,220 ft.) elevation on level to gentle slopes (<5%). Up to 80% of the unvegetated surface is covered by bare ground. Soils are generally deep, calcareous and alkaline sandy loams or clay loams derived from alluvium. This association occupies dry sites on valley floors in the Colorado Plateau. Total vegetation cover is variable; some disturbed stands may appear to be sparsely vegetated with total vegetation cover less than 10%. Stands are characterized by an open shrub canopy (5-35% cover) dominated by *Artemisia tridentata* ssp. *tridentata*. Associated shrubs may include *Chrysothamnus viscidiflorus*, *Ephedra viridis*, *Ericameria nauseosa*, *Gutierrezia sarothrae*, *Opuntia polyacantha*, *Atriplex* spp., and *Krascheninnikovia lanata*. Total woody canopy ranges from 5-35% cover. The sparse herbaceous layer (5-15% cover) is dominated by graminoids such as *Pleuraphis jamesii* (= *Hilaria jamesii*), *Achnatherum hymenoides*, *Aristida purpurea*, *Bouteloua gracilis*, *Elymus elymoides*, and *Sporobolus cryptandrus*. Forbs are sparse and variable; species recorded from plots include *Castilleja linariifolia* (Wyoming Indian paintbrush) and *Psoralidium lanceolatum* (lemon scurfpea).

CLASSIFICATION CONFIDENCE: 2 - Moderate

VEGETATION HIERARCHY:

Formation Class III - Shrubland
 Formation Subclass III.A - Evergreen shrubland
 Formation Group III.A.4 - Microphyllous evergreen shrubland
 Formation Subgroup III.A.4.N - Natural/Semi-natural microphyllous evergreen shrubland

Formation Name	III.A.4.N.a - Lowland microphyllous evergreen shrubland
Alliance Name	<i>Artemisia tridentata</i> (ssp. <i>tridentata</i> , ssp. <i>xericensis</i>) Shrubland Alliance

ECOLOGICAL SYSTEMS PLACEMENT:

Ecological system ID	Ecological system name
CES304.777	Inter-Mountain Basins Big Sagebrush Shrubland
CES304.778	Inter-Mountain Basins Big Sagebrush Steppe

GLOBAL STATUS: G2G4 (09Nov2005)

ROUNDED GLOBAL STATUS: G3 - Vulnerable

This association is known from southeastern Utah on the Colorado Plateau but likely occurs in adjacent Colorado, New Mexico and Arizona. Stands are relatively small and grow in deep, non-saline soils on bottomland, alluvial flats, and possibly mesatops. The lowland sites are easily accessible, and most have been grazed for decades and, in some cases, centuries by livestock. Overgrazing reduces the graminoid layer and damages the *Artemisia tridentata* ssp. *tridentata* shrubs. A number of stands are located in Capitol Reef National Park, although they have been subject to grazing. This association may have a relatively large range, but good-condition stands will be small and difficult to find. Until more information is available from field surveys, the rank should stay G2G4.

STATE STATUS: S5 (20Jan2008)

UNITED STATES DISTRIBUTION: AZ? CO? NM? UT

GLOBAL DISTRIBUTION: United States

GLOBAL RANGE:

This association is found on the Colorado Plateau in southeastern Utah and likely occurs in adjacent Colorado, New Mexico and Arizona.

DYNAMICS:

This association requires an unusual combination of fine-textured bottomland soils and a water table that is high enough to support *Artemisia tridentata* ssp. *tridentata*, but that are also dry enough and have neutral enough soil pH to favor *Pleuraphis jamesii*. Although most stands appear to be stable, if they burn, they will convert to mixed grassland. A few stands are subject to invasion by *Pinus edulis* and *Juniperus osteosperma*; in the absence of disturbance, they will eventually become woodlands.

LOCAL DESCRIPTION:

This somewhat disparate association was represented by two field sampling points. One area was east of Gallo Wash on sandy soil, moderately sloping pockets adjacent to exposed slickrock sandstone; *Juniperus monosperma* was nearby to the south and juniper seedlings were found in the plot. This area is distinguished from adjacent low shrubland vegetation by dominance of *Artemisia tridentata* (big sagebrush). It is floristically rich, and other co-dominant shrubs include *Ephedra torreyana*, *Artemisia nova*, *Rhus trilobata*, and *Gutierrezia sarothrae*. Abundant understory forbs include *Viguiera multiflora* (showy goldeneye), *Penstemon angustifolius* (broadbeard beard-tongue), and *Comandra umbellata* (bastard toadflax). Grasses included *Achnatherum hymenoides*, *Bouteloua gracilis*, *Hesperostipa comata*, and *Pleuraphis jamesii*. However, small (less than the minimum mapping unit) stands of *Artemisia tridentata* also occur near seep vegetation, and in small gulleys created by ephemeral runoff such as from the southern end of Chacra Mesa. The second sampled location for this association was at Pueblo Pintado, where constant disturbance from visitors and grazing occurs. *Lycium pallidum* was abundant and grasses included *Bouteloua gracilis*, *Pleuraphis jamesii*, and *Elymus elymoides*.

PLOT NUMBERS: 1031

ALLIANCE: *Atriplex canescens* Shrubland Alliance

Translated name:	Fourwing Saltbush Shrubland Alliance
Unique identifier:	A.869
Classification approach:	International Vegetation Classification (IVC)

ASSOCIATION: *Atriplex canescens* Shrubland (fig. 22)

Translated name:	Fourwing Saltbush Shrubland
Common name:	Fourwing Saltbush Shrubland
Unique identifier:	CEGL001281
Classification approach:	International Vegetation Classification (IVC)



Figure 22. Plot CHCU AA-27-West. *Atriplex canescens* Shrubland

SUMMARY:

This shrubland association is known from the Great Basin north into the southern Columbia Basin and east into Wyoming and the Colorado Plateau. It is common at middle elevations on alluvial fans and toeslopes in deep, sandy soils but will occur at lower elevations along alluvial benches where soils are often finer-textured and possibly saline/alkaline. Parent materials are variable. The vegetation is characterized by a sparse to moderately dense short-shrub layer (10–35% cover) dominated or codominated by *Atriplex canescens*, typically with a variable and often sparse herbaceous layer. Notable codominants in the shrub layer include *Chrysothamnus viscidiflorus*, *Coleogyne ramosissima*, *Ephedra nevadensis* (Nevada jointfir), *Eriogonum nummular* (= *Eriogonum kearneyi*) (money buckwheat), *Grayia spinosa*, *Gutierrezia sarothrae*, *Lycium pallidum*, or *Psoralea* spp. (dalea). *Ephedra viridis* may be present but is not a codominant. The herbaceous layer includes low cover of species such as *Achnatherum hyemoides*, *Aristida purpurea*, *Elymus elymoides*, *Pleuraphis jamesii*, and *Sporobolus cryptandrus*. Introduced species, especially *Bromus tectorum*, *Bromus diandrus* (ripgut brome), and *Salsola kali*, are common on disturbed sites and can create an herbaceous layer much more dense than on undisturbed sites. Winter annual forb cover is variable depending on annual precipitation.

CLASSIFICATION CONFIDENCE: 2 - Moderate

VEGETATION HIERARCHY

Formation Class	III - Shrubland
Formation Subclass	III.A - Evergreen shrubland
Formation Group	III.A.4 - Microphyllous evergreen shrubland

Formation Subgroup	III.A.4.N - Natural/Semi-natural microphyllous evergreen shrubland
Formation Name	III.A.5.N.b - Facultatively deciduous extremely xeromorphic subdesert shrubland
Alliance Name	<i>Atriplex canescens</i> Shrubland Alliance

ECOLOGICAL SYSTEMS PLACEMENT

Ecological system ID	Ecological system name
CES302.749	Sonora-Mojave Mixed Salt Desert Scrub
CES304.784	Inter-Mountain Basins Mixed Salt Desert Scrub

GLOBAL STATUS: G5 (23Feb1994)

ROUNDED GLOBAL STATUS: G5 - Secure

STATE STATUS: S5 (20Jan2008)

ENVIRONMENTAL SUMMARY:

This shrubland association is found on bajadas, low stream terraces, valley floors and toeslopes. Sites are flat to gently sloping with any aspect. It is commonly found on deep, sandy soils at middle elevations (1,235-2,256 m; 4,050-7,400 ft.) but will occur at lower elevations (down to 610 m; 2,000 ft.) along alluvial benches where soils are often finer-textured and possibly saline/alkaline (Beatley 1976). The unvegetated surface is predominantly bare soil and/or sand. Larger rocks and organic material are rare. Parent materials include volcanic tuff, shale and sandstone. At lower elevations, it may occur as a mosaic with *Lycium pallidum* - *Grayia spinosa*- or *Atriplex confertifolia*-dominated shrublands.

LOCAL DESCRIPTION:

This shrubland association was dominated by a low density of *Atriplex canescens*. *Ephedra torreyana*, *Gutierrezia sarothrae*, and *Opuntia polyacantha* (plains pricklypear) were present. Grasses included *Pleuraphis jamesii*, *Bouteloua gracilis*, *Vulpia octoflora* (sixweeks fescue), *Achnatherum hymenoides*, *Hesperostipa comata*, *Sporobolus airoides*, and *Elymus elymoides*. Forbs were abundant and include *Cymopterus purpurascens* (widewing springparsley), *Plantago patagonica* (woolly plantain), *Rumex hymenosepalus* (canaigre dock), *Halogeton glomerulus*, *Mentzelia albicaulis* (whitestem blazingstar), *Sphaeralcea fendleri* (Fendler's globemallow), *S. parvifolia* (smallflower globemallow), *S. coccinea* (scarlet globemallow), *Artemisia frigida* (prairie sagewort), *Abronia fragrans* (fragrant white sand verbena), *Oenothera caespitosa* (tufted evening-primrose), *Cryptantha micrantha* (redroot cryptantha), and *Oenothera albicaulis* (whitest evening-primrose). This association was found on variable substrates, on Naja and Tsegi Alluviums, Cliffhouse Sandstone, and Lewis Shale. Many of the points were found in canyon bottoms.

PLOT NUMBERS: 359, 334, 45, 116, 161, 172, 27, 117, 190, 201, 1016, 1018, 191, 866, 713, 184

ASSOCIATION: *Atriplex canescens* - *Krascheninnikovia lanata* Shrubland (fig. 23)

Translated name:	Fourwing Saltbush - Winterfat Shrubland
Unique identifier:	CEGL001285
Classification approach:	International Vegetation Classification (IVC)

CLASSIFICATION CONFIDENCE: 2 - Moderate

VEGETATION HIERARCHY:

Formation Class	III - Shrubland
Formation Subclass	III.A - Evergreen shrubland
Formation Group	III.A.4 - Microphyllous evergreen shrubland
Formation Subgroup	III.A.4.N - Natural/Semi-natural microphyllous evergreen shrubland

Formation Name	III.A.5.N.b - Facultatively deciduous extremely xeromorphic subdesert shrubland
Alliance Name	<i>Atriplex canescens</i> Shrubland Alliance

ECOLOGICAL SYSTEMS PLACEMENT

Ecological system ID	Ecological system name
CES302.749	Sonora-Mojave Mixed Salt Desert Scrub
CES304.784	Inter-Mountain Basins Mixed Salt Desert Scrub



Figure 23. Plot CHCU AA 220-West. *Atriplex canescens* – *Krascheninnikovia lanata* Shrubland

GLOBAL STATUS: G5 (23Feb1994).

ROUNDED GLOBAL STATUS: G5 - Secure

UNITED STATES DISTRIBUTION: CA? NV

GLOBAL DISTRIBUTION: United States

LOCAL DESCRIPTION:

This tall shrubland differed from that previous described (CEGL001281) *Atriplex canescens* Shrubland) primarily because *Krascheninnikovia lanata* and *Atriplex canescens* are co-dominant. Other shrubs included *Ephedra torreyana*, *E. viridis* (mormon tea), and *Gutierrezia sarothrae* and *G. microphylla* and, occasionally *Atriplex confertifolia*. Grasses included *Achnatherum hymenoides*, *Bouteloua gracilis*, *Vulpia octoflora* and *Pleuraphis jamesii*. Numerous forbs included *Abronia fragrans*, *Descurainia obtusa* (blunt tansymustard), *Sphaeralcea coccinea*, and *Cryptantha micrantha*. *Echinocereus triglochidiatus* (kingcup cactus) was present. This association was widespread, found on alluvium, aeolian deposits, Cliffhouse Sandstone and Lewis shale substrates on 0-10 degree slopes and is particularly well developed north of Clys Canyon headwaters where grazing has been prevented for over 60 years.

PLOT NUMBERS: 9, 14, 15, 18, 61, 141, 154, 156, 165, 174, 180, 194, 841, 1025, 1030

ALLIANCE: *Atriplex confertifolia* Shrubland Alliance

Translated name:	Shadscale Shrubland Alliance
Unique identifier:	A.870
Classification approach:	International Vegetation Classification (IVC)

ASSOCIATION: *Atriplex confertifolia* / *Pleuraphis jamesii* Shrubland (fig. 24)

Translated name: Shadscale / James' Galleta Shrubland
 Unique identifier: CEGLO01304
 Classification approach: International Vegetation Classification (IVC)



Figure 24. Plot CHCU AA 117-North. *Atriplex confertifolia* / *Pleuraphis jamesii* Shrubland

SUMMARY:

This shrubland association is reported from the southwestern Great Plains, Colorado Plateau, Great Basin, and Mojave Desert mountains. It can be found on two distinct substrates: coarse-textured, non-saline soils derived from sandstone or gravel or deep, fine-textured, alkaline, often saline soils derived from shale. Stands with coarse-textured soils tend to be on slopes, while those with fine-textured soils tend to be on low, relatively flat positions in the landscape (valley bottoms, basins, etc.). The common trait of these different substrates is that they are very dry either because of low precipitation or because of high internal plant moisture stress from soil salinity. The unvegetated surface is composed largely of bare soil, gravel, and large or small rocks. This association is characterized by a sparse to open canopy (1-25% cover) of short shrubs dominated by *Atriplex confertifolia* with a sparse to moderate graminoid layer dominated by *Pleuraphis jamesii*. Associated shrubs include *Ericameria nauseosa*, *Ephedra torreyana*, *Chrysothamnus viscidiflorus*, *Krascheninnikovia lanata*, *Gutierrezia sarothrae*, *Artemisia bigelovii*, *Picrothamnus desertorum* (bud sagebrush), *Grayia spinosa*, *Suaeda moquinii* (= *Suaeda fruticosa*) (Mojave seablite), and *Opuntia polyacantha* depending on substrate, or *Amphipappus fremontii* (Fremont's chaffbush), *Ambrosia dumosa* (burrobush), and *Lycium pallidum* in the Mojave Desert. If other *Atriplex* species are present, they do not dominate the canopy. Other graminoids include *Achnatherum hymenoides*, *Sporobolus cryptandrus*, and *Elymus elymoides* on sandy sites and *Bouteloua gracilis* and *Sporobolus airoides* on fine-textured soil. Forbs generally have low cover and may include *Sphaeralcea grossulariifolia* (gooseberryleaf globemallow), *Eriogonum inflatum* (desert trumpet), and species of *Chaenactis* (pincushion), *Phacelia* (phacelia), and *Chenopodium* (goosefoot). Introduced species such as *Bromus tectorum* and *Salsola kali* are common on some sites.

NVC SUMMARY: None available

CLASSIFICATION CONFIDENCE: 2 - Moderate

CLASSIFICATION COMMENTS:

This widespread shrubland association is only defined by the codominance of *Atriplex confertifolia* and *Pleuraphis jamesii*. Stands are found in different regions (from southwestern Great Plains to Great Basin), in different environments (clay bottomlands, dunes, desert mountains) and with different associated species. This association will

likely need to be subdivided as more classification information becomes available.

VEGETATION HIERARCHY:

Formation Class	III - Shrubland
Formation Subclass	III.A - Evergreen shrubland
Formation Group	III.A.5 - Extremely xeromorphic evergreen shrubland
Formation Subgroup	III.A.5.N - Natural/Semi-natural extremely xeromorphic evergreen shrubland
Formation Name	III.A.5.N.b - Facultatively deciduous extremely xeromorphic subdesert shrubland
Alliance Name	<i>Atriplex confertifolia</i> Shrubland Alliance

ECOLOGICAL SYSTEMS PLACEMENT

Ecological system ID	Ecological system name
CES304.784	Inter-Mountain Basins Mixed Salt Desert Scrub

GLOBAL STATUS: G3G5 (23Feb1994)

ROUNDED GLOBAL STATUS: G4 - Apparently Secure

STATE STATUS: SNR (20Jan2008)

GLOBAL DISTRIBUTION: United States

GLOBAL RANGE:

This shrubland association is reported from the southwestern Great Plains, Colorado Plateau, Great Basin, and Mojave Desert mountains.

DYNAMICS:

Ecological processes vary with landscape type, but droughty conditions are important in shaping and maintaining this association. In wetter year, trees such as *Juniperus osteosperma* may invade

LOCAL DESCRIPTION:

This association is widespread at Chaco Canyon, found primarily on the highly eroded low slopes of Chacra Mesa on Menefee Shale, and West and South Mesas on both the Menefee Formation and Sheetwash Alluvium substrates. *Atriplex confertifolia* is the dominant low shrub, albeit with sparse cover. Often *Sarcobatus vermiculatus* is found in low density at the base of the slope on the transition between the slope and the lowland vegetation. Other shrubs include *Lycium pallidum*, *Krascheninnikovia lanata*, and *Atriplex canescens*. Forbs include *Artemisia frigida*, *Erysimum capitatum*, and *Townsendia incana*. Grasses include *Pleuraphis jamesii*, *Sporobolus airoides*, and *Bromus tectorum*.

PLOT NUMBERS: Data missing

ALLIANCE: *Ephedra torreyana* Sparsely Vegetated Alliance

Translated name:	Torrey's Joint-fir Sparsely Vegetated Alliance
Unique identifier:	A.2571
Classification approach:	International Vegetation Classification (IVC)

ASSOCIATION: *Ephedra torreyana* - (*Atriplex canescens*, *Atriplex confertifolia*) Sparse Vegetation

Translated name:	Torrey's Joint-fir - (Fourwing Saltbush, Shadscale) Sparse Vegetation
Unique identifier:	CEGL005801
Classification approach:	International Vegetation Classification (IVC)

NVC SUMMARY: None available

CLASSIFICATION CONFIDENCE: 3 - Weak

CLASSIFICATION COMMENTS:

It is located within sparse badland habitats with substrate varying from clay soils, riverine cobbles, basaltic cobbles, and sandstone bluffs.

VEGETATION HIERARCHY

Formation Class	VII - Sparse Vegetation
Formation Subclass	VII.C - Unconsolidated material sparse vegetation
Formation Group	VII.C.3 - Sparsely vegetated soil slopes
Formation Subgroup	VII.C.3.N - Natural/Semi-natural sparsely vegetated soil slopes
Formation Name	VII.C.3.N.b - Dry slopes
Alliance Name	<i>Ephedra torreyana</i> Sparsely Vegetated Alliance

ECOLOGICAL SYSTEMS PLACEMENT

Ecological system ID	Ecological system name
CES304.765	Colorado Plateau Mixed Bedrock Canyon and Tableland

GLOBAL STATUS: GNR (29Aug2002)

ROUNDED GLOBAL STATUS: GNR - Not Yet Ranked

STATE STATUS: S? (20Jan2008)

LOCAL DESCRIPTION:

This shrub dominated association was co-dominated by *Ephedra torreyana*, and less often *E. viridis*, *Artemisia nova*, and in all but three sites, *Atriplex confertifolia*. Other shrubs varied—*Krascheninnikovia lanata*, *Cercocarpus montanus* or *Chrysothamnus Greenei*. Grasses included *Sporobolus airoides*, *S. cryptandrus*, and *Achnatherum hymenoides* and the invasive *Bromus tectorum*. Forbs included *Artemisia frigida*, *A. filifolia*, *Mirabilis multiflora* (Colorado four o'clock), *Eriogonum leptophyllum* (slender buckwheat), *E. alatum* (winged buckwheat), *Gilia leptomeria* (desert pale gilia), *Cymopterus fendleri*, *Descurainia pinnata*, and *Cryptantha micrantha*. The habitats were generally high level mesas in the Penasco Blanco area on West Mesa, Chacra Mesa, and Pueblo Alto Mesa. One sample point occurred on the upper elevation of South Mesa. Elevations ranged from 1,890-2,010 m. It was found primarily on Cliffhouse Sandstone on 0-13 degree slopes.

PLOT NUMBERS: 2, 36, 37, 38, 51, 52, 60, 119, 148, 199, 1023

ALLIANCE: *Forestiera pubescens* Temporarily Flooded Shrubland Alliance

Translated name:	Stretchberry Temporarily Flooded Shrubland Alliance
Unique identifier:	A.969
Classification approach:	International Vegetation Classification (IVC)

ASSOCIATION: *Forestiera pubescens* Shrubland (fig. 25)

Translated name:	Stretchberry Shrubland
Common name:	Wild Privet Shrubland
Unique identifier:	CEGL001168
Classification approach:	International Vegetation Classification (IVC)

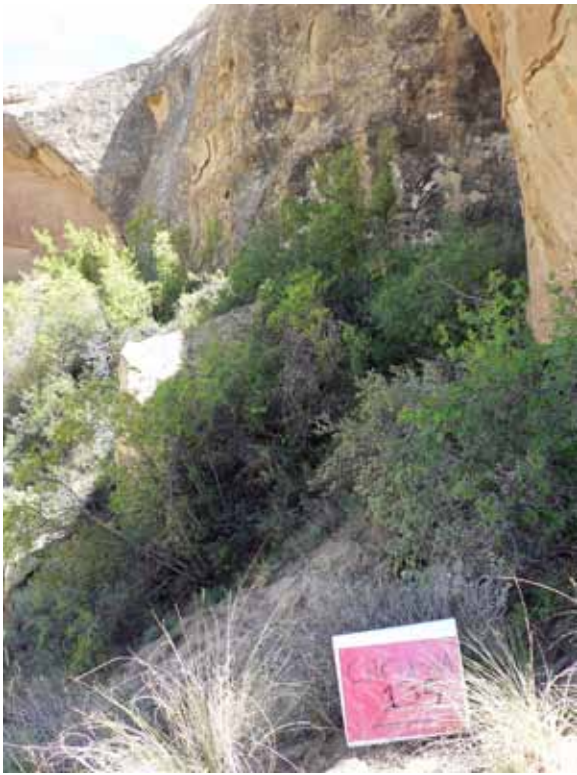


Figure 25. Plot CHCU AA 135. *Forestiera pubescens* Shrubland

SUMMARY::

This shrubland association, (now called Stretchberry Shrubland in NatureServe Explorer- <http://www.natureserve.org/explorer>) is reported from canyon bottoms, floodplains, sandy terraces along major rivers, and washes in southwestern Colorado, northeastern Arizona and southeastern Utah. Elevation ranges from 1340 to 1680 m (4400-5500 feet). Stands typically form a narrow, but continuous, band about 3 m above the channel on stream-banks and natural levees at the interface between the riparian zone and drier uplands. They occur on the outer edge of the active floodplain. Soils range from silty clays over clay loam to sandy loam derived from alluvium. This shrubland consists of a dense to open canopy of *Forestiera pubescens*, often with *Atriplex canescens*, *Ericameria nauseosa*, or *Rhus trilobata*, on the flat benches and floodplains adjacent to and above the river channel. There is often a mix of riparian and upland vegetation in these areas, with *Salix exigua* forming a dense band along the stream edge. This dense riparian shrubland can form a narrow, unfragmented, continuous cover that may alternate creekside to creekside, as part of the natural mosaic of the floodplain for one-tenth of a mile to several miles. *Phragmites australis*, a tall erect grass, or *Sporobolus airoides* often occur among the shrubs, with *Artemisia tridentata*, *Ericameria nauseosa* (= *Chrysothamnus nauseosus*), or pinyon-juniper dominating the adjacent upland vegetation. The dominance or codominance of *Forestiera pubescens* in the shrub layer characterizes this association.

