USGS-NPS National Vegetation Mapping Program: Wupatki National Monument, Arizona, Vegetation Classification and Distribution

By Monica Hansen[1], Janet Coles[2], Kathryn A. Thomas[1], Daniel Cogan[2], Marion Reid[3], Jim Von Loh[2], and Keith Schulz[3]

U.S GEOLOGICAL SURVEY
SOUTHWEST BIOLOGICAL SCIENCE CENTER

Final Report

Prepared for:

USGS-NPS National Vegetation Mapping Program

[1]Colorado Plateau Research Station
Southwest Biological Science Center
U.S. Geological Survey (USGS)
Flagstaff, AZ

[2]Remote Sensing and GIS Group
U.S. Bureau of Reclamation (USBR)
Denver, Colorado

[3]NatureServe
Boulder, Colorado

Flagstaff, Arizona
2004

TABLE OF CONTENTS

LIST OF TABLES **3**
LIST OF FIGURES **4**
LIST OF CONTACTS AND CONTRIBUTORS **5**
ACKNOWLEDGEMENTS **7**
LIST OF ABBREVIATIONS AND TERMS **8**
SUMMARY **9**
1. INTRODUCTION **11**
2. VEGETATION MAPPING PROJECT AREA **13**
LOCATION AND REGIONAL SETTING 14
CLIMATE 15
GEOLOGY AND TOPOGRAPHY 15
WILDLIFE 18
VEGETATION 19
LAND USE 22
3. METHODS **23**
PROJECT SCOPING AND PLANNING 23
PRELIMINARY DATA COLLECTION AND REVIEW OF EXISTING INFORMATION 25
AERIAL PHOTOGRAPHY AND BASE MAP ACQUISITION 25
SAMPLING DESIGN DEVELOPMENT 26
FIELD DATA COLLECTION 26
VEGETATION CLASSIFICATION AND CHARACTERIZATION 28
VEGETATION MAP PREPARATION 29
ACCURACY ASSESSMENT 32
4. RESULTS **37**
FIELD SURVEYS 37
VEGETATION CLASSIFICATION 38
MAP CLASSES AND AERIAL PHOTOGRAPHY INTERPRETATION 42
GIS DATABASE AND MAPS 51
ACCURACY ASSESSMENT 53
5. DISCUSSION **61**
VEGETATION CLASSIFICATION AND MAP CLASS DEVELOPMENT 62
ACCURACY ASSESSMENT 64
APPLICATIONS 64
6. BIBLIOGRAPHY **65**
7. GLOSSSRY **68**
GLOSSRY LITERATURE CITED 81

APPENDIX A A-1

A. CD-ROM README TEXT AND CD-ROM A-2

APPENDIX B B-1

B. PRECIPITATION AND TEMPERATURE AVERAGES FOR WUPATKI NATIONAL MONUMENT (AUGUST AND JANUARY 1949 – 2002) B-2

APPENDIX C C-1

C. FLOWCHART OF USGS-NPS NATIONAL PARKS VEGETATION MAPPING PROGRAM C-1

APPENDIX D D-1

D. PHOTOINTERPRETATION OBSERVATIONS, CLASSIFICATION RELEVÉS, AND ACCURACY ASSESSMENT OBSERVATIONS FORMS D-2

APPENDIX E E-1

E. FIELD KEY FOR THE WUPATKI NATIONAL MONUMENT VEGETATION COMMUNITY DESCRIPTIONS AND MAP CLASSES E-2

APPENDIX F F-1

F. NATIONAL VEGETATION CLASSIFICATION (NVC) LOCAL AND GLOBAL DESCRIPTIONS FOR WUPATKI NATIONAL MONUMENT F-2

APPENDIX G G-1

G. WUPATKI NATIONAL MONUMENT SPECIES LIST G-2

APPENDIX H H-1

H. VISUAL GUIDE AND DESCRIPTIONS OF THE WUPATKI NATIONAL MONUMENT MAP CLASSES H-2

LIST OF TABLES

TABLE 1. USGS-NPS VEGETATION MAPPING PROGRAM CRITERIA USED FOR DETERMINING SAMPLING NUMBERS IN THE ACCURACY ASSESSMENT 33
TABLE 2. DEFINITIONS USED IN THE 'FUZZY SET' ANALYSIS CLASSIFICATIONS AT WUPA 35
TABLE 3. WUPA NATIONAL VEGETATION CLASSIFICATION ASSIGNMENTS 38
TABLE 4. WUPA MAP CLASSES AND THEIR NVC COMPONENTS 42
TABLE 5. MAP CLASS OCCURRENCE IN WUPATKI NATIONAL MONUMENT AND ENVIRONS 52
TABLE 6. MAP CLASS PERFORMANCE 54
TABLE 7. ACCURACY ASSESSMENT CONTINGENCY TABLE (CRITERIA 5, EXACT MATCH) AND STATISTICAL ANALYSIS OF REFERENCE DATA WITH MAP CLASS DATA 58
TABLE 8. ACCURACY ASSESSMENT CONTINGENCY TABLE (CRITERIA 4, ACCEPTABLE ACCURACY) AND STATISTICAL ANALYSIS OF REFERENCE DATA WITH MAP CLASS DATA 59
TABLE 9. ACCURACY ASSESSMENT CONTINGENCY TABLE (CRTIERIA 3, UNDERSTANDABLE ACCURACY) AND STATISCAL ANAYLSIS OF REFERENCE DATA WITH MAP CLASS DATA 60

LIST OF FIGURES

FIGURE 1. LOCATION OF WUPATKI NATIONAL MONUMENT 13
FIGURE 2. WUPA VEGETATION MAP PROJECT BOUNDARIES AND LAND OWNERSHIP 14
FIGURE 3. SHADED RELIEF MAP OF THE WUPA VEGETATION MAP PROJECT AREA 17
FIGURE 4. VEGETATION TYPICAL OF WUPA INCLUDES A) SPARSELY VEGETATED SANDSTONE OUTCROPS, B) OPEN ONESEED JUNIPER (*JUNIPERUS MONOSPERMA*) WOODLANDS, C) GRASSLANDS, D) SPARSELY VEGETATED BADLANDS, E) STABILIZED SAND DUNES AND F) RIPARIAN VEGETATION 20
FIGURE 5. MAPPING PROJECT AREA OF THE WUPA VEGETATION MAP AND AERIAL PHOTO FLIGHLINES 25
FIGURE 6. AN EXAMPLE OF THE NVC PHYSIOGNOMIC AND FLORISTIC HEIRARCHY USING THE *PLEURAPHIS JAMESII – SPOROBOLUS AIROIDES* HERBACEOUS VEGETATION ASSOCIATION 28
FIGURE 7. EXAMPLE OF THE PHOTOINTERPRETATION PROCESS USING AERIAL PHOTO 10-009 AND CORRESPONDING (SCANNED) MYLAR OVERLAY 31
FIGURE 8. LOCATION OF WUPA PHOTOINTERPRETATION OBSERVATIONS AND CLASSIFICATION RELEVÉS 37
FIGURE 9. LOCATIONS OF ACCURACY ASSESSMENT FIELD OBSERVATIONS COLLECTED IN 2002 53

LIST OF CONTACTS AND CONTRIBUTORS

Bureau of Reclamation Remote Sensing and GIS Group Environmental Resources Services Technical Service Center PO 25007, Mail Code: D8260 Denver, CO 80225 Voice: 303-445-2266 Fax: 303-445-6337 Web: www.rsgis.do.usbr.gov	Daniel Cogan: Biologist Phone: 303-445-2291 Email: dcogan@do.usbr.gov Mike Pucherelli: Group Manager Phone: 303-445-2267 Email: mpucherelli@do.usbr.gov Contributors: Janet Coles, Jim Von Loh, Doug Crawford, Trudy Meyer, Jean Pennell, Allan Bell, John Carlson, David Salas
USGS Biological Resources Discipline Center for Biological Informatics PO 25046, MS-302 Denver, CO 80225 Fax: 303-202-4219 Web: http://biology.usgs.gov	Karl Brown: Project Coordinator, USGS-NPS Vegetation Mapping Program Phone: 303-202-4259 Email: karl_brown@usgs.gov Tom Owens: Ex-Project Coordinator, USGS-NPS Vegetation Mapping Program Phone: 303-202-4259 Email: tom_owens@usgs.gov
USGS Southwest Biological Science Center Colorado Plateau Research Station P.O. Box 5614 Northern Arizona University Flagstaff, AZ 86011 Web: http://www.usgs.nau.edu/	Kathryn Thomas: Principal Investigator Phone: 928-556-7466, x235 Email:Kathryn_A_Thomas@usgs.gov Monica Hansen: Plant Ecologist Phone: 928-556-7466, x252 Email: mlhansen@usgs.gov Contributors: Becci Anderson, Rebecca DeGroot, Charles Drost, Heather Folger, Jon Hellison, Mar-Elise Hill, Mimi Murov, Trevor Persons, Keith Pohs, Don Robinson, Gabe Valdez, J.J. Wynne