CLASSIFICATION CONFIDENCE: 2 - Moderate

VEGETATION HIERARCHY:

Formation Class	III - Shrubland
Formation Subclass	III.B - Deciduous shrubland
Formation Group	III.B.2 - Cold-deciduous shrubland
Formation Subgroup	III.B.2.N - Natural/Semi-natural cold-deciduous shrubland
Formation Name	III.B.2.N.d - Temporarily flooded cold-deciduous shrubland
Alliance Name	<i>Forestiera pubescens</i> Temporarily Flooded Shrubland Alliance

ECOLOGICAL SYSTEMS PLACEMENT

Ecological system ID	Ecological system name
CES306.821	Rocky Mountain Lower Montane Riparian Woodland and Shrubland

GLOBAL STATUS: G1G2 (30Nov1998)

ROUNDED GLOBAL STATUS: G1 - Critically Imperiled

The *Forestiera pubescens* riparian shrubland has not been documented outside of a few locations in Colorado. It probably occurs in Utah, Arizona, and New Mexico, although not in any great abundance. Indications of its possible presence are inferred from (1) the Flora of Utah, which lists fourteen collections of *Forestiera pubescens* from sandy terraces along the Colorado and San Juan rivers, and smaller tributaries in Emery, Garfield, Grand, Kane, San Juan, and Wayne counties (Welsh et al. 1987), and (2) Arizona floras that list *Forestiera pubescens* as *Forestiera neomexicana* (a synonym), but do not record the number or location of the collections. Livestock grazing is limited in this plant association due to the dense shrub cover, and *Forestiera pubescens* is not very palatable to livestock.

STATE STATUS: S? (20Jan2008)

UNITED STATES DISTRIBUTION: AZ, CO, NM? UT?

GLOBAL DISTRIBUTION: United States

GLOBAL RANGE: This association is known from Colorado in the San Miguel/Dolores River Basin

WETLANDS: Yes.

LOCAL DESCRIPTION:

This dense, tall shrubland was supported by a seep in a north-facing aspect in Cliffhouse sandstone on Chacra Mesa at 2,040 m elevation, as well as numerous unsampled seeps throughout Chaco Canyon. *Forestiera pubescens* is the dominant tall shrub. Other shrubs included *Ribes cereum* (wax currant), *Atriplex canescens*, *Rhus trilobata* and *Cercocarpus montanus*. The grass layer was composed of *Poa fendleriana*, *Achnatherum hymenoides*, *Elymus elymoides*, and an occasional amount of the invasive *Bromus tectorum*. Forbs included *Artemisia ludoviciana* (white sagebrush), *A. frigida*, and *Petradoria pumila* (grassy rockgoldenrod). Dense stands of *Artemisia tridentata* and *Cercocarpus montanus* are often found adjacent to, or in runoff below, the *Forestiera pubescens* shrubland in transitional, relatively wet, soils. While only one point was sampled, this may be a fairly common seep association, especially on Chacra Mesa (a seep inventory is being accomplished by another Inventory and Monitoring study in the park).

PLOT NUMBERS: 168

ASSOCIATION: *Lycium pallidum* - (*Atriplex canescens* / *Tetradymia canescens*) Shrubland

Translated name:	Pale Desert-thorn – (Fourwing saltbush / Gray horsebrush) Shrubland
Common name:	Pale Desert-thorn – (Fourwing saltbush / Gray horsebrush) Shrubland
Unique identifier:	CEGL00xxxx (Provisional)
Classification approach:	Provisional and local

LOCAL DESCRIPTION:

This shrubland association was dominated by *Lycium pallidum* with *Atriplex canescens*, *Tetradymia canescens*, or *Ephedra viridis* also in the shrub layer. Grasses include *Pleuraphis jamesii*, *Achnatherum hymenoides*, and *Vulpia octoflora*. Forbs included *Sisymbrium altissimum* (tall tumblemustard), *Erysimum capitatum*, *Sphaeralcea fendleri*, *S. coccinea*, *Mentzelia albicaulis*, *Oenothera caespitosa* (tufted evening-primrose), *Mirabilis multiflora*, *Yucca harrianae* (Spanish bayonet), and *Eriogonum corymbosum* (crispleaf buckwheat). This association was found on Cliffhouse sandstone, Menefee shale and various alluvium substrates from flat to 33 degree slopes.

PLOT NUMBERS: 104, 157, 195, 545, 903

ALLIANCE: *Purshia (stansburiana, mexicana)* Shrubland Alliance

Translated name:	(Stansbury Cliffrose, Mexican Cliffrose) Shrubland Alliance
Unique identifier:	A.833
Classification approach:	International Vegetation Classification (IVC)

ASSOCIATION: *Purshia stansburiana* - *Ephedra torreyana* Shrubland (fig. 26)

Translated name:	Stansbury Cliffrose - Torrey's Joint-fir Shrubland
Common name:	Stansbury Cliffrose - Torrey's Joint-fir Shrubland
Unique identifier:	CEGL00XXX (Provisional)
Classification approach:	International Vegetation Classification (IVC)



Figure 26. Plot CHCU AA 22-South. *Purshia stansburiana* / *Ephedra torreyana* Shrubland

SUMMARY:

The vegetation in this alliance occurs at middle elevations (800-2,000 m) of the Intermountain West, usually in washes, on cliffs, or on steep, rocky terrain. Precipitation averages 20-45 cm annually. These communities occur on skeletal soils derived from granitic or sedimentary parent materials. In central Utah the alliance is associated with limestone (Price and Brotherson 1987). These shrublands are dominated by *Purshia mexicana*, an erect evergreen shrub that grows up to 8 m tall, or by *Purshia stansburiana*. Associated shrubs include *Ericameria nauseosa* (= *Chrysothamnus nauseosus*), *Coleogyne ramosissima*, *Artemisia tridentata*, and *Yucca baccata* (banana yucca). The herbaceous ground layer is typically sparse, but can be moderately dense in stands which have been invaded by non-native annual grasses. Typical native species include *Sporobolus cryptandrus*, *Poa secunda*, and *Pseudoroegneria spicata*. Adjacent vegetation is usually *Pinus* - *Juniperus* woodlands, *Quercus gambelii* shrublands, or *Artemisia tridentata* shrublands

CLASSIFICATION COMMENTS:

This alliance was originally called *Purshia mexicana* Shrubland. All the associations in the alliance for the western U.S. are based upon the old taxon of *Purshia mexicana* var. *stansburiana*, which is now treated as *Purshia stansburiana*. *Purshia mexicana* is considered by most taxonomists to occur in far southern Arizona and into Mexico, with *Purshia stansburiana* occurring in the Colorado Plateau, Great Basin and Mojave regions. Until there is evidence justifying a *Purshia mexicana* shrubland alliance, it is considered part of this alliance.

VEGETATION HIERARCHY:

Formation Class	III - Shrubland
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Formation Subclass	III.A - Evergreen shrubland
Formation Group	III.A.4 - Microphyllous evergreen shrubland
Formation Subgroup	III.A.4.N - Natural/Semi-natural microphyllous evergreen shrubland
Formation Name	III.A.4.N.a - Lowland microphyllous evergreen shrubland
Alliance Name	<i>Purshia (stansburiana, mexicana)</i> Shrubland Alliance

UNITED STATES DISTRIBUTION: UT

GLOBAL DISTRIBUTION: Mexico? United States

GLOBAL RANGE:

This alliance has been described from California and Utah but may occur elsewhere across the Southwest from southeastern California east to Colorado and south into Mexico.

VEGETATION STRUCTURE:

These are microphyllous evergreen shrublands of 1-5 m in height and 25-30% cover. The herbaceous layer is often composed of a sparse cover of graminoids and forbs, but may be locally dense where these stands have been invaded by non-native annual grasses.

DYNAMICS:

Price and Brotherson (1987) report that there has been a noticeable decline in recruitment of *Purshia stansburiana* since 1957 at sites in Utah. They attributed the decline to competitive exclusion and increased fire frequency associated with invasion by non-native annual grasses.

LOCAL DESCRIPTION:

This tall shrub association was dominated by *Purshia stansburiana* (Stansbury cliffrose) and *Cercocarpus montanus*, and may include other shrubs such as *Artemisia nova*, *Ephedra torreyana*, *Gutierrezia sarothrae*, or *Rhus trilobata*. It was found on Cliffhouse sandstones and Kirtland shales on slopes from 2-18 degrees. It often occurred adjacent to open juniper woodlands but was distinct floristically and visually in the aerial photographs. This association occurred on West Mesa, north of Gallo campground and on the middle bench of sandstones near Pueblo Alto, as well as on sandstone outcrops north of Mockingbird Canyon headwaters. Grasses included *Hesperostipa comata*, *Pleuraphis jamesii*, and *Bouteloua gracilis*. Abundant forbs included *Dimorphocarpa wislizenii* (touristplant), *Artemisia frigida*, *Mirabilis multiflora*, *Petradoria pumila*, *Townsendia incana*, *Senecio multicapitatus* (broomlike ragwort), *Erysimum capitatum*, *Lesquerella fendleri* (Fendler's bladderpod), *Yucca harrimanae*, *Eriogonum alatum*, *Eriogonum umbellatum*, *Haplopappus drummondii* (Drummond's goldenbush), and *Stanleya pinnata*. Biotic crusts are often well developed. This association is notable because both dominant shrubs host actinorhizal nitrogen-fixers (see discussion section).

PLOT NUMBERS: 25, 54, 58, 103, 109, 151, 158

ALLIANCE: *Sarcobatus vermiculatus* Shrubland Alliance

Translated name:	Black Greasewood Shrubland Alliance
Unique identifier:	A.1041
Classification approach:	International Vegetation Classification (IVC)

ASSOCIATION: *Sarcobatus vermiculatus* - *Atriplex canescens* Shrubland (fig. 27)

Translated name:	Black Greasewood – Fourwing Saltbush Shrubland
Common name:	Black Greasewood – Fourwing Saltbush Shrubland
Unique identifier:	CEGL00XXX (Provisional)
Classification approach:	Provisional and local.



Figure 27. Plot CHCU AA 71. *Sarcobatus vermiculatus* – *Atriplex canescens* Shrubland

SUMMARY:

This widespread shrubland alliance has been described from badlands in the northern Great Plains, silt dunes around pluvial lakes in the Great Basin, and alluvial plains in north-central New Mexico. Sites are nearly flat to steep and are located on contouring microbenches on middle or lower slopes with generally southern aspects. The microbenches are the result of differential erosion of shale layers. Lowland sites may receive overland flow during intense summer thunderstorms, but drain and are not considered flooded. However, some sites have high water tables. Soils are generally fine-textured, poorly drained, calcareous, alkaline and saline. Soils from some sites have large amounts of rock. The soil surface is mostly bare ground often with white salt crust. Soils from some sites have large amounts of rock (Hansen and Hoffman 1988). The soil surface is mostly bare ground (50-80% cover) often with white salt crust (Brown 1971, Hansen and Hoffman 1988, Young et al. 1986). Shrublands included in this alliance are dominated by *Sarcobatus vermiculatus*. Other characteristic shrubs and dwarf-shrubs may include *Artemisia tridentata*, *Atriplex canescens*, *Atriplex confertifolia*, *Chrysothamnus* spp., *Grayia spinosa*, *Gutierrezia sarothrae*, or *Suaeda moquinii*. The herbaceous layer is absent to moderately sparse (<25%) and composed of scattered perennial grasses, such as *Pseudoroegneria spicata*, *Pleuraphis jamesii* (= *Hilaria jamesii*), *Achnatherum hymenoides* (= *Oryzopsis hymenoides*), *Sporobolus cryptandrus*, and *Bouteloua gracilis*. Annual grasses, especially the exotics *Bromus tectorum* and *Bromus japonicus* (Japanese brome), may be present. Forbs are sparse except on disturbed, weedy sites. Forb species may include *Eriogonum pauciflorum* (fewflower buckwheat), *Suaeda calceoliformis* (Pursh seepweed), *Thelypodium sagittatum* (arrow thelypody), *Halogeton glomeratus* (saltlover), and *Lepidium perfoliatum* (clasping pepperweed). Occasionally cacti, small trees or *Yucca* may be present in New Mexican stands. Diagnostic of this alliance is the *Sarcobatus vermiculatus*-dominated shrub layer in a shrubland that has a relatively shallow water table, but is not flooded.

CLASSIFICATION COMMENTS:

Sarcobatus vermiculatus stands are classified into alliances by flood regime or shrub canopy density. Stands described by Young et al. (1986) on silt dunes had less than 15% total mean shrub canopy and less herbaceous cover, and may be better classified in a sparsely vegetated alliance. The stands described by Hansen and Hoffman (1988) classified into the *Sarcobatus vermiculatus* / *Agropyron spicatum* habitat type also had relatively sparse shrub canopy (25% cover) and could be classified in either a shrub herbaceous or shrubland alliance. Information on stands reported by Dick-Peddie (1984) did not give mean shrub canopy cover, but non-flooded *Sarcobatus vermiculatus* stands tend to have relatively sparse shrub cover. More investigation is needed to determine if this alliance is needed.

VEGETATION HIERARCHY

Formation Class	III - Shrubland
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Formation Subclass	III.B - Deciduous shrubland
Formation Group	III.B.3 - Extremely xeromorphic deciduous shrubland
Formation Subgroup	III.B.3.N - Natural/Semi-natural extremely xeromorphic deciduous shrubland
Formation Name	III.B.3.N.a - Extremely xeromorphic deciduous subdesert shrubland without succulents
Alliance Name	<i>Sarcobatus vermiculatus</i> Shrubland Alliance

UNITED STATES DISTRIBUTION: CO, MT, ND, NM, NV, SD, WY?

GLOBAL DISTRIBUTION: United States

GLOBAL RANGE:

Shrublands included in this alliance have been described in badlands in southwestern Montana, alluvial fans in north central New Mexico, and on dunes around pluvial lakes in the Great Basin.

VEGETATION:

Stands included in this shrubland alliance occur on slopes of badlands in the northern Great Plains, on silt dunes around pluvial lakes in the Great Basin, and on non-flooded alluvial fans and stream terraces in New Mexico. Stands have a sparse to moderate woody layer (15-55% cover) dominated by the deciduous, facultative halophytic shrub *Sarcobatus vermiculatus*.

VEGETATION STRUCTURE:

Vegetation included in this alliance has a sparse to moderate cover of microphyllous, deciduous, xeromorphic shrubs 0.5-2 m tall. A sparse dwarf-shrub layer may also be present (<0.5 m). The herbaceous layer is sparse to moderately dense and dominated by tall and medium-tall bunch grasses or rhizomatous short grasses. Scattered cacti and trees may be present. Perennial forbs are sparse. Annual grasses and forbs may be seasonally present.

DYNAMICS:

Sarcobatus vermiculatus, like many facultative halophytes, is tolerant of alkaline and saline soil conditions that allow the species to occur on sites with less interspecific competition (Ungar et al. 1969, Branson et al. 1976). *Sarcobatus vermiculatus* is often found in lowland sites in xeric landscapes where soil moisture is supplemented by flooding or a high water table. Where the species occurs on upland sites there are often seeps that enhance the soil water. Hansen and Hoffman (1988) and Brown (1971) described xeric shale outcrop sites in southeastern Montana where water moves horizontally through porous lignite seams to the hillside, creating habitat for *Sarcobatus vermiculatus*. *Sarcobatus vermiculatus* is not ordinarily browsed, but Daubenmire (1970) found that under heavy stocking rates, the shrubs will develop a compact canopy. Hansen et al. (1995) also reported browsing damage with heavy spring and summer grazing, but noted that the species is moderately poisonous to livestock especially in the fall, and supplemental feed is recommended to avoid livestock loss. Hanson (1929) states that *Sarcobatus vermiculatus* can form an important part of winter forage for sheep. Fire will topkill *Sarcobatus vermiculatus*, but the shrubs will promptly resprout from the root crown (Daubenmire 1970).

LOCAL DESCRIPTION:

This tall shrubland association supported co-dominant *Sarcobatus vermiculatus* and *Atriplex canescens* and occasionally included *Lycium pallidum*, *Artemisia tridentata*, and *Ericameria nauseosus*. The relative density of *Sarcobatus* and *Atriplex* varies throughout the bottomland of Chaco Canyon, yet both species are generally present. Forbs included *Oenothera caespitosa*, *Mentzelia albicaulis*, *Sphaeralcea parvifolia*. Grasses included *Sporobolus airoides*, *Elymus elymoides*, and *Pleuraphis jamesii*. The association was found on flat canyon bottom on Naja and Tsegi Alluviums or Cliffhouse sandstone substrates. It often supported the invasive weed species *Bassia scoparia*, but *Bromus tectorum* was notably lacking. In contrast to other *Sarcobatus* dominated associations described in the NVC hierarchy, the *Sarcobatus vermiculatus*-*Atriplex canescens* association at Chaco Canyon has been protected from grazing since 1940 when Chaco Canyon National Monument was originally fenced. After more than 60 years rest from grazing pressure, this community has well-developed grass and forb understory and highly developed biotic crusts. In its present structure, this association at Chaco Canyon National Historic Park may represent the potential biotic community that is rarely realized in the southwest due to prolific grazing of *Sarcobatus* habitats. See discussion for further information.

PLOT NUMBERS TO ASSOCIATIONS: 11, 17, 153, 193, 227, 446, 458, 549, 660, 761, 939, 984, 1001, 1010, 1011, 1014, 1024, 1026

PLOT NUMBERS TO ALLIANCE: 24, 297, 363, 1002, 1012, 1013, 1015, 1029

3.3.4 Woodland

ALLIANCE: *Juniperus monosperma* Woodland Alliance (fig. 28)

Translated name:	One-seed Juniper Woodland Alliance
Unique identifier:	A.504
Classification approach:	International Vegetation Classification (IVC)



Figure 28 Plot CHCU-0033. *Juniperus monosperma* Woodland Alliance

ASSOCIATION: *Juniperus monosperma* / *Cercocarpus montanus* Woodland (fig. 29)

Translated name:	One-seed Juniper / Alderleaf Mountain-mahogany Woodland
Common name:	One-seed Juniper / Mountain-mahogany Woodland
Unique identifier:	CEGL000713
Classification approach:	International Vegetation Classification (IVC)

NVC SUMMARY: None available (description in development)

CLASSIFICATION CONFIDENCE: 3 - Weak

VEGETATION HIERARCHY:

Formation Class	II - Woodland
Formation Subclass	II.A - Evergreen woodland
Formation Group	II.A.4 - Temperate or subpolar needle-leaved evergreen woodland
Formation Subgroup	II.A.4.N - Natural/Semi-natural temperate or subpolar needle-leaved evergreen woodland
Formation Name	II.A.4.N.a - Rounded-crowned temperate or subpolar needle-leaved evergreen woodland
Alliance Name	<i>Juniperus monosperma</i> Woodland Alliance

ECOLOGICAL SYSTEMS PLACEMENT

Ecological system ID	Ecological system name
CES303.664	Southwestern Great Plains Canyon
CES304.767	Colorado Plateau Pinyon-Juniper Woodland



Figure 29. Plot CHCU AA 102. *Juniperus monosperma* / *Cercocarpus montanus* Woodland

CES304.782	Inter-Mountain Basins Juniper Savanna
CES306.834	Southern Rocky Mountain Juniper Woodland and Savanna
CES306.835	Southern Rocky Mountain Pinyon-Juniper Woodland

LOCAL DESCRIPTION:

This association, found at higher elevations 1,943-2,050 m, was dominated by *Juniperus monosperma* and accompanying tall shrubs *Purshia mexicana* (Mexican cliffrose), *Cercocarpus montanus*, *Gutierrezia sarothrae*, *Ephedra torreyana*, *Tetradymia canescens*, *Artemisia nova*, *Brickellia californica* (California brickellbush), and *Atriplex canescens*. *Juniperus monosperma* is often found in very low density and cover, yet mature trees characterize the association. Grasses included *Achnatherum hymenoides* and *Bouteloua gracilis* and occasionally *Poa fendleriana*. Forbs included *Eriogonum leptophylla*, *E. alatum*, *Petradoria pumila*, *Cryptantha flava* (Brenda’s yellow cryptantha), and *Aletes macdougalii* (MacDougal’s Indian parsley). This association was found on Menefee shale, Cliffhouse sandstone, and Kirtland shale. It occurred on canyon rims of South and West Mesa and on open slickrock habitats on Chacra Mesa) (fig. 29).