National Park Service 6400 N. Hwy 89 Flagstaff, AZ 86004 Fax: 520-526-4259 Web: http://www.nps.gov/waca Visitor Information : 928-526-3367	**National Park Service** Mike Story: Project Coordinator USGS-NPS Vegetation Mapping Program Phone: 303-969-2746 Email: mike_story@nps.gov **National Park Service** **Walnut Canyon NM** Steve Mitchelson: Resource Management Specialist Phone: 928-526-1157 Email: steve_mitchelson@nps.gov Paul Whitefield: Resource Management Specialist Phone: 928-526-1157 Email: paul_whitefield@nps.gov Contributors: Jeri De Young, Nicole Tancreto, Mary Blazing, Sam Henderson (former superintendent)
NatureServe NatureServe 2400 Spruce Street, Suite 201 Boulder, CO 80302 fax: 303-449-4328 web: www.natureserve.org	Marion S. Reid: Senior Regional Ecologist Phone: 303-541-0342 Email: marion_reid@natureserve.org Keith Schulz: Regional Vegetation Ecologist Phone: 303-541-0356 Email: keith_schulz@natureserve.org

ACKNOWLEDGEMENTS

Special thanks goes to Jim Von Loh who started and performed much of the preliminary RSGIG work on this project. After departure, he continued to support the project. Also, thanks to all the field crews who spent endless time walking all the corners of the beautiful Wupatki landscape: Monica Hansen, Jon Hellison, Don Robinson, Mimi Murov, Keith Pohs, Mar-Elise Hill and J.J. Wynne. We also would like to thank Keith Pohs and Trevor Persons for contributing to the Geology and Wildlife sections of the project report. Thanks to the park staff at Wupatki National Monument and at the headquarters office for quickly helping out with logistics, permitting, attending meetings, and for allowing us continuous access to roads throughout the park. We express special thanks to Heather Folger who put many hours into formatting this report.

LIST OF ABBREVIATIONS AND TERMS

AA	Accuracy Assessment
ABI	Association for Biodiversity Information (now known as NatureServe)
AML	Arc Macro Language
BOR	Bureau of Reclamation (Also USBR)
BRD	Biological Resource Discipline of the USGS
CBI	Center for Biological Informatics of the USGS/BRD
CIR	Color Infra-Red photography
CPRS	Colorado Plateau Research Station of the USGS/BRD
DEM	Digital Elevation Model
DLG	Digital Line Graph
DOQQ	Digital Orthophoto Quarter Quad(s)
DRG	Digital Raster Graphic
FGDC	Federal Geographic Data Committee
GIS	Geographic Information System(s)
GPS	Global Positioning System
MMU	Minimum mapping unit
NAD	North American Datum
NBII	National Biological Information Infrastructure
NPS	National Park Service
NRCS	Natural Resources Conservation Service
NVC	National Vegetation Classification
NVCS	National Vegetation Classification Standard
PLGR	Precision Lightweight GPS Receiver
RSGIG	Remote Sensing and Geographic Information Group of the Bureau of Reclamation
SBSC	Southwest Biological Science Center of the USGS
TES	Terrestrial Ecosystem Survey
TNC	The Nature Conservancy
USBR	United States Bureau of Reclamation
USDA-FS	United States Dept. of Agriculture – Forest Service
USDA-SCS	United States Dept. of Agriculture – Soil Conservation Service
USGS	United States Geological Survey
UTM	Universal Transverse Mercator
VMP	Vegetation Mapping Program
WUPA	Wupatki National Monument

SUMMARY

Wupatki National Monument (WUPA) Vegetation Mapping Project was initiated in the spring of 1999 as part of and in accordance with the U.S. Geological Survey-National Park Service (USGS-NPS) Vegetation Mapping Program, and was completed in the spring of 2004. The Vegetation Mapping Program is a cooperative effort administered by the USGS and the NPS, and was initiated as part of the NPS Inventory & Monitoring Program. The primary goal of the Vegetation Mapping Program is to classify, describe, and map vegetation for approximately 270 NPS units.

This mapping project was performed by the following organizations under contract to the CBI:

- The Remote Sensing and GIS Group (RSGIG), Technical Service Center, Bureau of Reclamation (BOR), Department of Interior, Denver, Colorado

- The Colorado Plateau Research Station (CPRS), Southwest Biological Science Center (SBSC), USGS, Flagstaff, Arizona

- NatureServe, Boulder, Colorado

Twenty-six vegetation map classes including two unique stands identified only in the photointerpretation, two land cover map classes, and seven Anderson Level II land-use map classes were used for interpretation of approximately 106,380 ac (43,050 ha) encompassing the monument (35,478 ac/14,357 ha) and surrounding environs (70,902 ac/28,693 ha). Vegetation map classes were determined through extensive field reconnaissance, data collection, and analysis in accordance with the National Vegetation Classification (NVC). The vegetation map was created from photographic interpretation of 1996, 1:12,000 scale color infrared aerial photographs (0.5 ha minimum mapping unit). All vegetation and land-use information was then transferred to a GIS database using the latest grayscale USGS digital orthophoto quarter-quads (DOQQs) as the base map and a combination of on-screen digitizing and scanning techniques. Overall thematic map accuracy for the entire mapping effort was assessed at 69.7% using the acceptable error criteria with a Kappa Index of 68.5%. The overall 90% confidence interval is 67.9% to 71.5%.

Final products are presented in this report and on the accompanying CD-ROM (Appendix A).

- Vegetation Classification Descriptions
- Land-use Classification System
- Vegetation Classification Key
- Digital and Hard Copy Vegetation Map
- Digital Project Boundaries
- Digital Field Points Coverage (Observation, Classification, Accuracy Assessment)
- Photos of Field Sites
- Accuracy Assessment Results

- FGDC-compliant Metadata

WUPA and similar national park vegetation mapping databases can be accessed at the USGS-NPS website: http://biology.usgs.gov/npsveg.

1. INTRODUCTION

The Vegetation Mapping component of the NPS Inventory and Monitoring Program is a cooperative effort by the U.S. Geological Survey (USGS) and the National Park Service (NPS) to classify, describe, and map vegetation communities in more than 270 national park units across the United States. The vegetation mapping efforts are an important part of the NPS Inventory and Monitoring Program, a long-term effort to develop baseline data for all national park units that have a natural resource component. Project activities are based on peer-reviewed, objective science. Comprehensive vegetation information is provided at national and regional levels, while also serving local management needs of individual parks. Stringent quality control procedures ensure that products are accurate and consistent for initial inventory purposes and replicable for monitoring purposes. The spatially enabled digital products produced by these efforts are available on the World Wide Web (http://biology.usgs.gov/npsveg).

The goals of these vegetation mapping projects are to provide comprehensive mapping of NPS vegetation resources that:

1. Is highly accurate
2. Meets scientific and Federal Geographic Data Committee (FGDC) standards
3. Has a nationally consistent, hierarchical, classification scheme
4. Has a level of detail useful to park management
5. Uses existing data when appropriate

Because producing an accurate, detailed, digitized vegetation map is a complicated undertaking, several government agencies and private organizations were involved in the project's successful completion.

The Remote Sensing and Geographic Information Group (RSGIG), United States Bureau of Reclamation (USBR), Denver Federal Center, Lakewood, Colorado[1]: 1) attended planning meetings, 2) conducted aerial photosignature field review and observation point data collection, 3) provided aerial photointerpretation, 4) attended a vegetation classification map class development meeting, 5) created the GIS vegetation database and 6) provided support and content for the final report.

The Southwest Biological Science Center (SBSC), Colorado Plateau Research Station (CPRS), USGS-BRD, Flagstaff, Arizona[2]: 1) attended planning meetings, 2) conducted field data

[1] The Remote Sensing and Geographic Information Group, organized in 1975, provides assistance and advice regarding the application of remote sensing and geographic information systems (GIS) technologies to meet the spatial information needs of the Bureau of Reclamation and other government clients. The mission of the Department of Interior's Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

[2] The Colorado Plateau Research Station is one of four research stations within the Southwest Biological Science Center. This research station was originally established in 1989 as a National Park Service Cooperative Park Studies Unit at Northern Arizona University in Flagstaff and was merged into the USGS Biological Resources Discipline in 1996. Major categories of research include ecoregional studies and conservation planning; endangered species studies; vegetation distribution, ecology, and dynamics; data management and dissemination; inventory and monitoring studies; and wildlife ecology.

collection and analysis, 3) provided data analysis and classification, 4) prepared the vegetation classification key and descriptions, 5) provided accuracy assessment data collection and analysis, 6) conducted the vegetation map accuracy assessment, and 7) prepared the final project report.

NatureServe's Western Regional Office in Boulder, Colorado[3] provided a review of CPRS vegetation data analyses and CPRS local vegetation descriptions as well as prepared global descriptions for the vegetation associations determined at WUPA.

[3] NatureServe has its roots in The Nature Conservancy (TNC) which, in 1974, began establishing and supporting state natural heritage programs. By 1994 the natural heritage programs expanded significantly and The Nature Conservancy established a new network, the Association for Biodiversity Information. Now known as NatureServe, it has assumed in managing the National Vegetation Classification (NVC) and providing scientific and technical support to the network. The NatureServe network now includes 74 independent natural heritage programs and conservation data centers across the Western Hemisphere.

2. VEGETATION MAPPING PROJECT AREA

Wupatki National Monument (WUPA) was designated a National Monument in 1924. This 35,478 ac (14,357 ha) monument preserves archeological ruins remnant from the ancient Pueblo people. WUPA is located approximately 35 miles northeast of Flagstaff, Arizona and is reached via U. S. Highway 89 north of Flagstaff (Figure 1). Recreational and educational activities include scenic drives and vistas, wildlife viewing, visitor natural and cultural history education, and research opportunities. In addition to the monument, the project area includes an environs area of approximately 70,902 ac (28,694 ha). The environs includes USDA Forest Service lands (southwest), privately owned land (north and south), Arizona state land (north and south), Bureau of Land Management (BLM) (east), Indian Allotments (north), and Navajo Nation land (east). The total project area is 106,380 ac (43,052 ha) (Figure 2).

Figure 1. Location of Wupatki National Monument.

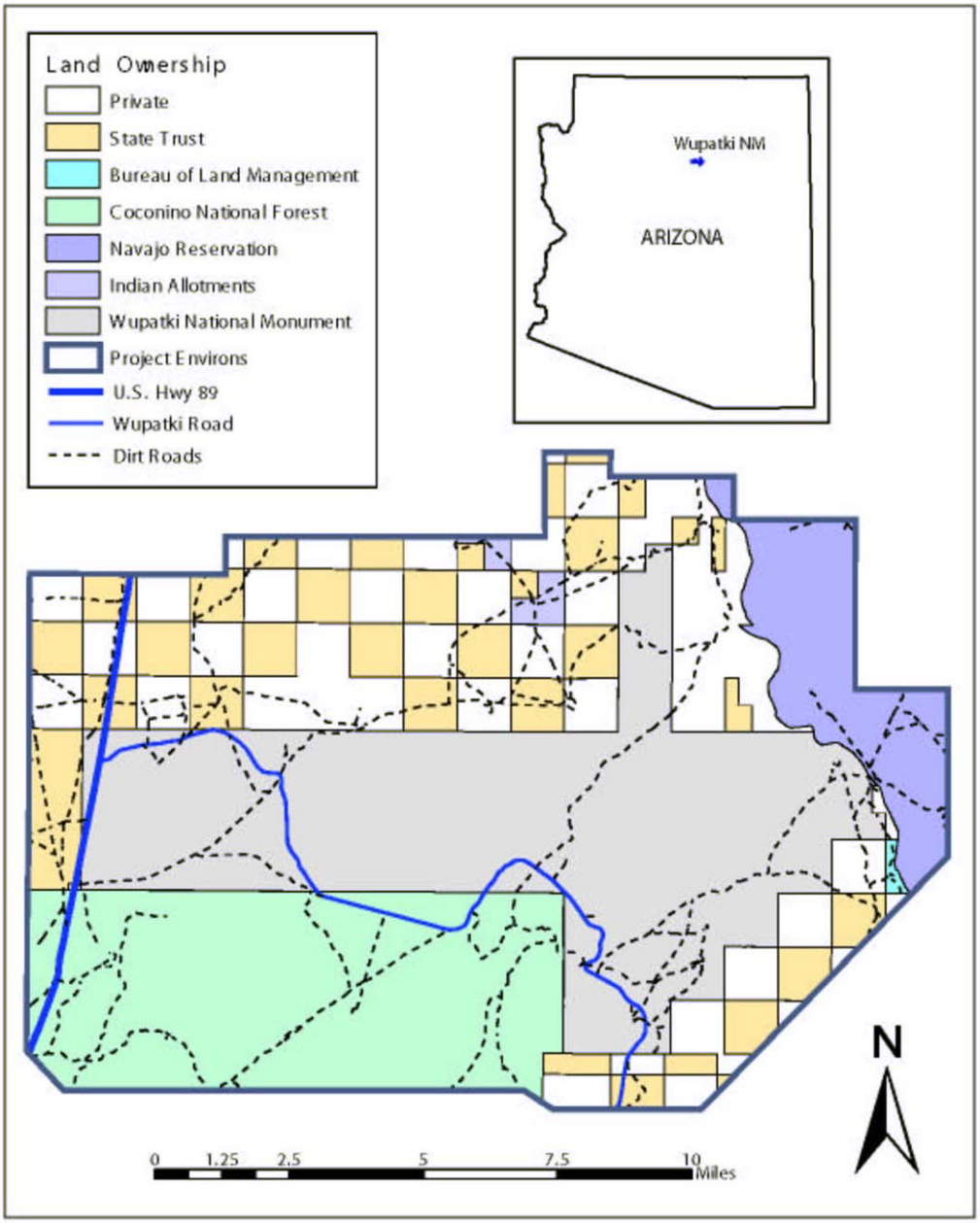


Figure 2. WUPA vegetation map project boundaries and land ownership.

Location and regional setting

WUPA is situated on the southwestern Colorado Plateau of north-central Arizona, within the San Francisco Peaks Volcanic Field (Cordasco et al. 1998, Zion Natural History Association 1985). It encompasses Painted Desert badlands to the east and is bounded on the east by the Little Colorado River, on the north by the Babbitt Ranches, on the west by US Highway 89, in the

southwest by the Coconino National Forest, and in the south and southeast by a private ranch. The north entrance to the monument is accessed directly from Highway 89. The south entrance is accessed by first entering Sunset Crater National Monument and continuing to travel north on the Painted Desert Vista road. The NPS Visitor Center is located at the southern end of the monument and is most easily accessed via the Painted Desert Vista road. None of the dirt roads used to access the monument are open to the general public. They serve as either routes for NPS personal or for access by Navajo Nation residents. A number of scenic overlooks, picnic tables, ruins, and hiking trails including the Wupatki Pueblo Trail, Lomatki Pueblo Trail, and Doney Mountain Trail are located in the monument.

Climate

WUPA is typified by a semi-arid climate that includes hot, moist summers and cool, dry winters (Appendix B). Precipitation events, often in the form of violent thunderstorms, occur from July through September and provide most of the annual moisture. Summer maximum temperatures are often 100 degrees F. (38 degrees C.), while winter minimum temperatures rarely go below freezing (NOAA 1997).

Geology and topography

WUPA's geology and topography are complex and diverse with varied substrates that influence plant species and vegetation communities found within the monument. WUPA is well known for the deep red siltstones which were used to construct the monument's ancient ruins; however, it also includes a number of other geologic units, including basalt flows, cinder cones, and extensive gravel fans.

WUPA is situated at the western edge of the Painted Desert between the Little Colorado River Valley to the east and the Coconino Plateau to the west. This plateau, a broad anticlinal fold, stretches northwestward toward the Grand Canyon and southward to Flagstaff. The Kaibab Formation, a gray limestone which caps the plateau in many areas, dips gently to the northeast below the younger Mesozoic rocks of the Painted Desert. The most striking of these colorful Mesozoic units is the Moenkopi Formation, a brick red rock consisting largely of shale with interbedded sandstone and badland forming mudstone. Some of the layers within this unit show ample evidence of an ancient sea that once covered the region. Cross-bedding, mudcracks, and ripple marks can be seen within this unit. Lying stratigraphically above the Moenkopi is a thin gravel, the Shinarump Conglomerate. This unit, which interestingly includes rounded pebbles of hard Precambrian rock, caps several mesas within the monument.

In contrast to these ancient rocks of sedimentary origin, basalt flows and a few cinder cones dot the landscape. These flows and cones are northeastern outliers of the San Francisco Volcanic Field, a large center of volcanic activity extending to the south and west. The field is approximately 6 million years old, and it is thought that eruptive activity has migrated from the southwest toward the northeast over time. The volcanoes and flows at WUPA and those of nearby Sunset Crater National Monument are geologically quite young, and are the youngest in the entire volcanic field. A few lava flows extend down to the Little Colorado River, and pockets of cinders deposited by the eruption of Sunset Crater approximately 1,000 years ago are also evident.

WUPA lies near the northeastern edge of the San Francisco volcanic field, which covers approximately 1,800 sq mi of the southern Colorado Plateau in north-central Arizona (Priest et al. 2001). The volcanic field, whose major feature is the 12,600 ft (3,840 m) high Humphery's Peak, formed during the latter part of the Cenozoic era.