PLOT NUMBERS: 7, 19, 33, 80, 92, 101, 102, 105, 111, 147, 155, 167, 188, 1031

ALLIANCE: <i>Pinus edulis</i> - (<i>Juniperus</i> spp.) Woodland Alliance	
Translated name:	Two-needle Pinyon - (Juniper species) Woodland Alliance
Unique identifier:	A.516
Classification approach:	International Vegetation Classification (IVC)

ASSOCIATION: <i>Pinus edulis</i> - <i>Juniperus</i> spp. / <i>Cercocarpus montanus</i> - Mixed Shrub Woodland (fig. 30)	
Translated name:	Two-needle Pinyon - Juniper species / Mountain-mahogany - Mixed Shrub Woodland
Unique identifier:	CEGL000780
Classification approach:	International Vegetation Classification (IVC)

SUMMARY:

This broadly defined woodland association is common on the Colorado Plateau, occurring on dry foothills and mesas from north-central New Mexico and southern Colorado west to the Mogollon Rim of Arizona, and in western Colorado and adjacent Utah. It can be found on any slope position, though lower slopes are less common.



Figure 30. Plot CHCU AA 301. *Pinus edulis* – *Juniperus* spp. / *Cercocarpus montanus* Woodland

Elevations range from 1,472 to 2,480 m (4,830-8,135 ft.). Stands occur on gentle to steep slopes on all aspects. The soils are variable but generally shallow, poorly developed and skeletal, ranging from clayey marl to loamy sands. The unvegetated surface is characterized by bedrock, large and small rocks, and/or bare soil with little litter. Sandstone or shale are the most common parent materials. This association is characterized by an open to moderately dense tree canopy (10-60% cover) dominated by a combination of *Pinus edulis* and *Juniperus* spp. The canopy averages 2-5 m tall, but some stands may be as tall as 10 m. *Pinus edulis* and *Juniperus* spp. codominate in most stands, but sometimes one may be more prevalent than the other. *Pinus edulis* and *Juniperus* spp. are also present as smaller individuals in the shrub and field strata. The species of *Juniperus* varies with geography and elevation. *Juniperus monosperma* is common in north-central New Mexico and southern Colorado. *Juniperus deppeana* is common in southern New Mexico, and *Juniperus osteosperma* is common from northwestern New Mexico west into Arizona and north into western Colorado and Utah. *Juniperus scopulorum* is more common in higher elevation stands. The total shrub cover may range from sparse to moderate. *Cercocarpus montanus* is the dominant shrub with up to 35% cover. It typically occurs as a short shrub but can be a tall shrub on some sites. Other shrubs may be present, including *Amelanchier* spp., *Artemisia tridentata*, *Ephedra viridis*, *Chrysothamnus viscidiflorus*, *Gutierrezia sarothrae*, *Fendlera rupicola* (cliff fendlerbush), *Garrya ovata* (eggleaf silktassel), *Mahonia* spp., *Nolina microcarpa* (sacahuista), *Quercus gambelii*, *Quercus grisea* (gray oak), *Rhus trilobata*, or species of *Yucca* and *Opuntia*. Herbaceous cover is variable, ranging from sparse to moderately dense, and generally dominated by graminoids (>5% cover) with scattered forbs. Extremely open stands of this association, usually occurring on fractured slickrock exposures, may have as little as 5% total vegetation cover and an upper canopy only 2 m tall.

CLASSIFICATION CONFIDENCE: 2 - Moderate

CLASSIFICATION COMMENTS:

This is a widely distributed and variable association, found throughout much of the Colorado Plateau, edges of the Colorado Rockies and south into New Mexico.

VEGETATION HIERARCHY:

Formation Class	II - Woodland
Formation Subclass	II.A - Evergreen woodland
Formation Group	II.A.4 - Temperate or subpolar needle-leaved evergreen woodland
Formation Subgroup	II.A.4.N - Natural/Semi-natural temperate or subpolar needle-leaved evergreen woodland
Formation Name	II.A.4.N.a - Rounded-crowned temperate or subpolar needle-leaved evergreen woodland
Alliance Name	<i>Pinus edulis</i> - (<i>Juniperus</i> spp.) Woodland Alliance

ECOLOGICAL SYSTEMS PLACEMENT

Ecological system ID	Ecological system name
CES304.766	Colorado Plateau Pinyon-Juniper Shrubland
CES304.767	Colorado Plateau Pinyon-Juniper Woodland
CES306.835	Southern Rocky Mountain Pinyon-Juniper Woodland

GLOBAL STATUS: G5 (23Feb1994).

ROUNDED GLOBAL STATUS: G5 - Secure

UNITED STATES DISTRIBUTION: AZ, CO, NM, OK? UT

GLOBAL DISTRIBUTION: United States

GLOBAL RANGE:

DYNAMICS:

Fires in this association are thought to be infrequent because *Pinus edulis*, *Juniperus osteosperma*, and *Juniperus monosperma* are killed or severely damaged by burns and do not resprout (Wright et al. 1979). *Cercocarpus montanus*, however, resprouts after burning and will re-establish relatively quickly (Pase and Lindenmuth 1971, Bradley et al. 1992). Conifers will re-establish more slowly. Stands occur in dry and often rocky habitats where fire frequency is low because of fuel discontinuity. When fire occurs, it will likely be severe because of greater fuel loads from decadent shrubs (Bradley et al. 1992).

LOCAL DESCRIPTION:

This woodland association was dominated by *Pinus edulis* and *Juniperus monosperma* with an open pinyon-juniper woodland structure. It was found on higher elevations of Chacra Mesa from 1,920-2,030 m, on Cliffhouse sandstones on low to moderate slopes 2-11 degrees. Shrubs include *Cercocarpus montanus*, *Artemisia nova*, *Purshia mexicana*, *Rhus trilobata*, *Atriplex canescens*, and *Gutierrezia sarothrae*. The association was rich with forb species, including *Petradoria pumila*, *Aletes macdougallii*, *Streptanthella longirostris* (longbeak streptanthella), *Yucca harrianae*, and *Astragalus* species. Grasses were present in low density; *Achnatherum hymenoides* was the most common grass species and *Poa fendleriana*, *Elymus elymoides* and *Hesperstipa comata* were occasionally present (fig. 30).

PLOT NUMBERS: 108, 166, 169, 170, 171, 197, 1027, 1028

3.3.5 Riparian and Temporarily Flooded Associations (Chaco Wash)

The vegetation of Chaco Wash was mapped and defined in 2002-2003 (Hanna and Floyd-Hanna, 2003 Report), therefore this area was not re-evaluated under the current protocols, therefore, there are no plots. This section includes descriptions for both shrublands and forests.

ALLIANCE: *Atriplex canescens* Shrubland Alliance

Translated name:	Fourwing Saltbush Shrubland Alliance
Unique identifier:	A.869
Classification approach:	International Vegetation Classification (IVC)

ASSOCIATION: *Artemisia tridentata* - *Atriplex canescens* - *Sarcobatus vermiculatus* / (*Achnatherum hymenoides*) Shrubland

Translated name:	Big Sagebrush - Fourwing Saltbush - Greasewood / (Indian Ricegrass) Shrubland
Common name:	Big Sagebrush - Fourwing Saltbrush - Greasewood / (Indian Mountain-ricegrass)
Unique identifier:	CEGL001355
Classification approach:	International Vegetation Classification (IVC)

SUMMARY:

This desert community is associated with sand dunes, which are found along the windward (eastern in the northern Great Basin) edge of large playa basins. Aspects and slopes of the dunes vary, but most are north-south, along the eastern playa edges of a completely flat landscape. In addition to the shrubs *Artemisia tridentata*, *Atriplex canescens*, and *Sarcobatus vermiculatus*, other occasional codominants include *Chrysothamnus viscidiflorus*, *Ericameria nauseosa* (= *Chrysothamnus nauseosus*), and *Grayia spinosa* (= *Atriplex spinosa*). The most abundant but sparse grass is *Achnatherum hymenoides* (= *Oryzopsis hymenoides*) although *Hesperostipa comata* (= *Stipa comata*), *Elymus lanceolatus*, and *Leymus cinereus* (basin wildrye) are occasionally found. Bare, alkaline sand provides significant cover. This community rapidly vanishes on the adjacent *Artemisia tridentata* ssp. *wyomingensis*-dominated slopes. This dune association represents a rich floral assemblage as compared to surrounding salt desert scrub and playa communities. This is attributable to higher soil temperatures in spring promoting early growth, lower salt concentrations, and greater accumulation of wind-blown seeds.

CLASSIFICATION CONFIDENCE: 1 - Strong

CLASSIFICATION COMMENTS

This association is referred to as “Dunes” and “Dunes-South” by Price and Seibert (1981).

VEGETATION HIERARCHY

Formation Class	III - Shrubland
Formation Subclass	III.A - Evergreen shrubland
Formation Group	III.A.5 - Extremely xeromorphic evergreen shrubland
Formation Subgroup	III.A.5.N - Natural/Semi-natural extremely xeromorphic evergreen shrubland
Formation Name	III.A.5.N.b - Facultatively deciduous extremely xeromorphic subdesert shrubland
Alliance Name	<i>Atriplex canescens</i> Shrubland Alliance

ECOLOGICAL SYSTEMS PLACEMENT

Ecological system ID	Ecological system name
CES304.777	Inter-Mountain Basins Big Sagebrush Shrubland

GLOBAL STATUS: G1 (29Mar1999)

ROUNDED GLOBAL STATUS: G1 - Critically Imperiled

This community is both very rare and fairly fragile. It is restricted, due to the limited sand input in most northern Great Basin playa valleys. Only about 8,100 ha (20,000 acres) of this habitat are estimated, although northern Nevada has been poorly inventoried. The association is threatened (in protected areas and outside of them), by increasing ORV use and occasional grazing. The lack of water generally precludes heavy grazing, but spring use by cattle can easily damage these fragile dunes.

UNITED STATES DISTRIBUTION: CA? NV? OR

GLOBAL DISTRIBUTION: United States

GLOBAL RANGE:

The location used for this description is the Alvord Basin. Similar dunes are found on the eastern edge of the Catlow Valley, and on the eastern edges of large playa valleys in northern Nevada.

LOCAL DESCRIPTION

This community was widespread along the broad reach adjacent to Chaco Wash with *Artemisia tridentata* and *Chrysothamnus* species (*C. nauseosus* and *C. viscidiflorus*) codominant. *Atriplex canescens* and *Gutierrezia* species also occurred at lower densities. This woody shrub association occupied 56% of the total area within the wash. The relative cover of these species varied. *Sarcobatus vermiculatus* tended to grow near the arroyo walls or in erosion fans. The invasive shrub *Tamarix chinensis* (salt cedar) was found and specific locations mapped in this association. It occupied 6% of Chaco Wash in 2003. Grasses included natives *Sporobolus airoides*, *Hilaria jamesii* and *Achnatherum hymenoides* and the invasive *Bromus tectorum*.

ALLIANCE: *Ericameria nauseosa* Shrubland Alliance

Translated name:	Rubber Rabbitbrush Shrubland Alliance
Unique identifier:	A.835
Classification approach:	International Vegetation Classification (IVC)

SUMMARY

This alliance includes both natural and semi-natural stands from localized areas across the northern Great Plains and throughout the western U.S. Naturally occurring stands have been described from areas of partially stabilized sands, in a region of actively moving dune deposits, from 1525-1800 m elevation in southeastern Idaho and in other areas of high natural disturbance such as on steep colluvial slopes, along drainages or in floodplains. The semi-natural stands included in this alliance are seral shrubland communities resulting from overgrazing by livestock, road building, or other cultural disturbance of typically grass-dominated communities. Elevations range from 1189 and 2104 m (3900-6900 feet). Soils are variable but generally well-drained and coarse-textured. The vegetation is characterized by an open to moderately dense, short-shrub layer (15-60% cover) that is dominated by *Ericameria nauseosa*. Depending on geography, associated shrubs may include scattered *Artemisia tridentata*, *Artemisia filifolia*, *Chrysothamnus viscidiflorus*, *Gutierrezia sarothrae*, *Rhus trilobata*, *Opuntia* spp., *Prunus virginiana*, *Symphoricarpos occidentalis*, and *Yucca* spp. The herbaceous layer can vary from moderately dense and dominated by graminoids to absent. Common native grasses include *Achnatherum hymenoides* (= *Oryzopsis hymenoides*), *Bouteloua* spp., *Elymus trachycaulus* ssp. *trachycaulus*, *Leymus flavescentis* (= *Elymus flavescentis*), *Pascopyrum smithii*, *Pleuraphis jamesii*, *Pseudoroegneria spicata*, and *Sporobolus cryptandrus*. Native forbs generally have low cover. Disturbed stands typically have high cover of introduced annual *Bromus* species.

CLASSIFICATION COMMENTS:

This alliance's concept has been recently expanded to include semi-natural vegetation. More classification information is needed to fully describe this alliance throughout its range of distribution.

VEGETATION HIERARCHY

Formation Class	III - Shrubland
Formation Subclass	III.A - Evergreen shrubland
Formation Group	III.A.4 - Microphyllous evergreen shrubland
Formation Subgroup	III.A.4.N - Natural/Semi-natural microphyllous evergreen shrubland
Formation Name	III.A.4.N.a - Lowland microphyllous evergreen shrubland
Alliance Name	<i>Ericameria nauseosa</i> Shrubland Alliance

UNITED STATES DISTRIBUTION: AZ, CO, ID, MT, ND, NV, SD, UT

GLOBAL DISTRIBUTION: United States

GLOBAL RANGE:

This alliance includes shrublands from localized areas across the northern Great Plains and throughout the western U.S.

STATE STATUS: S5 (20Jan2008)

VEGETATION:

This alliance includes both natural and semi-natural stands from localized areas across the northern Great Plains and throughout the western U.S. The vegetation is characterized by an open to moderately dense, short-shrub layer (15-60% cover) that is dominated by *Ericameria nauseosa*. Depending on geography, associated shrubs may include scattered *Artemisia tridentata*, *Artemisia filifolia*, *Chrysothamnus viscidiflorus*, *Gutierrezia sarothrae*, *Rhus trilobata*, *Opuntia* spp., *Prunus virginiana*, *Symphoricarpos occidentalis*, and *Yucca* spp. The herbaceous layer can vary from moderately dense and dominated by graminoids to absent. Common native grasses include *Achnatherum hymenoides* (= *Oryzopsis hymenoides*), *Bouteloua* spp., *Elymus trachycaulus* ssp. *trachycaulus*, *Leymus flavescens* (= *Elymus flavescens*), *Pascopyrum smithii*, *Pleuraphis jamesii*, *Pseudoroegneria spicata*, and *Sporobolus cryptandrus*. Native forbs generally have low cover, but may include species such as *Psoralea lanceolata* (= *Psoralea lanceolata*), *Machaeranthera canescens* (= *Aster canescens*), *Lygodesmia grandiflora*, and *Phacelia hastata* (= *Phacelia leucophylla*). Disturbed stands typically have high cover of introduced annual *Bromus* species such as *Bromus tectorum*, *Bromus japonicus*, and *Bromus rubens*. Introduced forbs may include *Melilotus officinalis*, *Salsola kali*, and *Bassia scoparia* (= *Kochia scoparia*).

VEGETATION STRUCTURE:

Vegetation included in this alliance has a moderately dense (40-60% cover) short-shrub layer less than 2 m tall. The herbaceous layer is relatively sparse (20-30% cover) and is usually less than 0.5 m tall. It is codominated by perennial grasses and forbs. Annual graminoids and forbs are seasonally present.

WETLAND INDICATOR: No

ENVIRONMENTAL SUMMARY:

This alliance includes both natural and semi-natural stands from localized areas across the northern Great Plains and throughout the western U.S. Naturally occurring stands have been described from areas of partially stabilized sands, in a region of actively moving dune deposits, from 1525-1800 m elevation in southeastern Idaho and in other areas of high natural disturbance such as on steep colluvial slopes, along drainages or in floodplains. Natural stands in the dune systems of southern Idaho occur in very specific environments, roughly 30-210 m windward from the pioneer vegetation type *Leymus flavescens* Herbaceous Vegetation (CEGL001563). These sand deposits have generally been stable for approximately 40 years. The soils are sand, from a few centimeters to over 4 m deep, left behind as the dunes advance. Stands on the Colorado Plateau occur in a variety of habitats such as gentle or steep slopes, dunes, and washes. Elevations range from 1189 and 2104 m (3900-6900 feet) elevation. Substrates may be eolian, alluvial, colluvial or derived from sandstone residuum. Soils are variable but are generally well-drained and coarse-textured. The semi-natural stands included in this alliance are seral shrubland communities resulting from overgrazing by livestock, road building, or other cultural disturbance of typically grass-dominated communities.

DYNAMICS:

In southern Idaho this shrubland is the second seral stage of five vegetation types found on this dune complex. The types are found in bands transverse to the direction of dune movement. The width of the vegetation bands is quite consistent throughout the sandhills area, and each band advances across the landscape at about the same rate as the dune advancement. This association has an approximate duration on a given deposit of 10-70 years. Semi-natural stands have largely been overlooked in the classification literature. Daubenmire (1970) described *Ericameria nauseosa*-dominated stands (to 40% cover) from the steppes of eastern Washington as the second level of degeneration of the *Bromus tectorum* zootic climax (when overgrazing by livestock continues after perennial grasses are replaced by *Bromus tectorum*).

LOCAL DESCRIPTION:

In Chaco canyon, rabbitbrush is often associated with several grasses and often with *Tamarix chinensis*.

ALLIANCE: *Salix (exigua, interior)* Temporarily Flooded Shrubland Alliance

Translated name:	(Coyote Willow, Sandbar Willow) Temporarily Flooded Shrubland Alliance
Unique identifier:	A.947
Classification approach:	International Vegetation Classification (IVC)

ASSOCIATION: *Salix exigua* Temporarily Flooded Shrubland

Translated name:	Coyote Willow Temporarily Flooded Shrubland
Unique identifier:	CEGL001197
Classification approach:	International Vegetation Classification (IVC)

SUMMARY:

This willow shrubland community is found throughout the northwestern United States and Great Plains. This type is an early successional stage that occurs along rivers and streams at lower elevations, on recently flooded riparian areas, and in moist swales and ditches that are frequently disturbed. Stands occur most commonly on alluvial sand, but silt, clay, or gravel may also be present. *Salix exigua* is the dominant canopy species (*Salix interior* or intermediates of the two willow species may be present in the eastern part of the range). It can form dense stands up to 4 m tall, but there are often patches where the shrub layer is absent. Seedlings and small saplings of *Populus deltoides* and *Salix amygdaloides* may be present. The herbaceous cover is sparse to moderate, but rarely exceeds 30%. Species present include *Cenchrus longispinus* (mat sandbur), *Polygonum lapathifolium* (curlytop knotweed), *Schoenoplectus americanus* (= *Scirpus americanus*) (chairmaker's bulrush), *Triglochin maritime* (seaside arrowgrass), and *Xanthium strumarium* (rough cocklebur). The composition of this community, especially the herbaceous layer, varies from year to year with succession or renewed disturbance.

CLASSIFICATION CONFIDENCE: 1 - Strong**CLASSIFICATION COMMENTS**

This type may be an early-successional shrubland that develops into *Salix exigua* / Mesic Graminoids Shrubland (CEGL001203), or the two types may be essentially synonymous. This plant association occupies a wide geographic range. The range of this type was reviewed and it was split into eastern, *Salix interior* Temporarily Flooded Shrubland (CEGL008562), and western components. The western stands may all be composed of *Salix exigua* (sensu stricto), and Great Plains stands may contain either *Salix exigua*, *Salix interior*, or intermediates of the two willow species, the *Salix interior* being distributed entirely in the Great Plains and eastward (Kartesz 1999).

Because this type is subject to repeated scouring by floods, pioneering herbaceous species are often buried or removed. Woody debris and deep sandy sediments help build the sites by becoming trapped among the basal stems of the willows. These sites are also potential sites for the reproduction of native cottonwoods. As sites develop, succession is initially towards mesic types with the undergrowth dominated by *Equisetum* spp. or mesic graminoids *Scirpus* spp. and ultimately toward cottonwoods. Dense stands usually deter livestock, but open stands may be susceptible to overuse resulting in reduced vigor and loss of the willow component in the stand.

The type can occur in a matrix with cottonwood-dominated forested wetlands on higher bars and emergent vegetation dominated by sedges, cattails, and bulrushes in intermittent overflow channels or oxbows, and along banks.

This type has been previously reported in the Rocky Mountain region by Kittel (1993), Kittel and Lederer (1993), Kittel et al. (1995, 1996), and Padgett et al. (1988).

VEGETATION HIERARCHY:

Formation Class	III - Shrubland
Formation Subclass	III.B - Deciduous shrubland
Formation Group	III.B.2 - Cold-deciduous shrubland
Formation Subgroup	III.B.2.N - Natural/Semi-natural cold-deciduous shrubland
Formation Name	III.B.2.N.d - Temporarily flooded cold-deciduous shrubland
Alliance Name	<i>Salix (exigua, interior)</i> Temporarily Flooded Shrubland Alliance

ECOLOGICAL SYSTEMS PLACEMENT

Ecological system ID	Ecological system name
CES303.676	Northwestern Great Plains Floodplain
CES306.821	Rocky Mountain Lower Montane Riparian Woodland and Shrubland

GLOBAL STATUS: G5 (06May1999)

ROUNDED GLOBAL STATUS: G5 - Secure

UNITED STATES DISTRIBUTION: CO, IA, ID, IL?, MT, ND, NE, NM, OK, OR, SD, TX, WA, WY

GLOBAL DISTRIBUTION: Canada, United States

GLOBAL RANGE: This type is widespread and common throughout its range

UNITED STATES DISTRIBUTION: CO, IA, ID, IL?, MT, ND, NE, NM, OK, OR, SD, TX, WA, WY

GLOBAL DISTRIBUTION: Canada, United States

GLOBAL RANGE:

This willow shrubland community is found along rivers and streams at lower elevations throughout the northwestern United States and Great Plains, ranging sporadically from Oklahoma northwest to the Dakotas and Manitoba, west to Washington, and south to the Rio Grande, San Juan and Canadian River watersheds in northern New Mexico. Part of this type's former range in the Great Plains and eastward is actually occupied, at least in part, by *Salix interior* [see *Salix interior* Temporarily Flooded Shrubland (CEGL008562)]

VEGETATION:

This community is dominated by shrubs, generally between 2 and 4 m tall. The most common of these is *Salix exigua* (*Salix interior* or intermediates of the two willow species may be present in the eastern part of the range). *Salix irrorata* (dewystem willow) and saplings of *Populus deltoides* or *Salix amygdaloides* are also frequently found in the shrub layer in lower elevation stands. This stratum can have moderate to high stem density in the community as a whole. The species in the shrub layer do not form a closed canopy, allowing significant light to reach the ground layer. There are often patches where the shrub layer is absent. The herbaceous cover is sparse to moderate, but rarely exceeds 30%. Older stands and places with less competition from the shrubs have greater herbaceous cover. The composition of the herbaceous layer can vary greatly. Species that are often found in this community are *Cenchrus longispinus*, *Polygonum lapathifolium*, *Schoenoplectus americanus* (= *Scirpus americanus*), *Triglochin maritima*, *Xanthium strumarium*, *Juncus balticus*, *Eleocharis palustris*, *Elymus repens* (= *Elytrigia repens*), *Poa pratensis*, *Phleum pratense*, *Agrostis scabra* (rough bentgrass), *Bromus inermis*, *Heracleum maximum* (common cowparsnip), *Achillea millefolium*, *Solidago* sp., *Equisetum arvense*, and *Linaria vulgaris*.