San Francisco Mountain, the highest and most massive volcano in the region, is readily visible from the monument. During the Pleistocene Epoch, which ended approximately 15,000 years ago, glaciers covered the upper reaches of the 12,000 ft (3,658 m) high cone. Outwash gravels associated with these masses of ice extend all the way down to WUPA. These are characterized by volcanigenic sand, pebbles, and cobbles whose origin is the high slopes of the peak.

Topography of WUPA consists of steep cinder cones, cliffs, rolling hills, broad flats, drainages, small canyons, and mesas (Figure 3). WUPA's elevation ranges from a high of 6,279 ft (1,914 m) and a low of 4,226 ft (1,288 m). Prominent landscape features in the project area include: Antelope Prairie (4,600 ft/1,360 m), Antelope Wash (4,600 ft/1,400 m), Ball Court Wash (5,500 ft/1,675 m), Box Canyon (5,300 ft/1,615 m), Citadel Sink (5,312 ft/1,620 m), Citadel Wash (5,100 ft/1,555 m), Deadman Wash (4,400-5,580 ft/1,340-1,700 m), Doney Mountain (5,589 ft/1,704 m), Hulls Wash/Hulls Canyon (5,400 ft/1,645 m), Inscription Point (4,405 ft/1,343 m), Kish Zhini Wash (4,300 ft/1,310 m), Little Colorado River (4,320 ft/1,317 m), Magnetic Mesa (5,380 ft/1,640 m/), North Mesa (5,340 ft/1,630 m), Tse Lichi Point (4,500 ft /1,370 m), White Mesa (5,200 ft/1,585 m), and Woodhouse Mesa (5,500 ft/1,675 m). The Wupatki Basin is a term referred by the photointerpreters in the report to describe the low-lying areas in the eastern portion of WUPA. Black Falls Crossing is the main road crossing on the Little Colorado River and is referred to throughout the report. Major ruins in the WUPA are Wupatki, Wukoki, Lomatki, Citadel, and Crack-in-the-rock. Several man made stock tanks occur throughout the project environs, including the Bar Doney Tank and Tuba City Road Tank. Three major springs also occur at WUPA, including Peshlakai Spring, Heizer Spring, and Wupatki Spring.

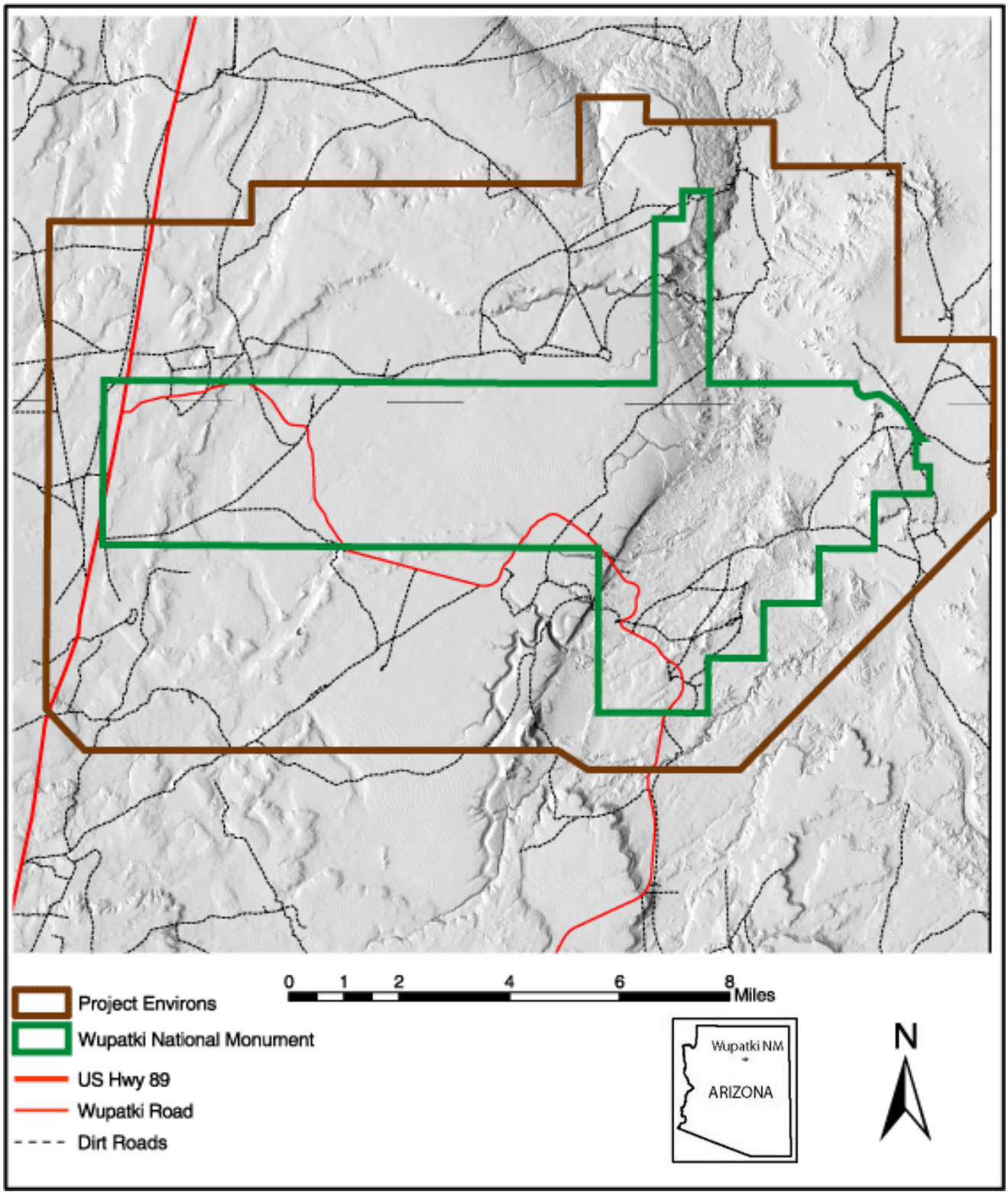


Figure 3. Shaded relief map of the WUPA vegetation map project area.

Wildlife

Information used to prepare this wildlife summary for WUPA includes Bateman (1976, 1978, 1980), Hoffmeister (1986), Nowak et al. (2003), Persons (2001), and Rosenstock (1999), as well as additional data gathered during inventory projects for mammals and herpetofauna currently being conducted by researchers at the USGS CPRS.

The grasslands and desert shrub areas at WUPA support a variety of mammal species characteristic of these lower elevation habitats. Pronghorn (*Antilocapra ameri*cana) are frequently seen in grasslands, and mule deer (*Odocoileus hemionus*), coyote (*Canis latrans*), bobcat (*Lynx rufus*), and porcupine (*Erethizon dorsatum*) are also common. Although rarely seen, both kit fox (*Vulpes macrotis*) and badger (*Taxidea taxus*) are present at WUPA. Desert cottontail (*Sylvilagus auduboni*) and black-tailed jackrabbit (*Lepus californicus*) are common to abundant, and gunnison's prairie dog (*Cynomys gunnisoni*) is found in a few grassland areas of the monument. Many of the most common small mammals at WUPA are rodents of the family Heteromyidae (kangaroo rats and pocket mice), and are characteristic of deserts and grasslands in the region. Species at WUPA include Ord's kangaroo rat (*Dipodomys ordii*), rock pocket mouse (*Chaetodipus intermedius*), silky pocket mouse (*Perognathus flavus*), plains pocket mouse (*P. flavescens*), and Arizona pocket mouse (*P. amplus*). The Arizona pocket mouse is represented at WUPA by a locally-distributed subspecies with distinctive dark pelage, called the Wupatki pocket mouse (*P. a. cineris*). Other common rodents include the pinyon mouse *(Peromyscus truei*), deer mouse (*P. maniculatus*), western harvest mouse (*Reithrodontomys megalotis*), northern grasshopper mouse (*Onychomys leucogaster*), and three species of woodrats (*Neotoma*). Although most small mammals at WUPA are nocturnal, white-tailed antelope squirrels (*Ammospermophilus leucurus*) and rock squirrels (*Spermophilus variegatus*) are commonly seen diurnal species. Many species of bats have been recorded from the monument, including such special interest species as Townsend's big-eared bat (*Corynorhinus townsendii*) and spotted bat (*Euderma maculatum*).

Breeding birds are not very abundant at WUPA, due to the sparse vegetation cover and dry conditions at the monument. Relatively common breeding species include Mourning Dove (*Zenaida macroura*), Common Poorwill (*Phalaenoptilus nuttallii*), Common Nighthawk (*Chordeiles minor*), Say's Phoebe (*Sayornis saya*), Loggerhead Shrike (*Lanius ludovicianus*), Common Raven (*Corvus corax*), Horned Lark (*Eremophila alpestris*), Rock Wren (*Salpinctes obsoletus*), Northern Mockingbird (*Mimus polyglottos*), Black-throated Sparrow (*Amphispiza bilineata*), Western Meadowlark (*Sturnella neglecta*), Scott's Oriole (*Icterus parisorum*), and House Finch (*Carpodacus mexicanus*). In winter, Mountain Bluebirds (*Sialia currucoides*) and Townsend's Solitaires (*Myadestes townsendi*) are sometimes present in flocks numbering in the thousands, and many other species pass through the monument during migration. Raptors that breed at or near WUPA include Golden Eagle (*Aquila chrysaetos*), Red-tailed Hawk (*Buteo jamaicensis*), Ferruginous Hawk (*Buteo regalis*), Cooper's Hawk (*Accipiter cooperii*), Prairie Falcon (*Falco mexicanus*), American Kestrel (*Falco sparverius*), Great-horned Owl (*Bubo virginianus*), and Long-eared Owl (*Asio otus*). Burrowing Owls (*Athene cunicularia*) have probably bred just north of the monument. Bald Eagles (*Haliaeetus leucocephalus*) are sometimes seen in winter.

WUPA has an impressive diversity of amphibian and reptile species, due to the meeting of major habitats (grassland and desert shrub) within the monument. Another important factor influencing the distribution of species at WUPA is its location within the Little Colorado River valley, which has likely acted as a corridor for the migration of desert species from the Grand Canyon region to the north. For amphibians, summer monsoon rains produce temporary pools used for breeding by New Mexico and plains spadefoot toads (*Spea multiplicata* and *S. bombifrons*), Great Plains toad (*Bufo cognatus*), red-spotted toad (*B. punctatus*), and Woodhouse's toad (*B. woodhousii*). Although rarely encountered, tiger salamanders (*Ambystoma tigrinum*) also occur at WUPA. Common lizard species found throughout most of the monument include common collared lizard (*Crotaphytus collaris*), longnose leopard lizard (*Gambelia wislizenii*), side-blotched lizard (*Uta stansburiana*), eastern fence lizard (*Sceloporus undulatus*), lesser earless lizard (*Holbrookia maculata*), and plateau striped whiptail (*Cnemidophorus velox*). In the grasslands and juniper woodlands greater short horned lizard (*Phrynosoma hernandesi*), tree lizard (*Urosaurus ornatus*), and little striped whiptail (*Cnemidophorus inornatus*) are also present. Lizard species restricted to the desert habitats in Wupatki Basin include desert spiny lizard (*Sceloporus magister*), western whiptail (*Cnemidophorus tigris*), and western banded gecko (*Coleonyx variegatus*), all of which are associated with the Little Colorado River valley and are near the terminus of their local distribution at WUPA. The most commonly observed snake species at WUPA are the gopher snake (*Pituophis catenifer*), striped whipsnake (*Masticophis taeniatus*), and western rattlesnake (*Crotalus viridis*). Other species found less frequently include western patch-nosed snake (*Salvadora hexalepis*), common kingsnake (*Lampropeltus getula*), glossy snake (*Arizona elegans*), and night snake (*Hypsiglena torquata*), while the milk snake (*Lampropeltis triangulum*) and ground snake (*Sonora semiannulata*) have each been recorded only once.

Vegetation

Vegetation of WUPA and its environs is diverse and unique, including nearly barren beds of cinder and rock outcrops, grassy prairie, open one-seed juniper (*Juniperus monosperma*) savanna, sparsely vegetated badlands, sand dunes, and densely vegetated riparian corridors (Figure 4). Although much of the project area of WUPA is sparsely vegetated, less than one percent of the project area is considered barren (< 2% total vegetation cover).

Barren areas include cinder barrens, basalt outcrops, and active river channels near the Little Colorado River. Cinder barrens may have only a single species, often Apache plume (*Fallugia paradoxa*). Basalt outcrops, if vegetated at all, may include a sparse shrub cover of California brickelbush (*Brickellia californica*) and skunkbush sumac (*Rhus trilobata*). Active river channels have continuous scouring of the surface and often are barren of vegetation, with the exception of persistent annual and perennial riparian species that arise in the intermittent periods between flooding.

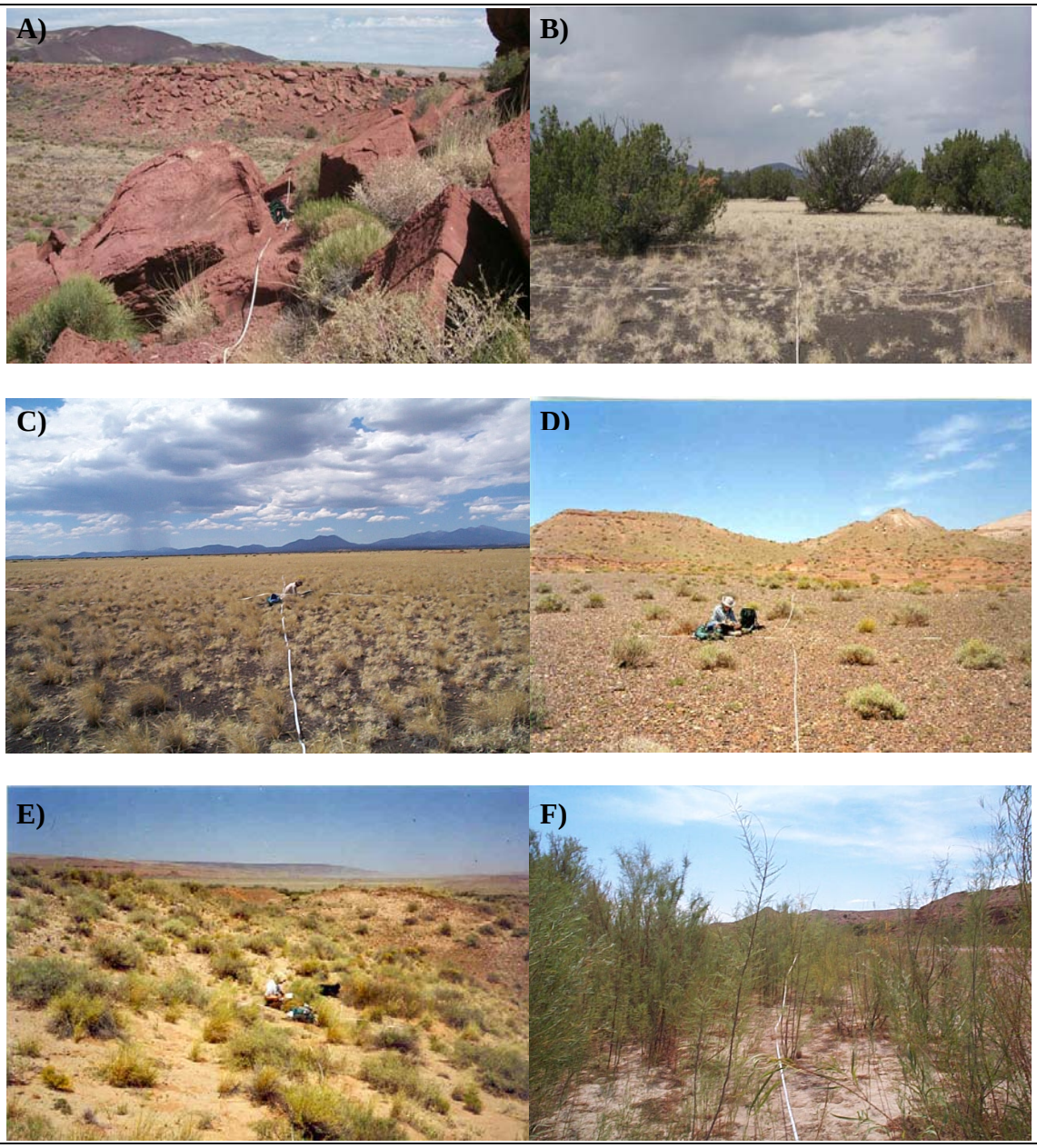


Figure 4. Vegetation typical of WUPA includes A) sparsely vegetated sandstone outcrops, B) open oneseed juniper (*Juniperus monosperma*) woodlands, C) grasslands, D) sparsely vegetated badlands, E) stabilized sand dunes and F) riparian vegetation.