In New Mexico, thickets of *Salix exigua* range from open to closed and attain heights of 1.5 to 3 m (4-9 ft.). *Salix irrorata* may be common but clearly not dominant. In the densest stands, *Salix exigua* dominates to the exclusion of other species. Seedlings or young saplings of native *Populus deltoides* and/or *Populus angustifolia* are present but usually widely scattered. In some stands, exotic species such as *Tamarix ramosissima* and *Elaeagnus angustifolia* are increasing in cover. The herbaceous understory can be diverse (85 species have been recorded for the type), but cover is low. Of the 18 wetland herbaceous species recorded for the type, the most prevalent are *Eleocharis palustris*, *Juncus bufonius*, *Juncus saximontanus*, *Schoenoplectus pungens* (= *Scirpus pungens*), *Argentina anserina* (silverweed cinquefoil), *Epilobium ciliatum* (fringed willowherb), *Equisetum laevigatum*, and *Mentha arvensis* (wild mint).

VEGETATION VARIABILITY:

In Nebraska, Steinauer and Rolfsmeier (1997) report that *Amorpha fruticosa* (desert false indigo), *Cornus sericea* (redosier dogwood), and *Salix lutea* (yellow willow) are also present in the shrub layer. In the herbaceous layer they report the following species: *Ambrosia artemisiifolia* (annual ragweed), *Symphotrichum lanceolatum* (white panicle aster), *Carex emoryi*, *Carex pellita* (woolly sedge), *Lippia lanceolata* (lanceleaf fogfruit), *Lycopus americanus* (American water horehound), *Polygonum* spp., *Rumex* spp., *Schoenoplectus pungens* (common threesquare), *Spartina pectinata* (prairie cordgrass), and *Urtica dioica* (stinging nettle). They note that *Amorpha fruticosa*, *Lippia lanceolata*, *Salix exigua*, and *Spartina pectinata* are diagnostic. They also describe three vegetation zones: (1) a low wet zone along river channels dominated by *Salix exigua*, (2) a willow shrubland zone on sandbars and banks slightly above the river channel dominated by *Salix exigua* with *Amorpha fruticosa* more common, and (3) a false indigobush/willow shrubland zone on drier sandbars and banks with *Amorpha fruticosa* (indigobush) equally or more common than *Salix exigua*.

WETLAND INDICATOR: Yes

ENVIRONMENTAL SUMMARY:

This community is found on recently deposited or disturbed alluvial material. The parent material is alluvial sand, although silt, clay, or gravel may be present. Soil development is poor to absent.

In New Mexico, this community occurs along wide, low-gradient streams and rivers in foothill regions and in low-land valleys and canyons at low to mid elevations of 1,430 to 1,910 m (4,700-6,250 ft.). The type is common on low alluvial bars that are subject to repeated flooding (1- to 5-year recurrence intervals). Soils are poorly stratified and generally consist of a thin layer of sandy loam at the surface overlying deep deposits of sand, gravel, or cobble. Rock fragments comprise upwards of 80% of the soil profile. These well-drained soils provide good aeration and rapid movement of water through the profile. Sites composed mostly of riverwash are moist at the surface for much of the season, while high bars may be dry on the surface, but tend to be moist at depths of 15 to 30 cm (6-12 in) during most years.

DYNAMICS:

This type originates after flash floods that create new deposits or scour existing alluvial material. This community is a primary or early secondary community and requires floods to create new areas on which it can develop. Once established, without further flooding disturbance and sediment deposition, this community may not exist for more than 10-20 years before it is replaced by a later seral stage.

LOCAL DESCRIPTION:

Coyote willow stands are adjacent to *Populus* woodlands, and intermingle with the woodlands in Chaco Wash (Hanna and Floyd-Hanna 2003).

ALLIANCE: *Tamarix* spp. Semi-natural Temporarily Flooded Shrubland Alliance

Translated name:	Salt-cedar species Semi-natural Temporarily Flooded Shrubland Alliance
Unique identifier:	A.842
Classification approach:	International Vegetation Classification (IVC)

SUMMARY

This alliance is composed of shrublands which form moderately dense to dense thickets on banks of larger streams, rivers and playas across the western Great Plains, interior and southwestern U.S., and northern Mexico. Stands are dominated by introduced species of *Tamarix*, including *Tamarix ramosissima*, *Tamarix chinensis*, *Tamarix gallica*, and *Tamarix parviflora*. Introduced from the Mediterranean, *Tamarix* spp. have become naturalized in various sites, including salt flats, springs, and especially along streams and regulated rivers, often replacing *Salix* or *Prosopis* spp. shrublands or other native vegetation. A remnant herbaceous layer may be present, depending on the age and density of the shrub layer. These species have become a critical nuisance along most large rivers in the semi-arid western U.S. Because of the difficulty to remove, *Tamarix* spp. may have irreversibly changed the vegetation along many rivers.

CLASSIFICATION COMMENTS

This broadly defined alliance is composed of many diverse *Tamarix* spp.-dominated vegetation communities from a wide variety of environments. Common species of *Tamarix* include *Tamarix ramosissima*, *Tamarix chinensis*, and *Tamarix parviflora*, but other species are reported from the western U.S., such as *Tamarix africana*, *Tamarix aphylla*, *Tamarix aralensis*, *Tamarix canariensis*, *Tamarix gallica*, and *Tamarix tetragyna* (Kartesz 1999). Powell (1988) reports that *Tamarix* spp. are a critical nuisance, most notably along the Rio Grande and Pecos River. Muldavin et al. (2000a) described 8 community types that will be reviewed as possible USNVC associations. Currently the sole USNVC *Tamarix* association, *Tamarix* spp. Temporarily Flooded Shrubland (CEGL003114), is equally broadly defined.

VEGETATION HIERARCHY:

Formation Class	III - Shrubland
Formation Subclass	III.A - Evergreen shrubland
Formation Group	III.A.4 - Microphyllous evergreen shrubland
Formation Subgroup	III.A.4.N - Natural/Semi-natural microphyllous evergreen shrubland
Formation Name	III.A.4.N.c - Temporarily flooded microphyllous shrubland
Alliance Name	<i>Tamarix</i> spp. Semi-natural Temporarily Flooded Shrubland Alliance

GLOBAL DISTRIBUTION: Mexico, United States

GLOBAL RANGE:

This semi-natural shrubland alliance is found along drainages in the semi-arid western Great Plains, interior western and southwestern U.S., and northern Mexico, from central and eastern Montana south to Colorado, western Oklahoma and Texas west to California.

STATE STATUS: SE (20Jan2008)

VEGETATION:

This semi-natural shrubland alliance occurs along streams, rivers and playas where it forms a moderate to dense tall-shrub layer that is solely or strongly dominated by species of *Tamarix* including *Tamarix ramosissima*, *Tamarix chinensis*, *Tamarix gallica*, and *Tamarix parviflora*. Other shrubs may include species of *Salix* (especially *Salix exigua*) and *Prosopis*, *Rhus trilobata*, and *Sarcobatus vermiculatus*, but with low cover (if shrub species are codominant, then stand is classified as a natural shrubland). Scattered *Acer negundo*, *Salix amygdaloides*, *Populus* spp., or *Elaeagnus angustifolia* trees may also be present. Depending on stand age and density of the shrub layer, an herbaceous layer may be present. Associated species include *Distichlis spicata*, *Sporobolus airoides*, and introduced forage species such as *Agrostis gigantea*, *Agrostis stolonifera*, and *Poa pratensis*. Introduced herbaceous species such as *Polypogon monspeliensis* (annual rabbitsfoot grass), *Conyza canadensis*, *Lepidium latifolium*, and others have been reported from shrublands in this association. *Tamarix* spp. have become a critical nuisance along most large rivers in the semi-arid western U.S. and, because of the difficulty to remove, may have irreversibly changed the vegetation along many rivers.

WETLAND INDICATOR: Yes

ENVIRONMENTAL SUMMARY:

The riparian shrublands included in this alliance occur across the western Great Plains, interior western and southwestern U.S., and northern Mexico. These widespread shrublands are common along larger streams, rivers, and around playas. Elevation ranges from 75 m below sea level to 1,860 m. *Tamarix* spp. have become naturalized in various sites, including riverbanks, floodplains, basins, sandbars, side channels, springs, salt flats, and other saline habitats. Stands grow especially well along regulated rivers where flood-regenerated native species of *Populus* are declining. Substrates are commonly thin sandy loam soil over alluvial deposits of sand, gravel or cobbles.

DYNAMICS:

Tamarix spp. are highly competitive shrubs that have invaded many riparian and wetland environments in the western U.S. Hansen et al. (1995) report that these shrubs are extremely drought- and salt-tolerant, produce prolific wind-dispersed seeds over much of the growing season, can resprout after burning or cutting, and, if kept moist, buried or broken branches will develop adventitious roots and grow. Stands seem to favor disturbed and flow-regulated rivers, but establish well in pristine areas, too. Under optimum conditions riparian areas can be converted to a dense thicket in less than 10 years (Hansen et al. 1995). Once established, stands are extremely difficult to eradicate, requiring cutting and herbicide application on stumps to prevent resprouting (Smith 1989).

LOCAL DESCRIPTION:

With Chaco Wash, 12 of the invasive *Tamarix chinensis* were mapped in 2003. This woody perennial forms dense stands through the wash, but no significant expansion was noted between 1974 and 2003.

ALLIANCE: *Populus fremontii* Seasonally Flooded Woodland Alliance

Translated name:	Fremont Cottonwood Seasonally Flooded Woodland Alliance
Unique identifier:	A.654
Classification approach:	International Vegetation Classification (IVC)

SUMMARY

Vegetation types within this alliance occur primarily on relatively flat floodplains (3-5% slope) along low-gradient rivers. Stands are found as gallery forests along perennial or seasonally intermittent streams and springs. They typically occupy the more mesic or hydric areas of the floodplain. Elevations range from 400-2000 m. Soils are derived from alluvial materials, deposited in stratified layers of clays, sands, silts, and gravels. Soil textures are variable but mainly sandy. Surface water is present for extended periods during the growing season, but is absent by the end of the growing season. The water table after flooding ceases is variable, extending from saturated to well below the ground surface. Adjacent upland communities are typically pinyon-juniper or oak shrublands. Communities within this alliance are classified as seasonally flooded woodlands. The canopy is dominated by open stands of *Populus fremontii* generally forming 30-70% cover. *Salix geyeriana* commonly occurs in the shrub layer in the Nevada stands. In New Mexico, the herbaceous layer is dominated by *Muhlenbergia rigens* with 30% cover. No other information on species composition is available.

CLASSIFICATION COMMENTS:

This alliance is poorly studied; further inventory and classification work are needed for all *Populus fremontii* communities. This is hindered by the alteration of species structure and composition that has occurred in most remaining stands because of hydrologic alterations, exotic species invasions, grazing, and other human impacts.

VEGETATION HIERARCHY:

Formation Class	II - Woodland
Formation Subclass	II.B - Deciduous woodland
Formation Group	II.B.2 - Cold-deciduous woodland
Formation Subgroup	II.B.2.N - Natural/Semi-natural cold-deciduous woodland

Formation Name	II.B.2.N.c - Seasonally flooded cold-deciduous woodland
Alliance Name	<i>Populus fremontii</i> Seasonally Flooded Woodland Alliance

UNITED STATES DISTRIBUTION: AZ? NM, NV

GLOBAL DISTRIBUTION: Mexico? United States

GLOBAL RANGE:

This alliance is presently reported only from Nevada and New Mexico. Given the range of *Populus fremontii*, the alliance may occur in other southwestern states, or in northern Mexico.

STATE STATUS: S2 (20Jan2008)

VEGETATION:

Communities within this alliance are classified as seasonally flooded woodlands. The canopy is dominated by open stands of *Populus fremontii* generally forming 30-70% cover. *Salix geyeriana* commonly occurs in the shrub layer in the Nevada stands. In New Mexico, the herbaceous layer is dominated by *Muhlenbergia rigens* with 30% cover (Bourgeron et al. 1995). No other information on species composition is available.

VEGETATION STRUCTURE:

The tree stratum is dominated by tall (10-25 m) single-stemmed, broad-leaved deciduous trees. The canopy is typically open (25-60%) depending on the stand. The shrub layer, when present, is typically dominated by multi-stemmed cold-deciduous shrubs; percent cover data are not available. The herbaceous layer is dominated by one or two graminoid species ranging from 25-60% cover.

WETLAND INDICATOR: Yes

ENVIRONMENTAL SUMMARY:

Vegetation types within this alliance occur primarily on relatively flat floodplains (3-5% slope) along low-gradient rivers. Stands are found as gallery forests along perennial or seasonally intermittent streams and springs. They typically occupy the more mesic or hydric areas of the floodplain. Elevations range from 400 to 2000 m. Soils are derived from alluvial materials, deposited in stratified layers of clays, sands, silts, and gravels. Soil textures are variable but mainly sandy. Surface water is present for extended periods during the growing season, but is absent by the end of the growing season. The water table after flooding ceases is variable, extending from saturated to well below the ground surface. Adjacent upland communities are typically pinyon-juniper or oak shrublands.

LOCAL DESCRIPTION:

The cottonwood stands along Chaco Wash were planted roughly 30 years ago and their current structure is defined in Hanna and Floyd-Hanna (2003). Considerable hybridization has occurred, and the trees are a mix of what is apparently *Populus angustifolia* and hybrids of this species with *P. fremontii*. Therefore, there is no perfect NVC association. We will tentatively use the association above for its description in CHCU.

This association was mapped along the Chaco, Fajada, and Gallo Washes in 2003 and the health and reproductive status of *Populus* stands in Chaco Wash was evaluated. Trees are either *Populus fremontii*, or they show leaf characteristics that suggest hybridization of *Populus angustifolia* and *Populus fremontii*. The trees were planted between 1930 and 1950, so it is assumed that the largest (i.e., oldest) trees were approximately 60 years old. The stands also showed considerable variation in size structure across the wash; in contrast to the vigorous re-sprouting in the eastern portion of the park there was virtually no regeneration in the western portion. All size classes were represented in what appears to be a healthy sustainable population in some areas. Elk grazing has reduced the vigor of some stands.

3.3.6 Potential new vegetation alliances from accuracy assessment fieldwork

The following are brief local descriptions of vegetation alliances that were documented during the accuracy assessment phase of this project. Component associations of the following alliances should be considered to better describe the vegetation types found in CHCU that were not documented during the field inventorying phase. Additional field work is necessary in order to properly document these vegetation types as occurring in CHCU. Finally, these vegetation types are not reflected in the vegetation map, but the park may update the vegetation map after reviewing the AA plots listed under each new alliance. Refer to Appendix D for field notes from the AA crews that further describe these types to the association level. Appendix D also describes a potential new association for *Verbesina enceliodes* – *Portulaca oleracea*. No alliance exists for this type and it is not included in the described alliances below.

ALLIANCE: *Artemisia filifolia* Shrubland Alliance (fig. 31)

Translated name: Sand Sagebrush Shrubland Alliance
 Unique identifier: A.816
 Classification approach: International Vegetation Classification (IVC)

LOCAL DESCRIPTION:

This vegetation type primarily was sampled on the southeastern portion of the park between Chacra Mesa and the park border (Plots 255, 257-259). This vegetation type, however, was observed as occurring throughout the park in areas of aolian sand deposits (fig. 31).

AA PLOTS: 6, 127, 196, 255, 257, 258, 259



Figure 31. Plot CHCU AA-127. *Artemisia filifolia* Shrubland Alliance

ALLIANCE: *Cercocarpus montanus* Shrubland Alliance

Translated name: Mountain-mahogany Shrubland Alliance
 Unique identifier: A.896
 Classification approach: International Vegetation Classification (IVC)

LOCAL DESCRIPTION:

A total of seven plots collected during the accuracy assessment phase did not correspond with the *Purshia stansburiana* – *Cercocarpus montanus* / *Ephedra torreyana* shrubland association created and mapped in this project. In these seven plots, *Purshia stansburiana* was not present and *Artemisia nova* was the most common dominating understory species (figs 32 - 35).

AA PLOTS: 46, 49, 138, 140, 143, 187, 227



Figure 32. Plot CHCU AA 46. *Cercocarpus montanus* Shrubland Alliance



Figure 33. Plot CHCU AA 49. *Cercocarpus montanus* Shrubland



Figure 34. Plot CHCU AA 49. *Cercocarpus montanus* Shrubland



Figure 35. Plot CHCU AA 187. *Cercocarpus montanus* / *Artemisia nova* / Mixed graminoids

ALLIANCE: *Purshia (stansburiana, mexicana)* Shrubland Alliance

Translated name:	(Stansbury's Cliffrose, Mexican Cliffrose) Shrubland Alliance
Unique identifier:	A.883
Classification approach:	International Vegetation Classification (IVC)

LOCAL DESCRIPTION:

This type was first described as *Purshia stansburiana* / *Artemisia nova* Shrubland, Appendix D). Often the dominant shrub associated with either *Purshia stansburiana*, *Cercocarpus montanus* or *Purshia stansburiana* – *Cercocarpus montanus* dominated polygons was *Artemisia nova*. *Ephedra torreyana* was usually present, but rarely the dominant “understory” shrub below the tall shrub stratum.

AA PLOTS: 21, 22, 23, 25

ALLIANCE: *Pinus edulis* - (*Juniperus* spp.) Woodland Alliance

Translated name:	Two-needle Pinyon - (Juniper species) Woodland Alliance
Unique identifier:	A.516
Classification approach:	International Vegetation Classification (IVC)

LOCAL DESCRIPTION

A total of seven woodland plots collected during the accuracy assessment phase did not correspond directly with the *Pinus edulis* – *Juniperus* spp. / *Cercocarpus montanus* Woodland association mapped in the vegetation map. All of the plots are located on Chacra Mesa and lack *Cercocarpus montanus*. Associated dominant understory species include *Atriplex canescens*, *Artemisia tridentata*, *Artemisia nova*, *Bouteloua gracilis* and *Purshia stansburiana*. Additional component associations are believed to be present on Chacra Mesa in addition to the *Cercocarpus montanus* association (figs. 36, 37, 38, and 39).

AA PLOTS: 240, 254, 284, 286, 294, 311, 314



Figure 36. Plot CHCU AA 254. *Pinus edulis* – *Juniperus* spp. *Artemisia tridentata* Woodland



Figure 37. Plot CHCU AA 284. *Pinus edulis* – *Juniperus monosperma* / *Bouteloua gracilis* Woodland



Figure 38. Plot CHCU AA 286. *Pinus edulis* – *Juniperus* spp. Cliff/rocky area



Figure 39. Plot CHCU AA 314. *Pinus edulis* – *Juniperus* spp. / *Atriplex canescens* Woodland

ALLIANCE: Weedy forbs (Non-NVC)

LOCAL DESCRIPTION:

This vegetation type primarily describes areas dominated by any mixture of *Verbesina encelioides* (golden crown-beard), *Portulaca oleracea* (little hogweed) and *Salsola kali*. Three AA plots document these types as occurring in CHCU. The *Verbesina encelioides* type was primarily observed in the southwestern portion of the park. *Portulaca oleracea* and *Salsola kali* were observed as occurring as dominants throughout the park (figs. 40 and 41).

AA PLOTS: 52, 304, 306



Figure 40. Plot CHCU AA 52. *Verbesina encelioides* Annual Herbaceous Vegetation



Figure 41. Plot CHCU AA 304. *Salsola kali* weedy vegetation

Table 11. Cameras used and file names for the photographs collected for the vegetation mapping project

Camera	Filename(s)
Canon S500	Files from this camera have a 3 digit number followed by a 3 or 4 digit value separated by a dash (e.g. 108-873). The number preceding the dash indicates a camera generated folder on the flash card while the second value is the image number. These were recorded in the field in this manner
Olympus C700UZ	These filenames are all preceded by the letter P and then a 7 digit number. The first three digits indicate the month and day the photo was taken. The following 5 digits indicate the frame number. These are camera generated filenames. These names are recorded in exactly this manner in the Access database.
HP Photosmart 315	These filenames follow two protocols as they were taken at different times. Some have a format similar to the Canon photos (e.g. xxx-yyyy) where the three digits preceding the dash are all the value 100 (a camera generated folder number) while the following digits indicate the frame number. These names match the records in the access database. Other files from this camera have had the names changed to represent the plot number followed by either a -1 or -2 or a letter indicating the azimuth of the photograph. These filenames are recorded the Access database.

3.4 Photographic database

Several photographs were taken at each plot location during both the inventory and accuracy assessment phases of the project. Each photograph was numbered and identifying details were entered into the CHCU PLOTS Database (Microsoft Access). The database is included on the CD that accompanies this report, and will be posted on the SCPN website (<http://science.nature.nps.gov/im/units/scpn/products.cfm>) and the USGS Vegetation Characterization Program web page (<http://biology.usgs.gov/npsveg/products/parkname.html>). Several different cameras were used during the course of this study by a variety of researchers so the file naming conventions differ. These cameras and file names are described in Table 11.

3.5 Vegetation map

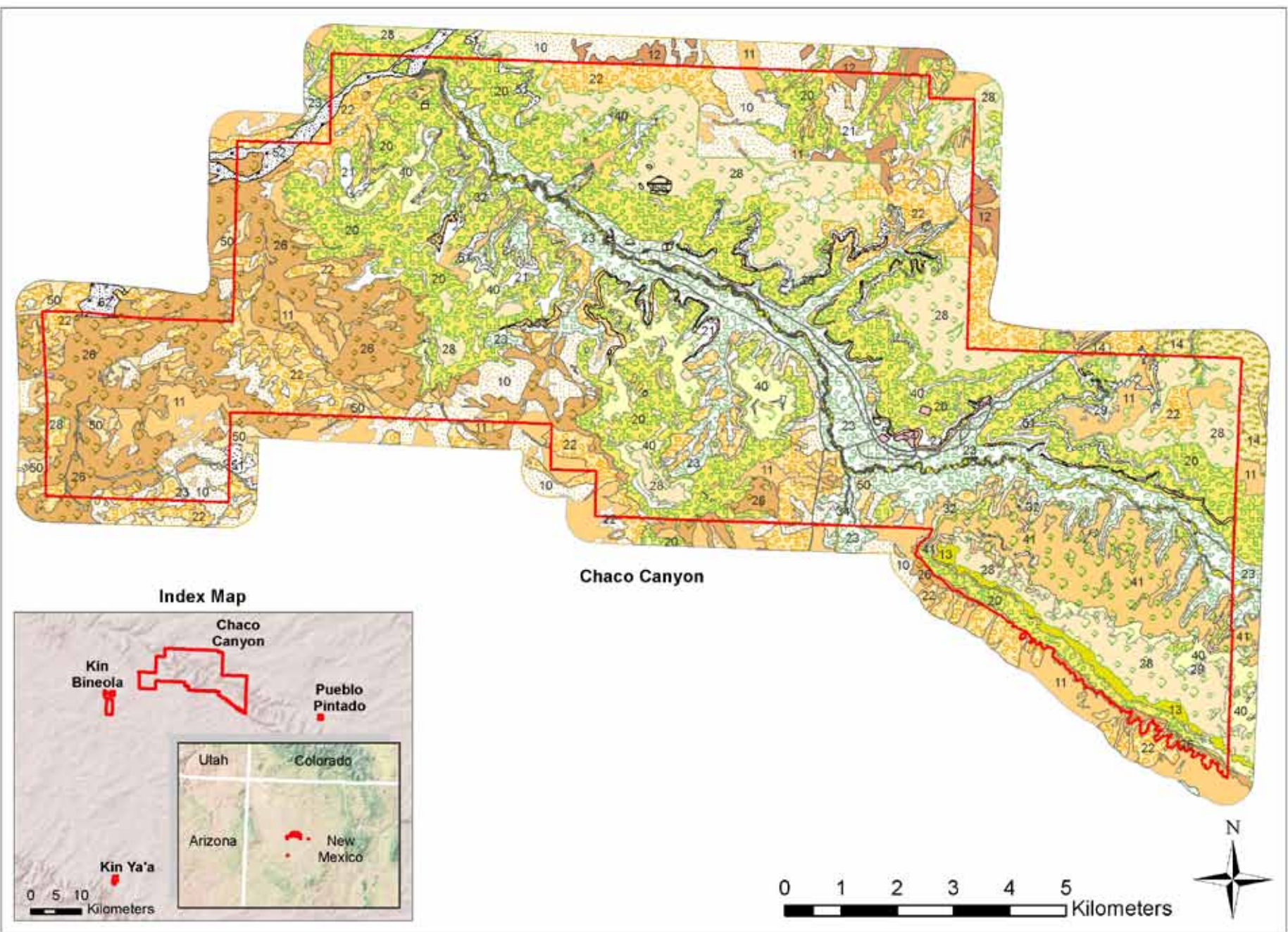
We mapped a total of 18,741 ha (43,311 ac) comprising CHCU and its environs. The area mapped within the park boundary was 13,987 ha (34,562 ac). For this project, we divided the park into four units for mapping: Chaco Canyon, Pueblo Pintado, Kin Ya'a, and Kin Bineola (table 12 and figs. 42, 43, and 44 (map legend)). Thirty map units were used to describe the landscape. Of these, seven were non-vegetated map units. All map units were developed using a combination of (1) an initial NVC vegetation classification

provided by NatureServe with input from park biologists and Bureau of Reclamation ecologists, (2) fieldwork, and (3) preliminary photo-interpretation. While developing the vegetation classification – map unit relationship, one often finds a many to one relationship. That is, many vegetation classes often end up being lumped into one map unit due to the difficulty in separating all of the individual vegetation classes from one another. The vegetation classification and map unit relationship is somewhat unique for CHCU in that, with only one exception, there is a one to one relationship of vegetation class to map unit. Table 13 shows the map units used for this effort.

The most frequently occurring map unit in the CHCU mapping area was #20, with 260 polygons. This was the only map unit containing a combination of

Table 12. Number of mapped acres in each map unit

Park unit	Mapped acres	
	Park	Park and buffer
Chaco Canyon	32,741	41,057
Pueblo Pintado	160	750
Kin Ya'a	260	1105
Kin Bineola	1,402	3,399
Total	34,562	46,311



Legend

 Park Boundary

Map Unit No., Vegetation Classification

-  10, James' Galleta - Alkali Sacaton Herbaceous Vegetation
-  11, Broom Snakeweed / Alkali Sacaton - James' Galleta Shrub Herbaceous Vegetation
-  12, Blue Grama Herbaceous Vegetation
-  13, Needle-and-Thread - Indian Ricegrass Herbaceous Vegetation
-  14, Grazed forb land
-  20, Black Sagebrush - Fourwing saltbush Shrubland
-  21, Stansbury Cliffrose - Torrey's Joint-fir Shrubland
-  22, Fourwing Saltbush Shrubland
-  23, Black Greasewood - Fourwing Saltbush Shrubland
-  25, Stretchberry Shrubland
-  26, Mound Saltbush / Alkali Sacaton - James' Galleta Shrub Herbaceous Vegetation
-  28, Fourwing Saltbush - Winterfat Shrubland
-  29, Basin Big Sagebrush / James' Galleta Shrubland
-  32, Shadscale / James' Galleta Shrubland
-  33, Coyote Willow Temporarily Flooded Shrubland
-  34, Salt-cedar species Semi-natural Temporarily Flooded Shrubland Alliance
-  35, Rubber Rabbitbrush Shrubland Alliance
-  40, One-seed Juniper / Alderleaf Mountain-mahogany Woodland
-  41, Two-needle Pinyon - Juniper species / Alderleaf Mountain-mahogany - Mixed Shrubs Woodland
-  42, Fremont Cottonwood / Coyote Willow Forest
-  50, Bare Soil
-  51, Bare Rock
-  52, Arroyo
-  53, Talus Slopes
-  54, NPS Developments
-  55, Transportation
-  56, Archaeological Sites
-  57, Containment Ponds

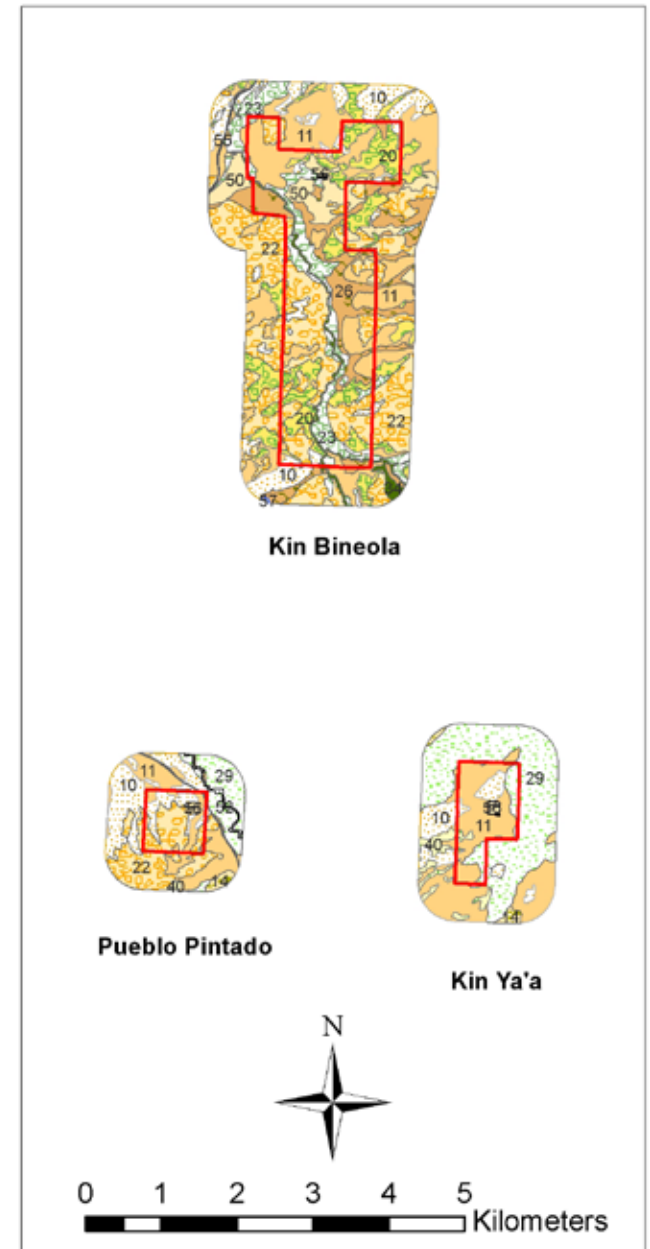


Figure 42. Vegetation map for Chaco Canyon, Kin Ya'a, Kin Bineola, and Pueblo Pintado at Chaco Culture National Historical Park

Table 13. Map units, vegetation types, and area statistics

Map unit	Vegetation association or alliance	Polygons (#)	Area (ac)	Area (ha)
10	<i>Pleuraphis jamesii</i> - <i>Sporobolus airoides</i> Herbaceous Vegetation	135	3,711	1,502
11	<i>Gutierrezia sarothrae</i> / <i>Sporobolus airoides</i> - <i>Pleuraphis jamesii</i> Shrub Herbaceous Vegetation	211	4,858	1,966
12	<i>Bouteloua gracilis</i> Herbaceous Vegetation	14	448	181
13	<i>Hesperostipa comata</i> - <i>Achnatherum hymenoides</i> Herbaceous Vegetation	2	231	93
14	Grazed forb land	7	447	181
20	<i>Artemisia nova</i> - <i>Atriplex canescens</i> Shrubland and <i>Ephedra torreyana</i> - (<i>Atriplex canescens</i> , <i>Atriplex confertifolia</i>) Sparse Vegetation	260	9,549	3,864
21	<i>Purshia stansburiana</i> - <i>Cercocarpus montanus</i> / <i>Ephedra torreyana</i> Shrubland	76	699	283
22	<i>Atriplex canescens</i> Shrubland Alliance	248	6,476	2,621
23	<i>Sarcobatus vermiculatus</i> - <i>Atriplex canescens</i> Shrubland	143	4,217	1,707
25	<i>Forestiera pubescens</i> Shrubland	32	15	6
26	<i>Atriplex obovata</i> / <i>Sporobolus airoides</i> - <i>Pleuraphis jamesii</i> Shrub Herbaceous Vegetation	108	4,551	1,842
28	<i>Atriplex canescens</i> - <i>Krascheninnikovia lanata</i> Shrubland	32	4,155	1,681
29	<i>Artemisia tridentata</i> ssp. <i>tridentata</i> / <i>Pleuraphis jamesii</i> Shrubland	34	716	290
32	<i>Atriplex confertifolia</i> / <i>Pleuraphis jamesii</i> Shrubland	19	570	231
33	<i>Salix exigua</i> Temporarily Flooded Shrubland	97	4	2
34	<i>Tamarix</i> spp. Semi-natural Temporarily Flooded Shrubland Alliance	584	92	37
35	<i>Ericameria nauseosa</i> Shrubland Alliance	7	386	156
40	<i>Juniperus monosperma</i> / <i>Cercocarpus montanus</i> Woodland	95	1,783	722
41	<i>Pinus edulis</i> - <i>Juniperus</i> spp. / <i>Cercocarpus montanus</i> Mixed Shrubs Woodland	53	1,430	579
42	<i>Populus fremontii</i> / <i>Salix exigua</i> Forest	650	27	11
50	Bare soil	25	542	219
51	Bare rock	76	541	219
52	Arroyo	4	394	159
53	Talus slopes	28	284	115
54	NPS developments	4	33	13
55	Transportation (roads, parking lots, etc.)	3	88	36
56	Archaeological sites	12	63	25
57	Containment ponds	3	1	0
Total		3,222	55,860	22,606

two vegetation associations: *Artemisia nova* - *Atriplex canescens* Shrubland and *Ephedra torreyana* - (*Atriplex canescens*, *Atriplex confertifolia*) Sparse Vegetation. The map unit encompassing the largest area was also map unit 20, covering 3,782 ha (9,345 ac), or about 20% of the project area. Area statistics for each of the map units are listed in Table 13. Each polygon

can be described using several vegetation codes. In addition, we have developed a vegetation code specifically for this mapping effort which has considerable local detail. We have also cross-walked the project specific vegetation code to several others that will permit analysis at various other scales and perspectives. These include two Anderson type land

cover codes and the ecological system codes. Using these, one can then link to external databases which may contain more information than provided here. This information is provided in a lookup table included within the geodatabase.

The individual map unit statistics are important in that they reveal much more than just the mean size. Often the mean area for each map unit is highly skewed. For example, many small polygons will show a higher frequency for the small polygons, yet a few large polygons may represent the greatest area. The use of mean as a summary statistic may then be highly misleading.

The utility of the vegetation map extends from the very basic to the very involved. Much depends upon the sophistication and imagination of the user. For more advanced investigations one might need a GIS analyst. The digital vegetation map is included with the project geodatabase and a hardcopy is attached as in the insert to this report.

3.6 Accuracy assessment

A summary of the number of A (primary) and B (secondary accuracy assessment points visited at CHCU is presented in Figure 43. We performed a fuzzy accuracy assessment on the digital thematic map for CHCU. Only vegetated map units were sampled and assessed. Five fuzzy classes that we considered using for this analysis are described in Table 9. The fuzzy accuracy assessment concept and class descriptions were first described by Gopal and Woodcock (1994) using fuzzy set theory described by Zadeh (1965).

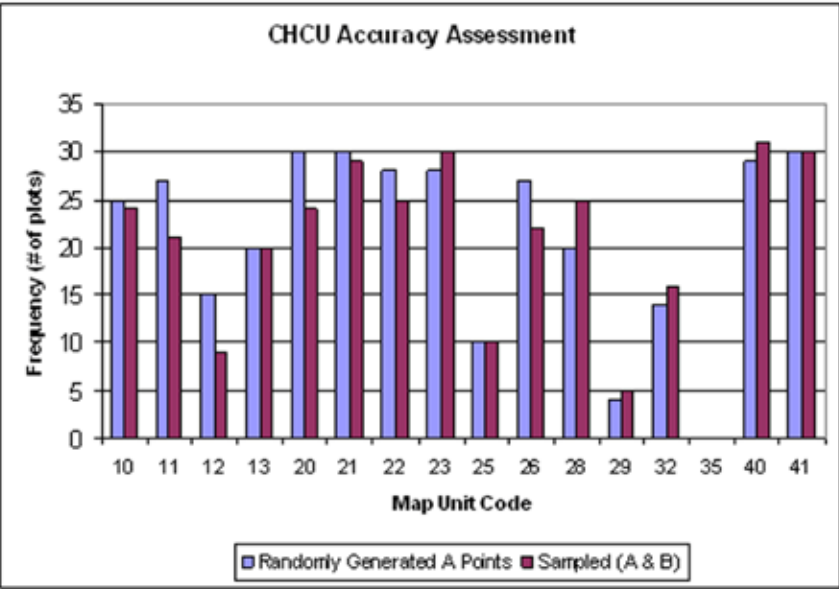


Figure 43. Summary of the number of A and B accuracy assessment points visited at CHCU

In this study, we analyzed the top three fuzzy classes that are considered “correct” using a contingency table. The overall map accuracies for each of the fuzzy classes are outlined in Table 14 and include a 90% confidence interval and Kappa statistic.

The contingency table, which provides detailed results for each map class, is shown in Tables 15, 16 and 17 for fuzzy classes 5, 4 and 3 respectively. We analyzed each map unit in terms of its individual accuracy, for omission and commission errors (producer’s accuracy and user’s accuracy respectively) for three levels of fuzzy accuracy and included a 90% confidence interval. A summary table of all map unit accuracies for both omission and commission for each fuzzy level is shown in Table 18. Individual map unit metrics are discussed below.

Table 14. Overall map accuracies for each fuzzy class

Fuzzy class	Overall map accuracy (%)	Confidence interval (%)	Kappa index (%)	Kappa confidence interval (%)	Overall omission error (%)	Overall commission error (%)
5	57.9	52.9 - 62.9	54.4	54.0 - 54.8	42.1	2.8
4	75.7	71.6 - 79.8	73.7	73.4 - 74.0	24.3	1.6
3	79.6	75.7 - 83.5	77.9	77.6 - 78.2	20.4	1.3

Table 15. Contingency table for fuzzy accuracy assessment level 5

																	Fuzzy 5	Sum	Commission Error %Correct	+/- (90% Confidence Interval)	Users Accuracy (Commission Error)
	Reference (Accuracy Assessment Field Data)																				
Predictive Data (Polygon Map Data)		10	11	12	13	20	21	22	23	25	26	28	29	32	35	40	41				
	10	12	2	1	0	1	0	1	0	0	5	1	0	0	0	0	0	0	23.0	52.2	19.3
	11	3	6	1	0	0	0	6	0	0	0	3	0	1	1	0	0	0	21.0	28.6	18.6
	12	5	1	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	9.0	22.2	28.4
	13	0	2	0	6	1	0	0	0	0	0	10	0	0	0	0	0	0	19.0	31.6	20.2
	20	1	0	1	1	13	2	2	2	0	0	0	0	1	0	0	0	0	23.0	56.5	19.2
	21	0	0	0	0	4	14	0	1	0	0	0	0	0	0	0	1	0	20.0	70.0	19.4
	22	5	0	0	0	1	0	10	1	0	0	0	0	0	1	1	0	0	19.0	52.6	21.5
	23	2	0	0	0	1	0	2	17	0	1	1	0	0	0	0	0	0	24.0	70.8	17.3
	25	0	0	0	0	0	1	0	0	5	0	0	0	0	0	0	2	0	8.0	62.5	34.4
	26	3	0	0	0	0	0	0	0	3	0	9	1	0	3	0	0	0	19.0	47.4	21.5
	28	1	3	1	1	4	0	8	0	0	0	7	0	0	0	0	0	0	25.0	28.0	16.8
	29	0	0	0	0	0	0	0	0	0	0	0	2	0	1	0	0	0	3.0	66.7	61.4
	32	0	0	0	0	0	0	0	0	1	0	0	3	0	11	0	0	0	15.0	73.3	22.1
	35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	n/a	n/a
	40	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	21	2	25.0	84.0	14.1
41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	27	27.0	100.0	1.9	
Sum		32	14	6	8	26	18	29	25	5	15	27	2	17	3	24	29	Total samples = 280 Total correct = 162			
% Accurate		37.5	42.9	33.3	75.0	50.0	77.8	34.5	68.0	100	60.0	25.9	100	64.7	0.0	87.5	93.1				
+/- (90% Confidence Interval)		15.6	25.3	40.0	31.4	18.1	18.9	16.2	17.3	10.0	24.1	15.7	25.0	22.0	16.7	13.2	9.5				
Overall total accuracy = 57.9% (lower and upper c.i.: 52.9 and 62.9)												Overall kappa index 54.4% (lower and upper c.i.: 54.0 and 54.8)									

Producers Accuracy (Omission Error)

* Confidence Interval (C.I.) is 90% two-sided limit

Table 16. Contingency table for fuzzy accuracy assessment level 4

Users Accuracy (Commission Error)																					
+/- (90% Confidence Interval)			Commission Error %Correct		Sum		Fuzzy 4														
		Reference (Accuracy Assessment Field Data)																			
Predictive Data (Polygon Map Data)		10	11	12	13	20	21	22	23	25	26	28	29	32	35	40	41				
	10	22	0	1	0	0	0	0	0	0	1	0	0	0	1	0	0	24.0	91.7	11.4	
	11	3	9	1	0	0	0	4	0	0	0	3	0	0	1	0	0	21.0	42.9	20.1	
	12	1	2	6	0	0	0	0	0	0	0	0	0	0	0	0	0	9.0	66.7	31.4	
	13	0	3	1	14	1	0	0	0	0	0	0	0	0	0	0	0	19.0	73.7	19.2	
	20	1	0	0	0	17	1	2	2	0	0	0	0	1	0	0	0	24.0	70.8	17.3	
	21	0	0	0	0	1	26	0	1	0	0	0	0	0	0	1	0	29.0	89.7	11.0	
	22	1	1	0	0	0	0	19	1	0	0	0	0	1	1	0	0	24.0	79.2	15.7	
	23	1	0	0	0	1	0	0	24	0	0	0	0	0	0	0	0	26.0	92.3	10.5	
	25	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	1	0	8.0	87.5	25.5
	26	3	0	0	0	0	0	0	3	0	11	1	0	2	0	0	0	20.0	55.0	20.8	
	28	0	1	2	0	7	0	6	0	0	0	10	0	0	0	0	0	26.0	38.5	17.6	
	29	0	0	0	0	0	0	1	0	0	0	0	3	0	1	0	0	5.0	60.0	46.0	
	32	0	0	0	0	1	0	0	0	0	0	2	0	12	0	0	0	15.0	80.0	20.3	
	35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	n/a	n/a	
	40	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	27	33.0	81.8	12.6	
41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	30.0	100.0	1.7		
Sum		32	16	10	14	28	28	32	31	7	12	16	3	16	4	29	35	Total samples = 313			
% Accurate		68.8	56.3	60.0	100	60.7	92.9	59.4	77.4	100	91.7	62.5	100	75.0	0.0	93.1	85.7	Total correct = 237			
+/- (90% Confidence Interval)		15.0	23.5	30.5	3.6	17.0	9.8	15.8	14.0	7.1	17.3	23.0	16.7	20.9	12.5	9.5	11.2				
Overall total accuracy = 75.7% (lower and upper C.I.*: 71.6 and 79.8)												Overall kappa index 73.8% (lower and upper c.i.: 73.4 and 74.0)									