Sparsely vegetated areas (ranging between two and 15% vegetative cover) at WUPA are dominated by substrate and range from Moenkopi shale badlands, Moenkopi sandstone outcrops, to cinder sparse flats. Vegetation, although sparse, is unique to these areas. Mound saltbush (*Atriplex obovata*) dominates cover in the badlands on the Navajo Reservation. In the badlands adjacent to the monument, the most commonly seen species are crispleaf buckwheat (*Eriogonum corymbosum*), Torrey's joint-fir (*Ephedra torreyana*), fourwing saltbush (*Atriplex canescens*), and shadscale (*Atriplex confertifolia*). Cinder sparse areas often contain a mix of Apache plume, annual herbaceous species and crispleaf buckwheat. Moenkopi sandstone rock outcrops typically contain a few species in the crevices of the rocks, including fourwing saltbush, Mormon tea (*Ephedra viridis*), and bush muhly (*Muhlenbergia porteri*).

Grassland species at WUPA include those common to the Great Basin and Great Plains and includes a variety of C3 and C4 species. Livestock grazing was eliminated in the park in the early 1980's (see NPS General Management Plan 2002). The major grass species include black grama (*Bouteloua eriopoda*), galleta (*Pleuraphis jamesii*), needle-and-thread (*Hesperostipa comata*), and alkali sacaton (*Sporobolus airoides*). All of the species occur in pure and mixed stands. Many of these grassland species are also often the dominant understory species in wooded and shrubby areas. Bush muhly is a common grass species that grows on and inside many of the shrubs at WUPA. It commonly occurs at WUPA; however, it does not spread across the landscape as seen with the other dominant grasses. Isolated stands in WUPA also contain grasslands dominated by sand bluestem (*Andropogon hallii)* and Indian ricegrass (*Achnatherum hymenoides*).

Shrublands are common at WUPA and occur throughout the park as sparse shrublands in the badlands and gradate elsewhere from moderately dense stands of mixed shrubs to dense riparian and wash shrublands. Many shrub species also commonly co-dominate in grasslands and form a steppe type structure. Shrubs that are often observed to co-occur with the herbaceous communities to form steppe vegetation include snakeweed (*Gutierrezia sarothrae*), rabbitbrush (*Ericameria nauseosa*), shadscale, fourwing saltbush, and Mormon tea. Moderately dense stands of shrublands include hummocks of cinders that support Torrey's joint-fir, crispleaf buckwheat, and Apache plume. The most common upland shrubs in the moderately dense shrubland areas include fourwing saltbush, Mormon tea, Torrey's joint-fir, snakeweed, and Apache plume. These shrubs often intermix in the uplands depending on substrate and other abiotic factors. In the sand dunes an indicator species, hoary rosemary-mint (*Poliomintha incana*), often occurs. Matted crinklemat (*Tiquilia latior*) is a small sub-shrub that is commonly found on the basalt lava flows on the eastern section of the project boundary. In the wash systems and the floodplains at WUPA a higher density of shrubs often occurs along the banks and in the washes including, fourwing saltbush, snakeweed, Apache plume, and rabbitbrush. Although many of these species are common to WUPA, they often form denser stands in the washes, including fourwing saltbush that is known to form thick monocultures in these wash systems. Invasive shrubs, saltcedar (*Tamarix* spp.) and camelthorn (*Alhagi maurorum*), occur in dense stretches along the Little Colorado River and are starting to invade up the drainages connecting the Little Colorado River. The native riparian obligate coyote willow (*Salix exigua*) still persists on the banks of the Little Colorado River and in some areas dominates vegetation cover.

Woodlands at WUPA are most commonly observed as an open savanna with the most common tree species being one-seed juniper. This vegetation type commonly occurs on cinder substrate in the southwestern section of the project area. The only true woodlands at WUPA are seen along the banks of the Little Colorado River with a Fremont cottonwood (*Populus fremontii*) canopy and a mix of saltcedar and coyote willow in the understory.

Land use

Various types of land use occur in the project area today; however, land use covers less than 1% of the project area (565 ac/229 ha). Current land use includes roads, NPS facilities including sewer tanks and park housing, commercial trading posts, gas stations, stores, residential land development, livestock stock tanks and dams, strip mines, pumice quarries, gravel pits, and corrals for sheep, buffalo, horses, and cattle. All of these land use activities limit vegetation development. The largest of the land use occurrences are the transportation routes; these include paved and dirt roads on 343 ac (139 ha). Many of these routes allow for park employees to access areas of the park that are not easily accessible and provide access for ranchers and Navajo Nation residents. The second largest development is strip mines, quarries, and gravel pits (155 ac/63 ha). Pumice was mined to incorporate into soap products and is also used in the stone-washed blue jean manufacturing process. Most of this activity occured outside of NPS land and is not actively being mined.

The ancient Pueblo people that occupied WUPA also used the landscape intensively for resource needs and managed them for sustained use. Some of the resource uses of ancient Pueblo people include gathering wild foods, planting crops, using native species for basketry and medicine, and using trees for firewood. This resource use ultimately shaped the landscape at WUPA. However, we were not able photointerpret any archeological features and only mapped current land use activities that we could visually distinguish from vegetated areas on the aerial photography.

3. METHODS

In mapping and classifying the vegetation of WUPA, we used the protocols and procedures established by the USGS/BRD (Appendix C) and described in *Field Methods for Vegetation Mapping, Standardized National Vegetation Classification System* (TNC and ESRI 1994a). The general work tasks were:

1. Project scoping and planning
2. Existing information review
3. Preliminary data collection
4. Aerial photography and base map acquisition
5. Sampling design development
6. Field data collection
7. Vegetation classification and characterization
8. Vegetation map preparation
9. Accuracy assessment

Project scoping and planning

WUPA vegetation mapping incorporated the combined expertise and oversight of several organizations: 1) oversight and programmatic considerations were managed by the Center for Biological Informatics (CBI) of the USGS/BRD, 2) NPS and WUPA personnel provided additional guidance on specific monument needs, 3) aerial photointerpretation and cartographic mapping were provided by the USBR/RSGIG, 4) the CPRS provided field data collection, data analysis and classification, the plant association local descriptions and key, and the accuracy assessment, and 5) NatureServe provided data analysis review and the global plant association descriptions. The specific technical responsibilities assigned to the cartographic and ecological teams are listed below:

RSGIG responsibilities and deliverables

1. Obtain existing color-infrared aerial photography from NPS
2. Collect observation point data to determine photosignatures, determine a preliminary classification, and familiarize interpreters with plant community characteristics and their range of variation
3. Prepare a preliminary photointerpretation to assist field data gathering efforts
4. Attend a meeting to determine final mapping classes, both vegetated and land use, to be used for the final photointerpretation
5. Interpret aerial photographs
6. Transfer interpreted information to a digital spatial database and produce hard copy (paper) vegetation maps
7. Create digital vegetation coverages including relevant attribute information
8. Conduct field verification of the accuracy of the draft vegetation map
9. Produce Arc/Info export file of observation point locations
10. Provide any ancillary digital files developed during the mapping process

11. Document FGDC compliant metadata files (Appendix A) for all created spatial data
12. Prepare materials for the final report describing procedures used in preparing products

CPRS responsibilities and deliverables

1. Develop a preliminary vegetation classification for the study area from existing data
2. Determine field data sampling locations and strategy
3. Collect field data to identify and describe plant associations in the project area
4. Analyze field data and prepare a final classification, local association descriptions, and a key to plant associations
5. Field test the final classification, descriptions, and plant association key
6. Collect accuracy assessment points, analyze them against the final photointerpretation and prepare statistics describing map accuracy
7. Produce Arc/Info export file of sampling locations, vegetation relevé and accuracy assessment locations, and Access database file of relevé data and jpeg image files of relevé photos
8. Develop FGDC compliant metadata files (Appendix A) for all vegetation relevé and accuracy assessment coverages and databases
9. Prepare a final report CD with all compiled products

NatureServe responsibilities and deliverables

1. Review vegetation classification developed by CPRS
2. Develop global plant association descriptions
3. Include newly described plant associations into the National Vegetation Classification (NVC) and present on a public web site (www.natureserve.org/explorer/)

A scoping meeting was held with all interested parties in March 1999 at the NPS office in Flagstaff, AZ. The purpose of this meeting was to inform monument staff and interested neighbors about the USGS-NPS Vegetation Mapping Program, learn about the monument's management and science issues and concerns, identify existing data sources, develop a preliminary schedule with assigned tasks, obtain a commitment from the monument to issue collecting permits, identify possible areas of cooperation with neighbors and partners, and define project boundaries.

Park management issues and concerns for which a vegetation map would be helpful with were identified during the scoping meeting and included: restoration of the grasslands for antelope, density of the junipers (*Juniperus monosperma*) and their possible encroachment into the grasslands, restoration of the floodplain plant communities and the removal of saltcedar (*Tamarix* sp.), and adequate sampling of the monument's diverse habitats.

The total mapping area was set at 106,380 ac (43,380 ha), including 35,478 ac (14,358 ha) within WUPA. This boundary was selected in order to include a 1-mile (1.6 km) environs area around the monument and other areas of special interest including the Babbitt Ranches, Coconino National Forest, and Navajo Nation land.

Preliminary data collection and review of existing information

To minimize duplication of previous work and to aid in the overall mapping project, we obtained existing data including maps and reports from various sources. Monument staff provided digital and/or hard-copy background maps for the project border and miscellaneous other digital files. We obtained site maps from the NPS and the Coconino National Forest, and topographic maps, digital elevation models (DEMs), digital line graphics (DLGs), and digital raster graphics (DRGs) from the USGS. Babbitt Ranches provided a copy of their recently completed Biological Assessment (Cordasco, et al. 1998). A preliminary list of plant associations and local land use types was prepared following a field reconnaissance survey conducted at the time of the scoping meeting.

Aerial photography and base map acquisition

NPS provided the aerial photography used in this project. The photographs are color-infrared and were acquired on June 3, 1996 by Merrick & Co. of Aurora, Colorado. They were flown at the 1:12,000 (1 inch=1000 feet) scale. The photographs were produced as 9 in x 9 in diapositives. Overlap averaged 50-60% and sidelap between flight lines was approximately 30-40%. Flight lines for the aerial photos are shown in Figure 5.

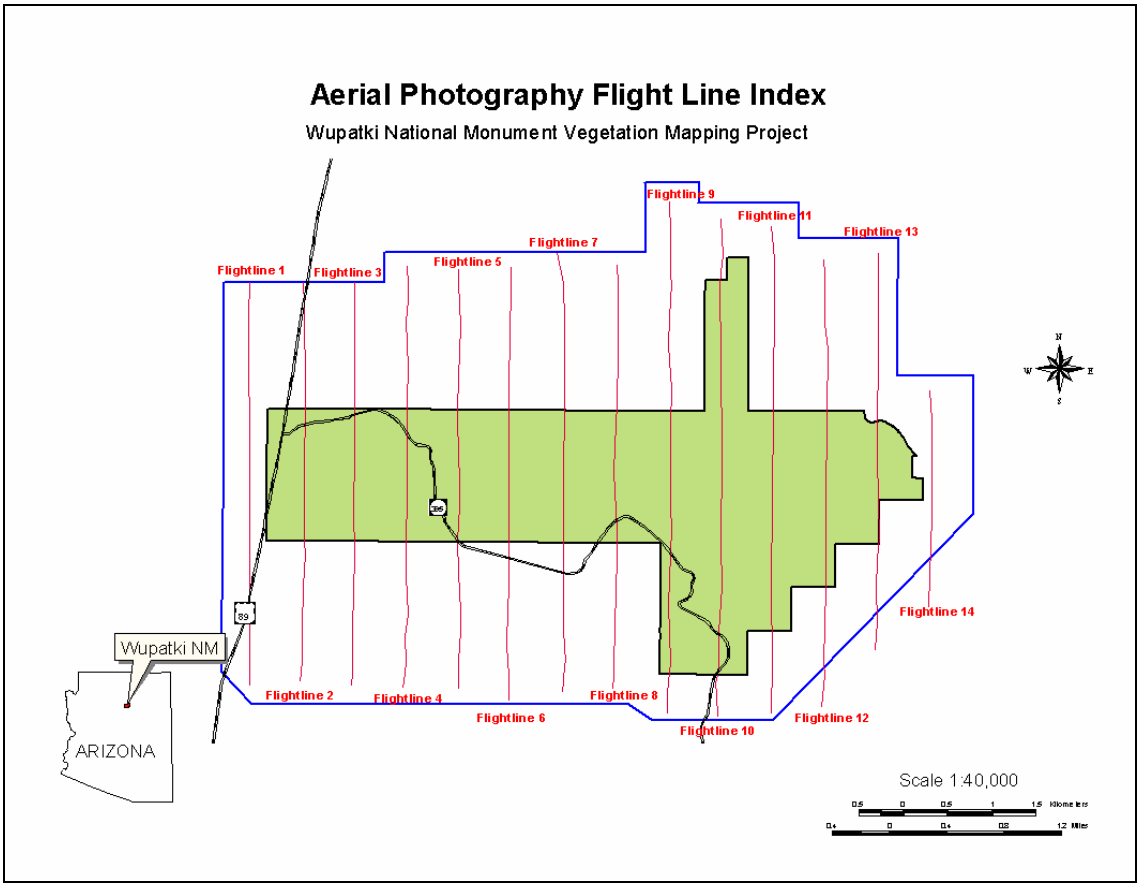


Figure 5. Mapping project area of the WUPA vegetation map and aerial photo flightlines.

We acquired base maps, standard USGS digital orthophoto quarter quads (DOQQs), for geo-referencing the vegetation map from the NPS. These maps are black-and-white, with a 1-meter per pixel resolution, UTM coordinate system, and NAD83 datum. The photos used to create the DOQQs were flown in October 1997. The DOQQs used for this project are the East of SP Mountain (NE and NW quarter quads), O'Leary Peak (NE quarter quad), Gray Mountain (SE and SW quarter quads), Wupatki SW (all quarter quads), Wupatki SE (all quarter quads), Strawberry Crater (NE and NW quarter quads), Wupatki NE (SE and SW quarter quads), and Roden Crater (NE and NW quarter quads).

Sampling design development

A gradsect sampling design was used to divide the park into ‘environmental types’ to stratify for field sampling. We identified, in a scoping session with USGS, BOR, and NPS scientists and managers, three environmental factors; elevation, soil, and geology; to be used to direct field sampling. Six elevation characteristics were derived from a Digital Elevational Model (DEM). Three soil and four geology classes identified in the Arizona Land Resource Information System (ALRIS). We developed a digital map (coverage) of environmental types in a GIS by overlaying a coverage of the derived topographic characteristics. The result was 90 possible 'environmental types' (six elevation classes x three soil classes x five geology classes); however, only 37 of these types actually occurred in the study area. We allocated potential relevé locations among the environmental types based on the percent contribution of each environmental type to the total study area. We used the allocated relevés to guide sampling. Within the environmental types we initially determined placement of relevés based on road accessibility and land ownership access. However, the environmental types were not always representative of the vegetation on the landscape and we modified the sampling design to include sampling multiple relevés in a single polygon if the vegetation was heterogeneous within an environmental type.

Field data collection

RSGIG ecologists conducted reconnaissance field surveys (in June 1999, May 2000, June 2001, and February 2002) during which photointerpretation observation sites were sampled. RSGIG ecologists photographed representative plant associations and noted their position on the landscape, collected data at sites representative of distinctive photosignatures, and recorded field observations directly on Mylar overlays on individual aerial photos.

The data collected described the habitat and vegetation structure and composition. Specific information recorded for each photointerpretation observation included Universal Transverse Mercator (UTM) X-Y coordinates (NAD83 datum), dominant species cover estimates, and a brief description of the environmental characteristics (see Appendix D for an example of the field form). The RSGIG team also conducted joint field sessions with CPRS plant ecologists to exchange observations, become familiar with field methodologies for vegetation relevé data collection, and discuss the project area. These joint sessions helped the ecologists become more familiar with the relationship of plant associations to photosignatures. Photointerpretation observations also guided the development of a draft list of map classes.

RSGIG plant ecologists conducted additional field observations in areas where strong substrate photosignatures masked the vegetation. In these areas, the RSGIG plant ecologists field-mapped all the polygon data. This problem occurred in the Wupatki Basin in areas where basalt and cinder substrate masked the vegetation on the color infrared photography.

Two CPRS plant ecologists conducted classification field surveys from early May through the end of August 2000. We used the standard relevé method to quantify the vegetation community (Muller-Dombois and Ellenberg 1974, USGS-NPS 2000). The field team subjectively determined field relevé positioning within each environmental type visited so as to represent vegetation assemblages that were relatively dominant, homogenous, and covered a minimum mapping unit area of half a hectare. The field team also sampled special features and unique vegetation types within the environmental assemblages that are of specific interest to the park.

Typically, we measured 400 m^2 circular relevés due to the complexity of the vegetation in the environmental types. If the vegetation distribution was better represented by rectangular or square relevés we used this relevé layout instead, as in linear riparian corridors. The habitat of the site was characterized by the relevé slope, aspect, elevation, soil characteristics, substrate type, topographic position, landform type, and whether it was wetland or upland. We also took two photographs that best represented the vegetation of the site and recorded the angles from which they were photographed. We documented site UTMs, landownership, and USGS quad. We recorded leaf phenology, leaf type, and physiognomic class for the overall vegetation. For all perennial species we also recorded strata layer [tree (>3 meters), shrub (0.5-3 meters), and ground (<0.5 meters)] and percent species cover. Within each of these strata layers each species' percent cover was calculated based on its absolute cover within the relevé. Therefore, we estimated each species percent cover for each strata layer on the assumption that the total cover of the relevé was 100%. We also estimated total cover for all vegetation for each lifeform based on a species morphological characteristics (total tree, shrub, and ground cover) and we calculated the percent cover of each lifeform relative to the total percent cover within the relevé. For instance, we would calculate the percent cover of all shrubs relative to the overall total cover of the relevé and also estimated separately the percent cover of all herbaceous species relative to the total cover. For example, the total relevé cover could be 40%, total shrub cover 30%, herbaceous cover 15%, and no tree cover; the shrub and herbaceous cover do not add up to 40% due to overlap of the herbaceous and shrub communities. Therefore, we also estimated total vegetation cover as an overall estimate from an aerial perspective and for each lifeform (tree, shrub, ground), which allowed us to assess the overlap between the lifeform classes. When the total lifeforms of tree, shrub, and ground are additive to the total cover using estimates from the ground based perspective, it implies that no overlap occurs within these relevés. We also measured each tree with >10cm dbh (diameter at breast height). In addition, we included calculations of percent cover for exotic species, individually and combined. Similarly, we measured percent cover for all sensitive species (as identified by the park management). The classification relevé datasheet is located in Appendix D.