Producers Accuracy (Omission Error)

* Confidence Interval (C.I.) is 90% two-sided limit

Table 17. Contingency table for fuzzy accuracy assessment level 3

																		Fuzzy 3	Sum	Commission Error %Correct	+/- (90% Confidence Interval)	Users Accuracy (Commission Error)
	Reference (Accuracy Assessment Field Data)																					
Predictive Data (Polygon Map Data)		10	11	12	13	20	21	22	23	25	26	28	29	32	35	40	41					
	10	22	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	24.0	91.7	11.4	
	11	4	11	0	0	0	0	3	0	0	0	1	1	0	1	0	0	0	21.0	52.4	20.3	
	12	1	1	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9.0	77.8	28.4	
	13	0	0	0	18	1	0	0	0	0	0	0	0	0	0	0	0	0	19.0	94.7	11.1	
	20	0	0	0	0	19	1	1	2	0	0	0	0	1	0	0	0	0	24.0	79.2	15.7	
	21	0	0	0	0	1	26	0	1	0	0	0	0	0	0	0	1	0	29.0	89.7	11.0	
	22	1	1	0	0	0	0	20	1	0	0	0	0	0	1	0	0	0	24.0	83.3	14.6	
	23	0	0	0	0	1	0	0	25	0	0	0	0	0	0	0	0	0	26.0	96.2	8.1	
	25	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	1	0	8.0	87.5	25.5	
	26	3	0	0	0	0	0	0	3	0	11	1	0	2	0	0	0	0	20.0	55.0	20.8	
	28	0	0	2	0	4	0	7	0	0	0	12	0	0	1	0	0	0	26.0	46.2	18.0	
	29	0	0	0	0	0	0	1	0	0	0	0	3	0	1	0	0	0	5.0	60.0	46.0	
	32	0	0	0	0	1	0	0	0	0	0	2	0	12	0	0	0	0	15.0	80.0	20.3	
	35	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0	n/a	n/a	
	40	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	27	5	33.0	81.8	12.6	
41	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	30	30.0	100.0	1.7		
Sum		31	13	9	18	27	28	33	32	7	12	16	4	16	3	29	35	Total samples = 313				
% Accurate		71.0	84.6	77.8	100	70.4	92.9	60.6	78.1	100	91.7	75.0	75.0	75.0	0.0	93.1	85.7	Total correct = 250				
+/- (90% Confidence Interval)		15.0	20.3	28.4	2.8	16.3	9.8	15.5	13.6	7.1	17.3	20.9	48.1	20.9	16.7	9.5	11.2					
Overall total accuracy = 79.9% (lower and upper c.i.: 75.7 and 83.5)												Overall kappa index 77.9% (lower and upper c.i.: 77.6 and 78.2)										
Producers Accuracy (Omission Error)																						

* Confidence Interval (C.I.) is 90% two-sided limit

Table 18. Map unit accuracies for omission and commission errors at all fuzzy levels

Map unit	Map unit name	Fuzzy 5		Fuzzy 4		Fuzzy 3	
		User's accuracy (%)	Producer's accuracy (%)	User's accuracy (%)	Producer's accuracy (%)	User's accuracy (%)	Producer's accuracy (%)
10	<i>Pleuraphis jamesii</i> - <i>Sporobolus airoides</i> Herbaceous Vegetation	37.5	52.2	68.8	91.7	71.0	91.7
11	<i>Gutierrezia sarothrae</i> / <i>Sporobolus airoides</i> - <i>Pleuraphis jamesii</i> Shrub Herbaceous	42.9	28.6	56.3	42.9	84.6	52.4
12	<i>Bouteloua gracilis</i> Herbaceous Vegetation	33.3	22.2	60.0	66.7	77.8	77.8
13	<i>Hesperostipa comata</i> - <i>Achnatherum hymenoides</i> Herbaceous Vegetation	75.0	31.6	100.0	73.7	100.0	94.7
20	<i>Artemisia nova</i> - <i>Atriplex canescens</i> Shrubland	50.0	56.5	60.7	70.8	70.4	79.2
	<i>Ephedra torreyana</i> - (<i>Atriplex canescens</i> , <i>Atriplex confertifolia</i>) Sparse Vegetation						
21	<i>Purshia stansburiana</i> - <i>Cercocarpus montanus</i> / <i>Ephedra torreyana</i> Shrubland	77.8	70.0	92.9	89.7	92.9	89.7
22	<i>Atriplex canescens</i> Shrubland	34.5	52.6	59.4	79.2	60.6	83.3
23	<i>Sarcobatus vermiculatus</i> - <i>Atriplex canescens</i> Shrubland	68.0	70.8	77.4	92.3	78.1	96.2
25	<i>Forestiera pubescens</i> Shrubland	100.0	62.5	100.0	87.5	100.0	87.5
26	<i>Atriplex obovata</i> / <i>Sporobolus airoides</i> - <i>Pleuraphis jamesii</i> Shrub Herbaceous Vegetation	60.0	47.4	91.7	55.0	91.7	52.4
28	<i>Atriplex canescens</i> - <i>Krascheninnikovia lanata</i> Shrubland	25.9	28.0	62.5	38.5	75.0	46.2
29	<i>Artemisia tridentata</i> ssp. <i>tridentata</i> / <i>Pleuraphis jamesii</i> Shrubland	100.0	66.8	100.0	60.0	75.0	60.0%
32	<i>Atriplex confertifolia</i> / <i>Pleuraphis jamesii</i> Shrubland	64.7	73.3	75.0	80.0	75.0	80.0%
35	<i>Ericameria nauseosa</i> Shrubland Alliance	0.0	Null	0.0	Null	0.0	Null
40	<i>Juniperus monosperma</i> / <i>Cercocarpus montanus</i> Woodland	87.5	84.0	93.1	81.8	93.1	81.8
41	<i>Pinus edulis</i> - <i>Juniperus</i> spp. / <i>Cercocarpus montanus</i> Woodland	93.1	100.0	85.7	100.0	85.7	100.0%

Because the accuracy assessment field effort involves more sampling points than the inventory effort to describe the vegetation, it also tends to find “new” or not yet described vegetation types. These undescribed types then are difficult to place within the current map unit classification and, consequently, impossible to assign to a correct or incorrect class because they were never in the set of types to be considered. Because these “new” types have some

characteristics of existing types they can be assigned as either correct or incorrect at fuzzy level’s 4 and 3. To handle these odd types we removed them from consideration for fuzzy level 5. Therefore, if one examines the contingency tables one will see that there are less data points for fuzzy level 5 than for fuzzy levels 4 and 3.

Figure 44. Error distribution for fuzzy class 5

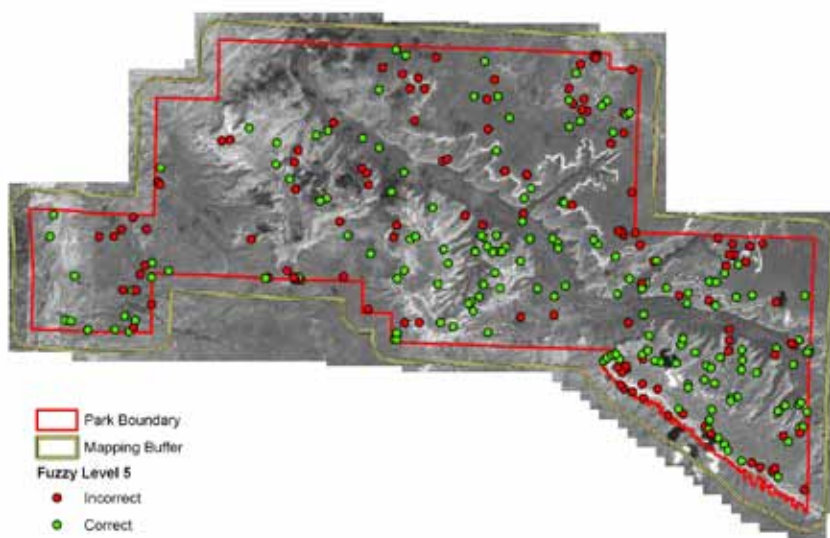


Figure 45. Error distribution for fuzzy class 4

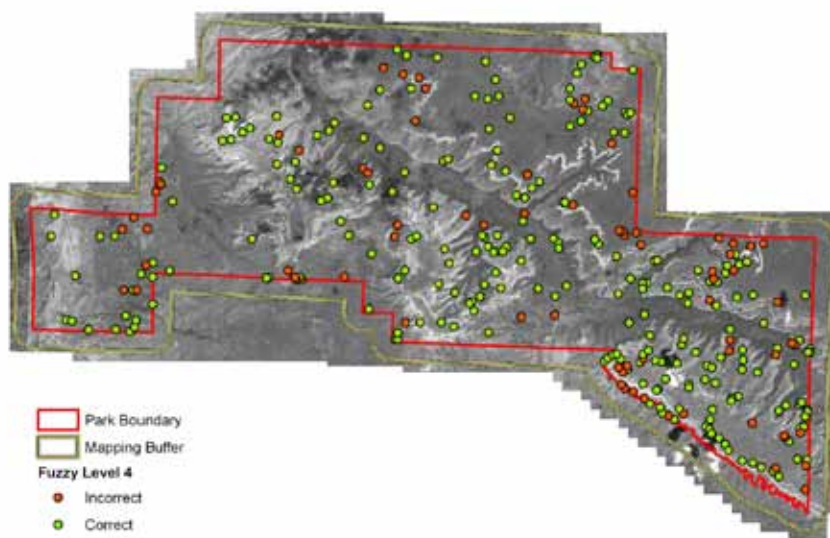
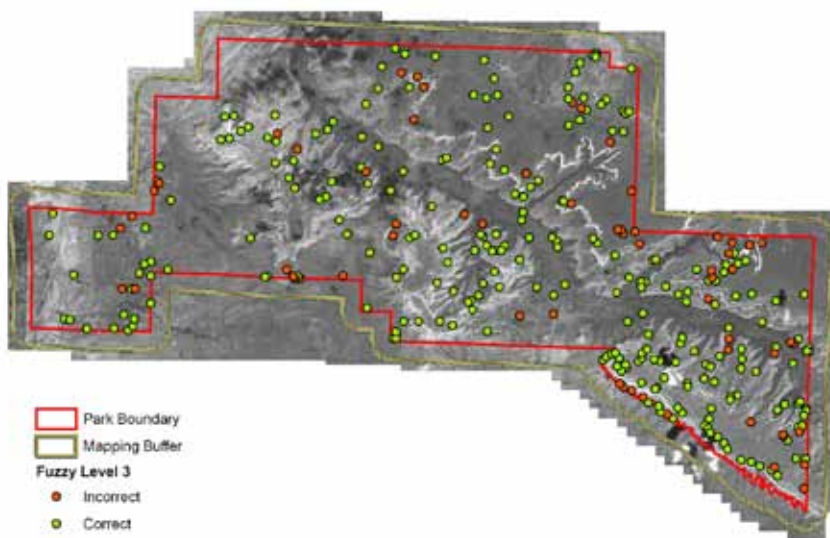


Figure 46. Error distribution for fuzzy class 3



3.7 Comparison of mean overall and omission/commission errors between fuzzy levels

Predictably, overall map accuracy increases as one relaxes requirements for individual map unit membership. Table 14 shows the increasing overall accuracy from fuzzy level 5 to fuzzy level 3. We also include a Kappa statistic as a metric of the overall accuracy. This statistic assumes that a certain number of correct classifications will occur by chance. Therefore, the Kappa statistic penalizes the overall map accuracy. The mean error for omission and commission also increases as one relaxes map unit membership requirements. Figures 45, 46, and 47 illustrate the error distribution for the accuracy assessment points from fuzzy level 5 to fuzzy level 3.

3.8 Potential “new” vegetation associations

The AA field crew described a number of vegetation types that were not originally described in the vegetation inventory phase of the project and identified them as potential new types (Appendix D). Because the AA crews sample a much greater number of points covering a greater area than the original sampling, it is common for new types to be discovered during accuracy assessment. The following list describes the unsampled vegetation types and their salient alliance or association. Refer to Appendix D and earlier in the results section for local vegetation descriptions.

3.8.1 Unsampled vegetation types discovered during AA and described in the field:

- *gracilis* Woodland
 - *Pinus edulis* – *Juniperus* spp. / Sparse Understory (or Rockland) Woodland
 - Weedy forbs (e.g., *Salsola kali*, *Portulaca oleraceae*, *Verbesina enceliodes*)
- #### 3.8.2 Corresponding NVC associations/alliances for “newly discovered” vegetation types in CHCU:
- *Artemisia filifolia* Shrubland Alliance
 - *Artemisia filifolia* Colorado Plateau Shrubland
 - *Cercocarpus montanus* Shrubland Alliance
 - *Cercocarpus montanus* / *Bouteloua curtipendula* Shrubland
 - *Cercocarpus montanus* / *Rhus trilobata* var. *trilobata* Shrubland
 - *Juniperus monosperma* Woodland Alliance
 - *Pinus edulis* – *Juniperus* spp. Woodland Alliance
 - *Pinus edulis* - (*Juniperus monosperma*) / *Bouteloua gracilis* Woodland
 - *Pinus edulis* - *Juniperus* spp. / *Artemisia tridentata* (ssp. *wyomingensis*, ssp. *vaseyana*) Woodland
 - *Pinus edulis* - *Juniperus* spp. / *Cercocarpus montanus* - Mixed Shrubs Woodland
-
- *Artemisia filifolia* – *Atriplex canescens* Shrubland
 - *Cercocarpus montanus* / *Artemisia nova* Shrubland
 - *Juniperus monosperma* / *Artemisia nova* Woodland
 - *Pinus edulis* – *Juniperus* spp. / *Artemisia tridentata* Woodland
 - *Pinus edulis* – *Juniperus* spp. / *Bouteloua*

4 Discussion

4.1 NVC classification

Chaco Culture National Historic Park has some of the largest and oldest grazing exclosures in the southwestern United States. Portions of the park have been fenced from sheep and cattle since the early 1940's, and new, fenced, acquisitions have been added during the last decade (Floyd et al 2003). Although grazing by elk continues, the absence of domestic grazing pressure in Chaco Wash has allowed *Populus* and *Salix* stands to recover (Floyd-Hanna and Hanna 2003). In the canyon bottom, *Sarcobatus vermiculatus* and *Atriplex canescens* stands may represent a biotic potential for this community rarely attained under the ubiquitous grazing pressure experienced outside of exclosures. This community supports well-developed biotic crusts containing nitrogen-fixing species, a well-developed grass understory (*Sporobolus airoides* and *Pleuraphis jamesii*), as well as high biodiversity in forb species.

Shrubs with roots that are associated with nitrogen fixing species occur in several of the associations described in this report, including

- CEGI000713 *Juniperus monosperma* / *Cercocarpus montanus* Woodland
- CEG000780 *Pinus edulis*-*Juniperus* spp. / *Cercocarpus montanus* Woodland
- the provisional *Purshia stansburiana*-*Cercocarpus montanus* / *Ephedra torreyana* shrubland.

Actinorhizal symbionts (*Frankia* sp.) in *Cercocarpus montanus* and *Purshia* species are well-documented elsewhere and it is likely that these species play a key role in nitrogen dynamics in the CHCU communities (Verghese and Misra 2002).

Lycium pallidum occurs throughout CHCU and is associated with archeological sites (Potter 1974). We found it in many associations, but not in large enough quantities to be visible in aerial photography.

This study did not address the floristically rich vegetation that is supported by numerous seeps found throughout CHCU. A separate study is addressing these habitats (Anne Cully, personal communication), which are often small and below the minimum mapping unit. However, we did describe one seep that appeared to have vegetation similar to many other seeps we have observed. Shrubs included *Foresteria pubescens*, *Ribes cereum* and *Rhus trilobata*. Stands of *Artemisia tridentata*, *Cercocarpus montanus*, and other shrubs may occur in areas adjacent to seeps. In at least one case we observed *Populus* trees.

4.2 Conservation status

Due to their conservation status (NatureServe 2006), four of the associations described in this report bear special attention:

- *Pleuraphis jamesii* - *Sporobolus airoides* Herbaceous Vegetation is globally ranked at G2G3 with a rounded status of G2 and is considered globally imperiled
- *Hesperostipa comata* - *Achnatherum hymenoides* Herbaceous Vegetation is globally ranked as G2?, with a rounded global status of G2 and is considered globally imperiled.
- *Foresteria pubescens* Shrubland is globally ranked as G1G2 with a rounded status of G1 and is considered critically imperiled.
- *Artemisia tridentata* ssp. *tridentata* / *Pleuraphis jamesii* Shrubland is globally ranked as G2G4 with a rounded status of G#. It is considered vulnerable.

For additional information about these types, see the descriptions in this document.

4.3 Non-native species

A survey of CHCU has identified four species of concern out of a potential list of 17 invasive species known from this geographic area (Floyd-Hanna and Hanna

2004).

- *Salsola kali* is the most pervasive of these, occurring throughout much of the bottomland adjacent to Chaco Wash, which is also the area most heavily impacted by visitation.
- *Halogeton glomeratus* is abundant in limited areas, especially Razito-Shiprock soils.
- *Kochia scoparia* is common, although rarely in high densities.
- *Bromus tectorum* occurs throughout the lower elevations of Chaco Canyon and is most common along roadsides.

Although we did not look exhaustively at factors that might promote invasions of these habitats, our pilot data suggest strongly that soil type and texture may be important factors that determine which areas in the bottomland of CHCU might be susceptible to invasions of exotics. Two soil types; Notal Silty Clay Loam and Battlerock-notal complexes, are the most susceptible. Conversely, the presence of moderate or well developed microbial crusts correlated with lower invasive densities. Finally, roads, with their concomitant levels of disturbance, contribute to invasions of exotic species in the canyon bottomland. (Floyd-Hanna and Hanna 2004)

4.4 Aerial photography and base imagery

The photographs used for the project were of adequate scale but of poor quality. A green tinge covers all the photographs. It is difficult to determine, without looking at the original negatives, whether the problem was from the original acquisition of the development process. The IKONOS base imagery used for the project was generally very good. The only drawbacks were the slight low cloud cover in the southeast section by Chacra Mesa and some high thin cloud cover in the center of the image. The IKONOS imagery was provided in three separate images, but it would have been preferable to have these

all as one image.

4.5 Photo-interpretation and map units

Since vegetation at CHCU had a limited amount of ecological variability, we were able to maintain a one-to-one relationship of vegetation association to map unit in all but one instance. In larger, more diverse parks, one typically will have to collapse a number of associations into one map unit. All of the descriptions of vegetated map units in this report include the national characteristics as well as the local variations.

4.6 Map accuracy

Judging the accuracy of a thematic map is as important as the actual creation of that map, yet the methods for collecting and interpreting accuracy assessment data remains problematic. While the concept of accuracy assessment is straightforward, the practicality (measurement and expression) can be tricky (Foody 2001). Foody (2001, 2002), and even the park mapping protocols (ESRI et al. 1994) discuss the many sources of thematic error which may lead to misinterpretation of accuracy assessments. For example, the improper use or reporting of accuracy data may lead to over or underestimation of map unit accuracy. Other sources of problems include inaccurate reference data, dataset misregistration, poor or inappropriate sampling design, spatial variation of accuracy, error magnitude, and procedural errors during the creation of the digital products. This project has attempted to address these potential pitfalls and the problem areas are discussed below.

The term ground truth can be misleading as even classification of a location on the ground is subject to interpretation (Foody 2001, Bird et al. 2000). Using dichotomous keys to determine vegetation association leaves room for the interpretation of vegetative characteristics and even presence of species. For example, the original vegetation classification may have

been developed from samples collected during significantly different climatic periods (e.g. wet year vs. dry year) or even during different seasons). A temporal change in the landscape due to disturbance (e.g., fire, landslides, flooding etc.) between the time of photo acquisition/interpretation and the time of field sampling is also common. Also, vegetation association descriptions depend heavily on estimations of cover that, despite extensive training of field crew prior to sampling, could be different enough from the actual values to produce erroneous site classifications.

Exacerbating all of these potential problems is the underlying, but false assumption that the vegetation classes are discrete rather than continuous. We know that vegetation types are rarely distinguished by sharp boundaries but instead, grade into one another (Gleason 1917, 1926, Whittaker 1956, 1962, Curtis 1959). The degree of gradation is often related to the steepness of the environmental gradient. “Steep environmental gradients tend to produce distinct vegetation boundaries where gradual environmental gradients tend to produce wider transition zones between vegetation types.” (TNC and ESRI, 1994). Environmental gradients within CHCU tend to be less severe than in parks with a greater elevation range. Thus, assigning a location or sample to a single discrete vegetation type or description is suspect.

The field key also assumes that any accuracy samples described in a plot have already been described when in reality a new association may be confounding the classification in the field. Implicit is that the vegetation classification is complete and correct. Because the emphasis for this project is on the vegetation map rather than the vegetation classification, we have not assessed the classification. In a statistically perfect world, another round of samples would have been collected to test the vegetation classification prior to any mapping. The prohibitive costs for

this test preclude it from ever happening. Given that source data may be rife with problems, Foody (2001) suggests that “... the typical accuracy assessment is rather a measurement of the degree of agreement or correspondence between the two data sets, rather than an evaluation of the closeness of the thematic map to reality.” This is probably the case with this project.

A useful and increasingly popular strategy that helps to compensate for the inherent difficulties in assessing the accuracy of maps is the use of qualifiers, or fuzzy procedures. The use of “fuzzy” techniques to describe the accuracy of thematic maps is a useful, if somewhat ambiguous tool. In this case, one is forced to interpret the thematic accuracy of a product from multiple perspectives and with a number of caveats. There is no “one” figure to use as an estimate for either overall or individual map unit accuracy. It is now standard to couch the results in the statistical parlance of confidence intervals and sample sizes. Its use in many thematic products today stems from the recognition that the binary approach of either “right” or “wrong” belies the true nature of most map units and even the view of the person or persons providing the “reference” data. The great utility of a fuzzy approach is that it acknowledges degrees of correctness. Only occasionally do map units have discrete boundaries; more often grading into one another over distances ranging from a few to hundreds of meters. The necessity of drawing discrete lines representing non-discrete entities requires other than a binary approach. The relationship between this “fuzzy” approach to map accuracy assessment is described below.

Given the detail of the map and the variability of the vegetation, we believe the accuracy assessment for CHCU was successful for several reasons. First, we made sure that the overall sampling design followed closely the protocols described by the NVMP. We did make some allowances for practicality and statistical

necessities. Second, boundaries between polygons were minimally avoided, but not so much so that only large homogenous areas were sampled. Third, the distribution of the sample points was excellent and most map units received an adequate number of points per type from which to draw general conclusions at each fuzzy level (Appendix D). Finally, the spatial distribution of the AA sample points across the park was very good and the field crews made every effort to reach many difficult sites.

4.7 The accuracy standard for the NBS/NPS Vegetation Mapping Program

The Vegetation Mapping Program standards for accuracy are 80% for both overall accuracy and individual class accuracy. However, the program recognizes that these levels of accuracy may be difficult to achieve:

“Given that vegetation mapping is necessarily interpretive, it is recommended that relaxed

requirements be used in terms of acceptable levels of error as well as confidence levels in the estimate. Otherwise, regardless how carefully the mapping process is carried out, it is unlikely that accuracy requirements will be met.” (ESRI et al. 1994)..

With the advent of fuzzy accuracy procedures we now have the capability to express the accuracy of a thematic map in several ways, ranging from very stringent to relaxed. The choice of which standard to use would depend on the subject being mapped. In the case of vegetation mapping, the preferred rigor would be relaxed (fuzzy 3) vs. stringent (fuzzy 5).

When the vegetation mapping program began, fuzzy accuracy was recognized, but considered experimental with little use or publication. At this point, twelve years after the publication of the Accuracy Assessment Procedures (ESRI et al. 1994), much theory has been published but not necessarily used in applications. Even in the vegetation mapping program these techniques have not been used to any great extent. In addition to this project we know of only six others vegetation mapping projects that have used fuzzy accuracy assessment (Hansen et al. 2004, a, b, c, Fenton et al. 2007, Salas et al. 2005 and Cogan et al. 2005). It has also been used informally at Zion National Park (Cogan – pers comm.). The overall fuzzy accuracies of the mapping for these parks are presented in Table 19 for comparative purposes. The trends across this small set are similar. Given the suggestions from the program standards and the results of four fuzzy accuracy assessments within the vegetation mapping program, we recommend that the standard for stated and recognized accuracy be fuzzy level 3. The definition for fuzzy level 3 as proposed by Gopal and Woodcock (1994) is “Reasonable or Acceptable Answer: Maybe not the best possible answer but it is acceptable; this answer does not pose a problem to the user if it is seen on the map. Correct”. Therefore, it would seem

Table 19. Comparisons of fuzzy accuracies among seven national park units

National park unit	Fuzzy 5	Fuzzy 4	Fuzzy 3
Rocky Mountain National Park ¹	50.3%	74.7%	86.7%
Walnut Canyon National Monument ²	50.0%	69.2%	96.9%
Sunset Crater Volcano National Monument ³	53.9%	70.3%	86.8%
Wupatki National Monument ⁴	59.1%	69.7%	92.2%
Lake Meredith National Recreation Area ⁵	60.4%	67.7 %	80.9 %
Grand Teton National Park ⁶	65.5%	72.8%	82.4%
Chaco Culture National Historical Park ⁷	57.9%	75.7%	79.9%
Mean	56.7%	71.4%	86.5%

¹ Salas et al. 2005

² Hansen et al. 2004a

³ Hansen et al. 2004b

⁴ Hansen et al. 2004c

⁵ Fenton et al. 2007

⁶ Cogan et al. 2005

⁷ This document

reasonable to accept this level as a program standard.

4.8 Recommendations

We suggest that this project could be improved in two areas. First, accuracy assessment results could be incorporated into the final product. Typically, one reports the accuracy and lets it go at that. However, a great deal of information could be incorporated from the accuracy assessment to improve the map. This process, though, is not simply intersecting the AA points with the polygon data and then updating with the AA vegetation label. Often, AA points may land within inclusions, inside an otherwise homogenous polygon, and updating without careful consideration of each point would not be recommended. Because the AA data for CHCU revealed potential new vegetation types, the park might also want to flag these areas for consideration into the vegetation classification of the park should additional funds become available. In addition, the park may want to consider further work in the outlier units of Kin Ya'a, Kin Bineola and Pueblo Pintado. These areas received scant attention due to their extreme remoteness and it is likely that the vegetation interpreted for these areas is different from that described for the main unit.

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Appendix A: Plant Association Key

Key to the plant vegetation associations at Chaco Culture National Historical Park

1. A. Riparian vegetation associated with periodic flooding in Chaco Wash: (2)
 B. Upland habitats not periodically flooded by Chaco Wash: (3)
2. A. Trees present, may be accompanied by dense willow thickets:
Populus Fremontii Temporarily Flooded Woodland Alliance
 B. Trees absent, stands dominated by dense shrub thickets: (4)
3. A. Trees present: (5)
 B. Trees absent, communities dominated by grasses or shrubs: (6)
4. A. Dominated by *Salix exigua* thickets; *Tamarix chinensis* and other shrubs may be present:
Salix (exigua, interior) Temporarily Flooded Shrubland Alliance
 B. Dominated by *Tamarix chinensis* stands:
Tamarix spp. Semi-natural Temporarily Flooded Shrubland Alliance
5. A. Wet, seep habitats, trees deciduous: *Populus*, *Forestiera* (not described in this report)
 B. Dry, non-seep habitats, trees coniferous: (7)
6. A. Seep habitats lacking trees, dominated by *Forestiera pubescens*, *Rhus trilobata*, *Ribes cereum*:
Forestiera pubescens Shrubland
 B. Dry habitats on bench adjacent to Chaco Wash, on canyon floor, or slopes and uplands: (8)
7. A. *Pinus edulis* present, often co-dominant with *Juniperus monosperma* and shrubs:
Pinus edulis - *Juniperus* spp. / *Cercocarpus montanus* - Mixed Shrubs Woodland
 B. *Pinus edulis* lacking, *Juniperus monosperma* present, often sparse:
Juniperus monosperma / *Cercocarpus montanus* Woodland
8. A. Dominated by shrubs: (9)
 B. Shrubs lacking or very sparse, dominated by grasses and forbs: (10)
9. A. Open, low shrubland dominated by *Atriplex obovata*, low, matted form, vegetation sparse on Menefee shales or alluviums:
Atriplex obovata / *Sporobolus airoides* - *Pleuraphis jamesii* Shrub Herbaceous Vegetation
 B. Shrublands sparse to dense characterized by single-rooted low and tall shrubs: (11)
10. A. Grasslands actively grazed outside NPS boundary, dominated by *Bouteloua gracilis* and sparse forbs:
Bouteloua gracilis Herbaceous Vegetation
 B. Dense diverse grass cover of matted or perennial grasses, typically within NPS boundary: (12)
11. A. Dense tall shrublands dominated by *Sarcobatus vermiculatus*:
Sarcobatus vermiculatus - *Atriplex canescens* Shrubland (provisional)
 B. *Sarcobatus vermiculatus* absent: (13)

12. A. Grasslands dominated by *Sporobolus airoides* and *Pleuraphis jamesii*, often on flat canyon floor:
***Pleuraphis jamesii* - *Sporobolus airoides* Herbaceous Vegetation**
 - B. Grass stands dominated by perennial bunchgrasses, interspersed in piñon-juniper woodlands or shrublands:
***Hesperostipa comata* - *Achnatherum hymenoides* Herbaceous Vegetation**
13. A. Shrublands of low elevations (include) dominated by *Ericameria nauseosus*, *Artemisia tridentata*, and scattered other shrubs including *Atriplex canescens*:
***Ericameria nauseosa* Shrubland Alliance**
 - B. Shrublands not as above: (14)
14. A. Sparse open shrubland with *Gutierrezia sarothrae* (less than 25% cover) accompanied by perennial bunch grasses:
***Gutierrezia sarothrae* / *Sporobolus airoides* - *Pleuraphis jamesii* Shrub Herbaceous Vegetation**
 - B. Shrubs dense, greater than 25% cover: (15)
15. A. *Artemisia* species present: (16)
 - B. *Artemisia* species absent: (17)
16. A. Dense *Artemisia tridentata* stands, often dominated by grasses:
***Artemisia tridentata* ssp. *tridentata* / *Pleuraphis jamesii* Shrubland**
 - B. *Artemisia nova* dominant or co-dominate with other low shrubs such as *Atriplex canescens* and *Ephedra viridis*:
***Artemisia nova* - *Atriplex canescens* Shrubland (provisional)**
17. A. Shrubland dominated by *Purshia stansburiana*, *Cercocarpus montanus*, with rich forb understory, Cliffhouse sandstones higher elevations (include):
***Purshia stansburiana*-*Cercocarpus montanus*/*Ephedra torreyana* Shrubland (provisional)**
 - B. Shrublands lacking *Purshia stansburiana*: (18)
18. A. Low shrublands (generally less than 1 m) with shrubs including *Atriplex canescens* but *Atriplex confertifolia* either lacking or very sparse (less than 5% cover): (19)
 - B. Low shrublands (generally less than 1 m) with *Atriplex confertifolia* dominant and perennial bunchgrasses present, often at eroded base of cliffs:
***Atriplex confertifolia* / *Pleuraphis jamesii* Shrubland**
19. A. *Atriplex canescens* co-dominant with *Krascheninnikovia lanata*:
***Atriplex canescens* - *Krascheninnikovia lanata* Shrubland**
 - B. *Atriplex canescens* co-dominant with *Ephedra* species and other shrubs: (20)
20. A. *Ephedra torreyana* present with >25% cover:
***Ephedra torreyana* - (*Atriplex canescens*, *Atriplex confertifolia*) Sparse Vegetation**
 - B. *Atriplex canescens* dominant, but accompanied by a mix of other shrubs including *Lycium pallidum* (near archeological sites) and *Tetradymia canescens*: ***Atriplex canescens* Shrubland**

Appendix B

Chaco Culture National Historical Park plant community and map class lookup tables

Table B-1. Cross-reference of map units to vegetation types in the vegetation map of Chaco Culture National Historical Park

Map unit	Plant association or alliance
0	<i>Lycium pallidum</i> - <i>Atriplex canescens</i> / <i>Tetradymia canescens</i> Shrubland
10	<i>Pleuraphis jamesii</i> - <i>Sporobolus airoides</i> Herbaceous Vegetation
11	<i>Gutierrezia sarothrae</i> / <i>Sporobolus airoides</i> - <i>Pleuraphis jamesii</i> Shrub Herbaceous Vegetation
12	<i>Bouteloua gracilis</i> Herbaceous Vegetation
13	<i>Hesperostipa comata</i> - <i>Achnatherum hymenoides</i> Herbaceous Vegetation
14	Grazed forb land
20	<i>Artemisia nova</i> - <i>Atriplex canescens</i> Shrubland
20	<i>Ephedra torreyana</i> - (<i>Atriplex canescens</i> , <i>Atriplex confertifolia</i>) Sparse Vegetation
21	<i>Purshia stansburiana</i> - <i>Cercocarpus montanus</i> / <i>Ephedra torreyana</i> Shrubland
22	<i>Atriplex canescens</i> Shrubland Alliance
23	<i>Sarcobatus vermiculatus</i> - <i>Atriplex canescens</i> Shrubland
25	<i>Forestiera pubescens</i> Shrubland
26	<i>Atriplex obovata</i> / <i>Sporobolus airoides</i> - <i>Pleuraphis jamesii</i> Shrub Herbaceous Vegetation
28	<i>Atriplex canescens</i> - <i>Krascheninnikovia lanata</i> Shrubland
29	<i>Artemisia tridentata</i> ssp. <i>tridentata</i> / <i>Pleuraphis jamesii</i> Shrubland
32	<i>Atriplex confertifolia</i> / <i>Pleuraphis jamesii</i> Shrubland
33	<i>Salix exigua</i> Temporarily Flooded Shrubland
34	<i>Tamarix</i> spp. Semi-natural Temporarily Flooded Shrubland Alliance
35	<i>Ericameria nauseosa</i> Shrubland Alliance
40	<i>Juniperus monosperma</i> / <i>Cercocarpus montanus</i> Woodland
41	<i>Pinus edulis</i> - <i>Juniperus</i> spp. / <i>Cercocarpus montanus</i> - Mixed Shrubs Woodland
42	<i>Populus fremontii</i> / <i>Salix exigua</i> Forest
50	Bare soil
51	Bare rock
52	Arroyo
53	Talus slopes
54	NPS developments
55	Transportation
56	Archaeological sites
57	Containment ponds

Table B-2a. Classification of plant communities at Chaco Culture National Historical Park based on the 1997 U.S. National Vegetation Classification physiognomic-floristic hierarchy for terrestrial vegetation (FGDC 1997; Grossman et al. 1998). Table includes 1) NVCS classification status (E=established association within NVCS. P=provisional classification, and not yet accepted by NVCS; 2) number of plots in which the plant association is found. The vegetation of Chaco Wash was analyzed in an earlier project by Hanna and Floyd-Hanna and was not revisited for this study. So there are no plots to list, and "Chaco Wash" is entered in the plots column; 3) NatureServe Code, and 4) Map Unit to which the plant association has been assigned. If it was difficult to assign the vegetation type unequivocally to an association, then it was classified only to the alliance level and dashes appear in the association column.

Formation	Alliance	Association	Classification status	# of plots	NatureServe code	Map unit
Class: II Woodland						
Subclass: II.A - Evergreen woodland						
Group: II.A.4 - Temperate or subpolar needle-leaved evergreen woodland						
Subgroup: II.A.4.N - Natural/Semi-natural temperate or subpolar needle-leaved evergreen woodland						
A.4.N.a - Rounded-crowned temperate or subpolar needle-leaved evergreen woodland	<i>Pinus edulis</i> - (<i>Juniperus</i> spp.) Woodland Alliance	<i>Pinus edulis</i> - <i>Juniperus</i> spp. / <i>Cercocarpus montanus</i> - Mixed-Shrubs Woodland	E	8	CEGL000780	41
	<i>Juniperus monosperma</i> Woodland Alliance	<i>Juniperus monosperma</i> / <i>Cercocarpus montanus</i> Woodland	E	13	CEGL000713	40
Class: I Forest						
Subclass: I.B - Deciduous forest						
Group: I.B.2 - Cold-deciduous wood forest						
Subgroup: I.B.2.N - Natural/Semi-natural cold-deciduous forest						
II.B.2.N.d - Temporarily flooded cold-deciduous forest	<i>Populus fremontii</i> Temporarily Flooded Forest Alliance	<i>Populus fremontii</i> / <i>Salix exigua</i> Forest	E	Chaco Wash	CEGL000666	42
Class: III - Shrubland						
Subclass: III.A - Evergreen shrubland						
Group: III.A.4 - Microphyllous evergreen shrubland						
Subgroup: III.A.4.N - Natural/Semi-natural microphyllous evergreen shrubland						
III.A.4.N.a - Lowland microphyllous evergreen shrubland	<i>Artemisia nova</i> Shrubland Alliance	<i>Artemisia nova</i> - <i>Atriplex canescens</i> Shrubland	P	14	CEGL00XXX	20
	<i>Artemisia tridentata</i> (ssp. <i>tridentata</i> , ssp. <i>xericensis</i>) Shrubland Alliance	<i>Artemisia tridentata</i> ssp. <i>tridentata</i> / <i>Pleuraphis jamesii</i> Shrubland	E	2	CEGL001015	29

Formation	Alliance	Association	Classification Status	# of plots	NatureServe Code	Map unit
III.A.4.N.c - Temporarily flooded microphyllous shrubland	<i>Ericameria nauseosa</i> Shrubland Alliance	<i>Purshia stansburiana</i> - <i>Ephedra torreyana</i> Shrubland	E	Chaco Wash	A.835	35
	<i>Purshia (stansburiana, mexicana)</i> Shrubland Alliance		P	7	CEGL00XXX	21
	<i>Tamarix</i> spp. Semi-natural Temporarily Flooded Shrubland Alliance	--	E	Chaco Wash	A.842	34
Class: III - Shrubland						
Subclass: III.A - Evergreen shrubland						
Group: III.A.5 - Extremely xeromorphic evergreen shrubland						
Subgroup: III.A.5.N - Natural/Semi-natural extremely xeromorphic evergreen shrubland						
III.A.5.N.b - Facultatively deciduous extremely xeromorphic subdesert shrubland	<i>Atriplex canescens</i> Shrubland Alliance	<i>Atriplex canescens</i> Shrubland	E	17	CEGL001281	22
	<i>Atriplex canescens</i> Shrubland Alliance	<i>Atriplex canescens</i> - <i>Krascheninnikovia lanata</i> Shrubland	E	15	CEGL001285	28
	<i>Atriplex confertifolia</i> Shrubland Alliance	<i>Atriplex confertifolia</i> / <i>Pleuraphis jamesii</i> Shrubland	E	missing data	CEGL001304	32
		<i>Lycium pallidum</i> - <i>Atriplex canescens</i> / <i>Tetradymia canescens</i> Shrubland	P	6	CEGL00XXX	0
Class: III - Shrubland						
Subclass: III.B - Deciduous shrubland						
Group: III.B.2 - Cold-deciduous shrubland						
Subgroup: III.B.2.N - Natural/Semi-natural cold-deciduous shrubland						
III.B.2.N.d - Temporarily flooded cold-deciduous shrubland	<i>Forestiera pubescens</i> Temporarily Flooded Shrubland Alliance	<i>Forestiera pubescens</i> Shrubland	E	1	CEGL001168	25
	<i>Salix (exigua, interior)</i> Temporarily Flooded Shrubland Alliance	<i>Salix exigua</i> Temporarily Flooded Shrubland	E	Chaco Wash	CEGL001197	33
Class: III - Shrubland						
Subclass: III.B - Deciduous shrubland						
Group: III.B.3 - Extremely xeromorphic deciduous shrubland						
Subgroup: III.B.3.N - Natural/Semi-natural extremely xeromorphic deciduous shrubland						

Table B-2a *continued*

Formation	Alliance	Association	Classification status	# of plots	NatureServe code	Map unit
III.B.3.N.a - Extremely xeromorphic deciduous subdesert shrubland without succulents	<i>Sarcobatus vermiculatus</i> Shrubland Alliance	<i>Sarcobatus vermiculatus</i> - <i>Atriplex canescens</i> Shrubland	P	18	CEGL00XXX	23
Class V - Herbaceous Vegetation Subclass V.A - Perennial graminoid vegetation Group V.A.5 - Temperate or subpolar grassland Subgroup V.A.5.N - Natural/Semi-natural temperate or subpolar grassland						
V.A.5.N.d - Medium-tall bunch temperate or subpolar grassland	<i>Hesperostipa comata</i> Bunch Herbaceous Alliance	<i>Hesperostipa comata</i> - <i>Achnatherum hymenoides</i> Herbaceous Vegetation	E	2	CEGL001703	13
V.A.5.N.e - Short sod temperate or subpolar grassland	<i>Bouteloua gracilis</i> Herbaceous Alliance	<i>Bouteloua gracilis</i> Herbaceous Vegetation	E	1	CEGL001760	12
	<i>Pleuraphis jamesii</i> Herbaceous Alliance	<i>Pleuraphis jamesii</i> - <i>Sporobolus airoides</i> Herbaceous Vegetation	E	6	CEGL001778	10
Class V - Herbaceous Vegetation Subclass V.A - Perennial graminoid vegetation Group V.A.7 - Temperate or subpolar grassland with a sparse shrub layer Subgroup: V.A.7.N - Natural/Semi-natural temperate or subpolar grassland with a sparse shrub layer						
V.A.7.N.e - Medium-tall temperate or subpolar grassland with a sparse needle-leaved or microphyllous evergreen shrub layer	<i>Sporobolus airoides</i> - (<i>Pleuraphis jamesii</i>) Shrub Herbaceous Alliance	<i>Gutierrezia sarothrae</i> / <i>Sporobolus airoides</i> - <i>Pleuraphis jamesii</i> Shrub Herbaceous	E	6	CEGL001776	11
		<i>Atriplex obovata</i> / <i>Sporobolus airoides</i> - <i>Pleuraphis jamesii</i> Shrub Herbaceous Vegetation	E	10	CEGL001775	26
Class VII - Sparse Vegetation Subclass VII.C - Unconsolidated material sparse vegetation Group VII.C.3 - Sparsely vegetated soil slopes Subgroup: VII.C.3.N - Natural/Semi-natural sparsely vegetated soil slopes						
VII.C.3.N.b - Dry slopes	<i>Ephedra torreyana</i> Sparsely Vegetated Alliance	<i>Ephedra torreyana</i> - (<i>Atriplex canescens</i> , <i>Atriplex confertifolia</i>) Sparse Vegetation	E	11	CEGL005801	20

Table B-2b. Classification of plant communities at Chaco Culture National Historical Park based on the 1997 U.S. National Vegetation Classification physiognomic-floristic hierarchy for terrestrial vegetation (FGDC 1997; Grossman et al. 1998). This table, a continuation of Table B-2a, includes 1) Ecological system ID; and 2) Ecological System Name (Comer et al. 2003)(note: associations can occur in more than one ecological system type); 3) global conservaton status of association (NatureServe 2006); and 4) Map unit to which the plant association has been assigned. If it was difficult to assign the vegetation type unequivocally to an association, then it was classified only to the alliance level and dashes appear in the association column and no global status is given (n/a). If the vegetation type was a proposed type, then n/a was noted in all but the map unit column.

Formation	Alliance	Association	Ecological system ID	Ecological system name	Rounded global status	Map unit
Class: II Woodland						
Subclass: II.A - Evergreen woodland						
Group: II.A.4 - Temperate or subpolar needle-leaved evergreen woodland						
Subgroup: II.A.4.N - Natural/Semi-natural temperate or subpolar needle-leaved evergreen woodland						
A.4.N.a - Rounded-crowned temperate or subpolar needle-leaved evergreen woodland	Pinus edulis - (Juniperus spp.) Woodland Alliance	Pinus edulis - Juniperus spp. / Cercocarpus montanus - Mixed Shrubs Woodland	CES304.766	Colorado Plateau Pinyon-Juniper Shrubland	G5 - Secure	41
			CES304.767	Colorado Plateau Pinyon-Juniper Woodland		
			CES306.835	Southern Rocky Mountain Pinyon-Juniper Woodland		
	Juniperus monosperma Woodland Alliance	Juniperus monosperma / Cercocarpus montanus Woodland	CES303.664	Southwestern Great Plains Canyon	not yet ranked	40
			CES304.767	Colorado Plateau Pinyon-Juniper Woodland		
			CES304.782	Inter-Mountain Basins Juniper Savanna		
Class: I Forest						
Subclass: I.B - Deciduous forest						
Group: I.B.2 - Cold-deciduous forest						
Subgroup: I.B.2.N - Natural/Semi-natural cold-deciduous forest						

Table B-2b continued

Formation	Alliance	Association	Ecological system ID	Ecological system name	Rounded global status	Map unit
II.B.2.N.d- Temporarily flooded cold-deciduous forest	<i>Populus fremontii</i> Temporarily Flooded Forest Alliance	<i>Populus fremontii</i> / <i>Salix exigua</i> Forest	CES304.045	Grest Basin Foot-hill and Lower Montane Riparian Woodland and Shrubland	GNR - not yet ranked	42
			CES306.821	Rocky Mountain Lower Montane Riparian Woodland and Shrubland		

Class: III - Shrubland

Subclass: III.A - Evergreen shrubland

Group: III.A.4 - Microphyllous evergreen shrubland

Subgroup: III.A.4.N - Natural/Semi-natural microphyllous evergreen shrubland

III.A.4.N.a - Lowland microphyllous evergreen shrubland	<i>Artemisia nova</i> Shrubland Alliance	<i>Artemisia nova</i> - <i>Atriplex canescens</i> Shrubland	n/a	n/a	n/a	20
	<i>Artemisia tridentata</i> (ssp. <i>tridentata</i> , ssp. <i>xericensis</i>) Shrubland Alliance	<i>Artemisia tridentata</i> ssp. <i>tridentata</i> / <i>Pleuraphis jamesii</i> Shrubland	CES304.788	Inter-Mountain Basins Semi-Desert Shrub-Steppe	G3 - Vulnerable	29
			CES304.777	Inter-Mountain Basins Big Sagebrush Shrubland		
			CES304.778	Inter-Mountain Basins Big Sagebrush Steppe		
	<i>Ericameria nauseosa</i> Shrubland Alliance	--	CES304.777	Inter-Mountain Basins Big Sagebrush Shrubland	G5 - Secure	35
	<i>Purshia (stansburiana, mexicana)</i> Shrubland Alliance	<i>Purshia stansburiana</i> - <i>Ephedra torreyana</i> Shrubland	n/a	n/a	n/a	21
III.A.4.N.c - Temporarily flooded microphyllous shrubland	<i>Tamarix</i> spp. Semi-natural Temporarily Flooded Shrubland Alliance	--	n/a	n/a	n/a	34

Class: III - Shrubland

Subclass: III.A - Evergreen shrubland

Group: III.A.5 - Extremely xeromorphic evergreen shrubland

Subgroup: III.A.5.N - Natural/Semi-natural extremely xeromorphic evergreen shrubland

Table B-2b *continued*

Formation	Alliance	Association	Ecological system ID	Ecological system name	Rounded global status	Map unit
III.A.5.N.b - Facultatively deciduous extremely xeromorphic subdesert shrubland	Atriplex canescens Shrubland Alliance	Atriplex canescens Shrubland	CES302.749	Sonora-Mojave Mixed Salt Desert Scrub	G5 - Secure	22
			CES304.784	Inter-Mountain Basins Mixed Salt Desert Scrub		
	Atriplex canescens Shrubland Alliance	Atriplex canescens - Krascheninnikovia lanata Shrubland	CES302.749	Sonora-Mojave Mixed Salt Desert Scrub	G5 - Secure	28
	Atriplex confertifolia Shrubland Alliance	Atriplex confertifolia / Pleuraphis jamesii Shrubland	CES304.784	Inter-Mountain Basins Mixed Salt Desert Scrub	G4 - Apparently Secure	32
			CES304.784	Inter-Mountain Basins Mixed Salt Desert Scrub		
		Lycium pallidum - Atriplex canescens / Tetradymia canescens Shrubland	n/a	n/a	n/a	0
Class: III - Shrubland						
Subclass: III.B - Deciduous shrubland						
Group: III.B.2 - Cold-deciduous shrubland						
Subgroup: III.B.2.N - Natural/Semi-natural cold-deciduous shrubland						
III.B.2.N.d - Temporarily flooded cold-deciduous shrubland	Forestiera pubescens Temporarily Flooded Shrubland Alliance	Forestiera pubescens Shrubland	CES306.821	Rocky Mountain Lower Montane Riparian Woodland and Shrubland	G1 - Critically Imperiled	25
			CES303.676	Northwestern Great Plains Floodplain		
	Salix (exigua, interior) Temporarily Flooded Shrubland Alliance	Salix exigua Temporarily Flooded Shrubland	CES306.821	Rocky Mountain Lower Montane Riparian Woodland and Shrubland	G5 - Secure	33

Table B-2b *continued*

Formation	Alliance	Association	Ecological system ID	Ecological system name	Rounded global status	Map unit
Class: III - Shrubland						
Subclass: III.B - Deciduous shrubland						
Group: III.B.3 - Extremely xeromorphic deciduous shrubland						
Subgroup: II.B.3.N - Natural/Semi-natural extremely xeromorphic deciduous shrubland						
III.B.3.N.a - Extremely xeromorphic deciduous subdesert shrubland without succulents	<i>Sarcobatus vermiculatus</i> Shrubland Alliance	<i>Sarcobatus vermiculatus</i> - <i>Atriplex canescens</i> Shrubland	n/a	n/a	n/a	23
Class V - Herbaceous Vegetation						
Subclass V.A - Perennial graminoid vegetation						
Group V.A.5 - Temperate or subpolar grassland						
Subgroup V.A.5.N - Natural/Semi-natural temperate or subpolar grassland						
V.A.5.N.d - Medium-tall bunch temperate or subpolar grassland	<i>Hesperostipa comata</i> Bunch Herbaceous Alliance	<i>Hesperostipa comata</i> - <i>Achnatherum hymenoides</i> Herbaceous Vegetation	CES303.817	Western Great Plains Foothill and Piedmont Grassland	G2 - Imperiled	13
			CES304.787	Inter-Mountain Basins Semi-Desert Grassland		
V.A.5.N.e - Short sod temperate or subpolar grassland	<i>Bouteloua gracilis</i> Herbaceous Alliance	<i>Bouteloua gracilis</i> Herbaceous Vegetation	CES303.672	Western Great Plains Shortgrass Prairie	G4 - Apparently Secure	12
			CES303.817	Western Great Plains Foothill and Piedmont Grassland		
			CES304.787	Inter-Mountain Basins Semi-Desert Grassland		
			CES302.735	Apacherian-Chihuahuan Semi-Desert Grassland and Steppe		
	<i>Pleuraphis jamesii</i> Herbaceous Alliance	<i>Pleuraphis jamesii</i> - <i>Sporobolus airoides</i> Herbaceous Vegetation			G2 - Imperiled	10

Table B-2b *continued*

Formation	Alliance	Association	Ecological system ID	Ecological system name	Rounded global status	Map unit
Class V - Herbaceous Vegetation						
Subclass V.A - Perennial graminoid vegetation						
Group V.A.7 - Temperate or subpolar grassland with a sparse shrub layer						
Subgroup: V.A.7.N - Natural/Semi-natural temperate or subpolar grassland with a sparse shrub layer						
V.A.7.N.e - Medium-tall temperate or subpolar grassland with a sparse needle-leaved or microphyllous evergreen shrub layer	Sporobolus airoides - (Pleuraphis jamesii) Shrub Herbaceous Alliance	Gutierrezia sarothrae / Sporobolus airoides - Pleuraphis jamesii Shrub Herbaceous	CES304.788	Inter-Mountain Basins Semi-Desert Shrub-Steppe	GU - Unrankable	11
			CES304.784	Inter-Mountain Basins Mixed Salt Desert Scrub	GU - Unrankable	26
			CES304.787	Inter-Mountain Basins Semi-Desert Grassland		
			CES304.788	Inter-Mountain Basins Semi-Desert Shrub-Steppe		
Class VII - Sparse Vegetation						
Subclass VII.C - Unconsolidated material sparse vegetation						
Group VII.C.3 - Sparsely vegetated soil slopes						
Subgroup: VII.C.3.N - Natural/Semi-natural sparsely vegetated soil slopes						
VII.C.3.N.b - Dry slopes	Ephedra torreyana Sparsely Vegetated Alliance	Ephedra torreyana - (Atriplex canescens, Atriplex confertifolia) Sparse Vegetation	CES304.765	Colorado Plateau Mixed Bedrock Canyon and Tableland	GNR - Not Yet Ranked	20

Appendix C

Developing a MSAVI image for Chaco Canyon National Historical Site

David Salas

Arid environments are noted for having a high soil reflectivity component that makes the use of other vegetation indices such as the NDVI (Normalized Difference Vegetation Index) difficult. Two indices have since been developed for use in arid environments and have received widespread acceptance. These are the Soil Adjusted Vegetation Index (Huete 1988) and the Modified Soil Adjusted Vegetation Index (Qi et al. 1994).

Soil Adjusted Vegetation Index (SAVI)

According to Sensemann et al. 1996.

Several attempts have been made to develop vegetation indices that minimize variance of the spectral reflectance due to background soil type. The objective is to isolate the portion of the reflectance attributable to differences in the vegetation. Two types of indices have come from this effort: (1) vegetation indices that require the use of constant value in the equation to account for variance due to soil and (2) vegetation indices that require a defined line of soil in the reflectance signal. A soil line is a line or plane in n-dimensional spectral space that passes through imagery pixels that are completely void of vegetation (i.e., bare ground). In general, pixels increasingly distant from the soil line in a spectral space represent a relative increasing vegetation amount, cover, or vigor. The SAVI, introduced by Huete in 1988, attempts to account for variation in soil background. The key to the SAVI is the equation's soil constant, L. L is used to minimize the variability due to soil and differs depending on the general density

of vegetation. In introducing the SAVI, Huete (1988) correlated SAVI with a Leaf Area Index of broad-leaf cotton and above ground biomass of narrow-leaf grass test plots.

Modified Soil Adjusted Vegetation Index (MSAVI)

The MSAVI (Qi et al. 1994) is a modification of Huete's original SAVI. MSAVI attempts to further account for differences in soil background by replacing the constant L with a dynamic soil-adjusting factor. The MSAVI was applied to a cover measure of cotton and was demonstrated to better account for soil variability than SAVI on cotton field test plots (Qi et al. 1994). The following equation is used for calculating MSAVI:

$$MSAVI = (2NIR + 1 - \sqrt{(2NIR + 1)^2 - 8(NIR - RED)}) / 2$$

Where MSAVI = Modified Soil Adjusted Vegetation Index; NIR = Near Infrared Band; SQRT = Square Root; and Red = Red Band

In this study we chose to use MSAVI as the vegetation index to use since it was found to be less sensitive to soil brightness variations including shadows than other spectral vegetation indices (Chehbouni et al., 1994). This is of importance since the contribution of bare soil to scene reflectance is very significant for partially covered surfaces.

The IKONOS imagery for CHCU came as three separate images. These images were merged together and averaged where they

overlapped. Using the MSAVI formula within ERDAS Imagine, we produced a primary MSAVI image. This image was then further processed with the “clump” and “eliminate” processes to simplify the data and produce the final MSAVI image used to determine vegetative cover.

We include a mean value and standard deviation for MSAVI for each polygon attribute in the geodatabase and within the main unit of the Park. The values range from very low vegetation density with a value of 1 to high density with a value of 5. The standard deviation gives one an idea of the homogeneity of the vegetation density within each polygon. High standard deviation values suggest a wider variability of density while low values show greater uniformity.

Appendix D

Chaco Culture National Historical Park:

Accuracy assessment data collection summary (Field set 1 of 2)

Dan Cogan, Jim Von Loh, and Cory Bolen

8/30/2006

David Salas of the Bureau of Reclamation, Remote Sensing and GIS Group provided approximately 360 accuracy assessment points (AA) for Chaco Culture National Historical Park (CHCU) as GPS coordinates in an Excel spreadsheet. Two sets of AA points were prepared, i.e., an A list and a B list. A total of 337 points were randomly selected, stratified by the map units used for vegetation mapping, buffered to 40 m from the polygon edges, and further screened so as not to fall on inaccessible isolated mesa tops and vertical canyon walls. The coordinates were downloaded to Garmin hand-held GPS receivers as an aid to navigation in the field.

Notebooks were supplied to field team members and included the following resources:

- printed copies of the digital orthophotography marked with the locations of the accuracy assessment points
- a field key to mapping units
- hard-copy lists of GPS coordinates for reference
- a species list
- lists of plant associations and mapping units

AA point sampling maps included the unlabeled vegetation polygons produced during the photointerpretation process and the location of AA points with the point number. These map sheets were a valuable planning and landscape evaluation aid during the field effort. AA

field forms were supplied to each field team member on an as-needed basis.

Weather was an issue during the time we collected Field Set 1, as rain fell almost daily onsite and within the watershed causing heavy flows in the arroyos and washes in and around CHCU. Sites such as Chacra Mesa could not be accessed because of the dangerous flows coursing down incised drainages up to 2 m deep. Shallow washes sometimes spread up to 75 m-wide, saturating fine sediments which acted like quicksand making affected areas impassable. Lightning and rainfall during the field day caused some slow-down of work and shortened one field day by approximately two hours. However, because of the rainfall, the vegetation of CHCU was comparatively lush for this environment and likely exhibited cover and composition values higher than those recorded during classification plot sampling. Some plant species present this year were unidentifiable during classification plot field work.

The following actions/observations occurred/were made during this effort:

- CHCU NPS Resource Manager Brad Shattuck outlined two areas of canyon heads where access was restricted due to culturally sensitive resources and field researchers could not enter. The two corresponding map book tiles that contain the two forbidden areas are B07 and Ell.
- The field key was ineffective due to

the presence of low cover of dwarf and short shrubs and also because of the intermixing of diagnostic species.

- Many AA points fell in ecotones along polygon edges (near polygon lines) making them difficult to classify in the field.
- Canopy cover by *Juniperus monosperma* trees was below 10% and often below 5% in nearly every stand sampled.
- The stands visited typically supported sparse *Purshia stansburiana* tall shrubs or *Cercocarpus montanus* short shrubs, but rarely were these species observed together.
- In general, AA points were widely distributed with significant travel time (average of 600 m - 800 m) required to access each point.
- Visiting AA point centroids on mesas involved locating and accessing breaks in cliff walls, a time-consuming activity.
- In general, *Atriplex canescens* and *Gutierrezia sarothrae* were the most commonly occurring shrubs in the mapping area.
- Due to the recent drought year(s?) much of the *Gutierrezia sarothrae* that were probably alive during the field sampling and aerial photo acquisition phase, were dead in the accuracy assessment phase of the project. Dead *Gutierrezia sarothrae* cover was estimated, when relevant (>1% cover), on the data sheets.
- The *Atriplex confertifolia* / *Pleuraphis jamesii* association sampled on the mesas north of Chaco Canyon was most often dominated by *Atriplex canescens* not *Atriplex confertifolia*.
- In the few AA points that we sampled which had been mapped as *Ephedra torreyana* Sparse

Vegetation, *Ephedra torreyana* cover had increased as compared to other areas observed previously in the park, and occurred as a co-dominant with a variety of other shrubs (*Artemisia nova*, *Ericameria nauseosa*, *Atriplex canescens*). A complementary map unit for this type is *Artemisia nova* – *Atriplex canescens* shrubland, which also describes *Ephedra torreyana* as occurring.

- Map unit 20 describes two different associations:
 - *Artemisia nova* – *Atriplex canescens* Shrubland
 - *Ephedra torreyana* – (*Atriplex canescens*, *Atriplex confertifolia*) Sparse Vegetation

Whenever an unknown species was encountered during AA data collection, a sample was collected and examined by a botanist and/or keyed to accurately establish its identity. Each form received a quality assurance overview by the senior field ecologist. Digital photographs were taken of AA sites during data collection, collected on flash cards, and downloaded to the senior ecologist's laptop computer.

Proposed new map types:

- *Artemisia filifolia* / *Achnatherum hymenoides*

This type was consistently found on sand deposits in the canyons, especially in the canyons in and around the south mesa.

AA plots 127, 258

- *Verbesina encelioides* - *Portulaca oleracea*

This type was found on disturbed and sparsely vegetated sites on the valley floor. The substrate was clay-silt and was often interspersed with the *Atriplex obovata* type.

AA plots 52

- ***Salsola kali* Weedy Vegetation**

In addition to *Verbesina encelioides* and *Portulaca oleracea*, *Salsola kali* (Russian thistle) was observed throughout the mapping areas. A weedy map class may be needed to describe areas that are dominated by these species.

AA plots 306, 304

- ***Cercocarpus montanus* / *Artemisia nova* Shrubland**

AA plots 46, 49, 187, 138, 40, 143, 227,

- ***Purshia stansburiana* / *Artemisia nova* Shrubland**

Often the dominant shrub associated with either *Purshia stansburiana*, *Cercocarpus montanus* or *Purshia stansburiana* – *Cercocarpus montanus* dominated polygons was *Artemisia nova*. *Ephedra torreyana* was usually present, but rarely the dominant “understory” shrub below the tall shrub stratum.

AA plots 21, 22, 23, 25,

- ***Pinus edulis* - (*Juniperus* spp.) Woodland Alliance**

A total of seven woodland plots collected during the accuracy assessment phase did not correspond directly with the *Pinus edulis* – *Juniperus* spp. / *Cercocarpus montanus* Woodland association mapped in the vegetation map. All of the plots were located on Chacra Mesa and lack *Cercocarpus montanus*. Associated dominant understory species include *Atriplex canescens*, *Artemisia tridentata*, *Artemisia nova*, *Bouteloua gracilis* and *Purshia stansburiana*. Additional component associations are believed to be present on Chacra Mesa in addition to the *Cercocarpus montanus* association.

AA Plots: 240, 254, 284, 286, 294, 311, 314

Between August 21 and 25, 2006, the field crews collected 201 AA points. Field days were planned around collecting as many

primary points as possible; however, when secondary points occurred along a planned route for the day, they were surveyed in anticipation of points that might be missed in the future. Because of inclement weather on the first trip a second trip in October was planned to pick up the remaining points missed on the first trip, primarily located on Chacra Mesa. An additional 114 points were collected on the second trip for a total of 315 AA points. Figures 14 and 42 through 44 show the locations of the collected AA points.

Appendix D continued**Chaco Culture National Historical Park:
Accuracy assessment data collection summary
(Field set 2 of 2)**

Cory Bolen

10/9/2006 - 10/14/2006

This document is intended to summarize the accuracy assessment (AA) data collected during the week of October 9, 2006 at Chaco Cultural National Historic Park (CHCU). A total of 114 random points (A and B points; see Field Set 1 and Methods sections) were visited during the second field visit. A total of 337 random points (A points) were originally generated before the accuracy assessment field work began. Of the 337 random points a total of 315 points were visited as a result of the two separate field visits (August and October) (see attached summary table). Of the 321 field points, 34 were B points with the remaining field visited points representing A points.

A total of 15 vegetation map units had accuracy assessment field points generated for them. Of the 15 map units, 8 were completely sampled in the field. That is, an equal or greater number of points (combination of A and B points) were visited in the field than the number of random A points originally generated. In contrast, seven map units received less field visits than the original number of randomly generated AA points. The under-sampled map units are listed below.

- *Artemisia nova* – *Atriplex canescens* Shrubland, *Ephedra torreyana* Sparse Vegetation (Map Unit 20)
 - *Purshia stansburiana* – *Cercocarpus montanus* / *Ephedra torreyana* Shrubland (Map Unit 21)
 - *Atriplex canescens* Shrubland (Map Unit 22)
 - *Atriplex obovata* / *Sporobolus airoides* – *Pleuraphis jamesii* Shrub Herbaceous Vegetation (Map Unit 26)
- The majority of the October field sampling occurred on Chacra Mesa and on the valley floor near the park's paved loop road. A number of important vegetation patterns were observed during this sampling phase and are listed here. This list is intended to add to the knowledge already documented by Dan Cogan and others after the first sampling phase in August.
1. There was no *Tetradymia canescens* observed in the field during the second field visit. The Park's digital herbarium specimen of this species was also consulted after the field visit to verify/review key plant features.
 2. Rangelands on top of Chacra Mesa were composed primarily of the *Bouteloua gracilis* and *Hesperostipa comata* – *Achnatherum hymenoides* associations. Within these grasslands, various shrub communities also occurred, composed of such species as
- *Pleuraphis jamesii* – *Sporobolus airoides* Herbaceous Vegetation (Map Unit 10)
 - *Gutierrezia sarothrae* / *Sporobolus airoides* – *Pleuraphis jamesii* Shrub Herbaceous (Map Unit 11)
 - *Bouteloua gracilis* Herbaceous Vegetation (Map Unit 12)

Krashennikovia lanata, *Ericameria nauseosa*, *Gutierrezia sarothrae*, *Ephedra viridis* and *Chrysothamnus Greenei*.

3. In areas of Chacra Mesa dominated by *Achnatherum hymenoides*, *Hesperostipa comata* presence may have been underestimated and *Achnatherum hymenoides* slightly overestimated. *Hesperostipa comata* is believed to have “flowered” early in the season making it difficult to identify in the field due to the lack of floret parts.
4. In the *Pinus edulis* – *Juniperus* spp. Woodland Alliance, several associations may occur in CHCU in addition to the *Cercocarpus montanus* association. Additional associations observed in the field include *Pinus edulis* – *Juniperus monosperma* / *Bouteloua gracilis* Woodland, “*Pinus edulis* – *Juniperus* spp. / *Artemisia tridentata* Woodland, and “*Pinus edulis* – *Juniperus* spp. / Sparse Understory (or Rockland) Woodland.
5. In general, the *Pinus edulis* – *Juniperus* spp. / *Cercocarpus montanus* Woodland association occurs on the upper side slopes on the mesas adjacent (above) to canyon/mesa walls. Slopes vary from gently to steep, with ground cover being dominated by bedrock, large rocks, small rocks, and bare soil. Further away from the canyon rims and closer to the top of the mesa, associations are typically have more cover and species richness in the understory. Shoulder slopes, in the general sense, may be used to characterize these areas.

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