We entered the classification relevé data into a Microsoft Access 2000 (version 9.0) database. We standardized plant names to the USDA PLANTS (USDA NRCS 1999) nomenclature. After the data were entered we performed spatial and data entry quality control checks.

Vegetation classification and characterization

Vegetation classification was based on guidelines developed from the U.S. National Vegetation Classification (NVC) (TNC and ERSI 1994b) and the National Vegetation Classification Standard (NVCS) adopted by the FGDC (1997). The NVCS classifies vegetation on seven hierarchical levels with the finest levels of the classification being the alliance and the association (Figure 6).

Physiognomic and Floristic Hierarchy

SYSTEM: TERRESTRIAL
CLASS Herbaceous Vegetation
SUBCLASS Perennial graminoid vegetation
GROUP Temperate or subpolar grassland
SUBGROUP Natural/Semi-natural
physiognomic levels FORMATION Short sod temperate or subpolar grassland
floristic levels ALLIANCE *Pleuraphis jamesii* Herbaceous Alliance
ASSOCIATION *Pleuraphis jamesii - Sporobolus airoides* Herbaceous Vegetation

Figure 6. An example of the NVC physiognomic and floristic hierarchy using the *Pleuraphis jamesii – Sporobolus airoides* Herbaceous Vegetation association.

The goal of the USGS-NPS vegetation mapping program is to classify vegetation types to the association level. The definition of an association as put forward by the Ecological Society of America Vegetation Classification Panel is "A vegetation classification unit consistent with a defined range of species composition, diagnostic species, habitat conditions, and physiognomy" (Jennings et al. 2003). Occasionally, a vegetation type cannot be defined to the association level, and the vegetation is described to the courser alliance level. An alliance consists of a group of plant associations that share a uniform physiognomy and is characterized by one or more diagnostic species, which at least one of these species is found in the uppermost vegetation stratum (Mueller-Dombois and Ellenberg 1974).

Associations are named by the dominant and/or indicator species occurring in the community. If more than one species is characteristic of the association, then the species in the dominant strata is listed first and separated by a forward slash (/) from species in the lower strata or if species occur in the same strata they are separated by a dash (-). Parentheses are used when species are frequently present, but do not necessarily occur all the time, yet are considered an important part of the community structure when present. The nomenclature for alliances is based on the dominant and diagnostic species, and includes at least one species from the uppermost stratum in the alliance name.

We initially analyzed vegetation using multivariate classification analyses. Matrices of species absolute cover organized by relevé and species were extracted from the field relevé for use in a vegetation classification and ordination software program, PC-Ord, v 4.10 (McCune and Mefford 1999). Six matrices based on division of relevés by lifeform were examined: 1) all relevés, 2) relevés with greater than 60% cover tree species, 3) relevés with greater than 25% (but less than

60%) cover tree species, 4) relevés with greater than 25% cover shrub species (and less than 25% cover tree and herbaceous species), 5) relevés with greater than 25% cover grass and forb species (but less than 25% cover tree or shrub species) and 6) relevés with less than 25% cover. We calculated the cover of trees, shrubs or grasses in a relevé by adding the separate cover estimates for each species of that particular lifeform. The percentage used to separate each lifeform type is based on FGDC criteria for NVCS formation classes and as interpreted by NatureServe (nee ABI) (Grossman et al. 1998, Reid 2000 pers. comm.). Due to WUPA's arid landscape many relevés had greater than 25% total cover but less than 25% of tree, shrub or herbaceous cover. In those cases, we assigned the relevé a formation class based on the dominant lifeform, or if the relevé was ecologically similar to a particular alliance within another formation class, and did not have the necessary cover values, these were lumped within the dominant alliance (Reid 2001 pers. comm.).

We used algorithms within PC-Ord to examine species association patterns in each matrix. An agglomerate group averaging method, Unweighted Pair Group Method Using Arithmetic Mean (UPGMA), commonly known as cluster analysis, was next applied with the distance measure defined as Sorensen's coefficient (also known as the Czekanowski or Jaccard coefficient). We labeled each relevé in the cluster analysis with preliminary alliance and association labels based on iterative examination of the cluster analysis graphic output (a dendrogram), preliminary alliance descriptions for the western states (Reid et al. 1999) and the cover values for species in each relevé.

NatureServe reviewed the results of the data analysis, and the initial placement of relevés within associations and alliances. A number of vegetation types identified from the analysis represented associations already documented in the NVC, and registered in NatureServe Explorer, an online encyclopedia of life (www.natureserve.org/explorer). In some cases the vegetation types from the analysis did not correspond to existing associations in the NVC (i.e. appeared to be new associations), and these were treated in three different ways according to the amount of information supporting them from the project. Those with ≥ 3 relevés, or with fewer relevés but covering substantial mapping area were incorporated into the NVC as new plant associations. Those with few relevés (typically <3), seemingly uncommon or of uncertain floristic composition, were designated as "provisional" plant associations in the NVC, and require additional sampling to fully understand their floristic and ecological characteristics. The last group of vegetation types were those represented by only one or two relevés, that seemed essentially unique to the WUPA project area. Until further inventory is completed, these should be thought of as "local" vegetation assemblages and we describe these throughout the report as local assemblages. A few relevés were classified only to the coarser alliance level.

A dichotomous key to the vegetation association/alliances as well as to the corresponding map classes was developed prior to the 2002 accuracy assessment field season. We used the key in the 2002 data collection for accuracy assessment (Appendix E).

Vegetation map preparation

The five following steps were used to create the WACA vegetation map: 1) map class development, 2) aerial photograph interpretation, 3) digital transfer, 4) map validation, and 5)

metadata. Following these steps, we performed a more formal accuracy assessment of the vegetation map to determine errors of omission and commission with the goal of achieving a minimum of 80% map accuracy.

Map class development

Final WUPA map classes used for interpreting the aerial photographs were derived (1) from plant associations and alliances described by CPRS, (2) from the Anderson (1976) Level II land use classification system, (3) from land cover classes, and (4) from unique stands specific to WUPA. In some cases, one NVC association corresponded to one mapping class; more often, because of difficulties in interpreting the CIR photographs, map classes described more than one plant association and were combined into mosaics or complexes of associations. For instance, we combined the galleta mixed grassland associations (*Pleuraphis jamesii – Sporobolus airoides* Herbaceous Vegetation and *Bouteloua eriopoda – Pleuraphis jamesii* Herbaceous Vegetation) into a Galleta Mixed Grasslands map class. In some instances, map classes consisted of a mixture of associations that we mapped in other places as a one-to-one relationship. For example, Wupatki Wash System is a landform that is easy to interpret on the aerial photography, but it is not easy to distinguish specific vegetation associations in the washes that we know to occur elsewhere in WUPA. Also, in the washes the structure of the associations appears to have a higher density and height than on the uplands. Therefore, we formed a new map class Wupatki Wash System to distinguish this landform type and incorporated vegetation associations that we described and mapped elsewhere in WUPA. The Anderson Level II land use classes included semi-natural vegetation and cultural types, i.e. roads, facilities, residential land, corrals, etc. Finally, we created special map classes for vegetation or land use recognized by the photointerpreters but not part of the NVC. These special map classes include Cinder Barren, Active River Channel, Fourwing Saltbush Upland Drainageways, and Unclassified Mixed Shrubland.

Aerial photograph interpretation

The CIR film used at WUPA has the ability to highlight subtle differences in vegetation, especially among wetland types, but communities on black substrates such as cinder and basalt tend to be rendered invisible. RSGIG interpreted the aerial photographs using the classification relevé NVC-derived map classes, RSGIG field notes, and photointerpretation observations to prepare the GIS vegetation database.

Photointerpretation is a manual process; we covered each 9-in x 9-in aerial photograph or transparency with sheets of translucent Mylar. The aerial photos and their overlays were backlit on a light table and their photographic signature read. Using a stereoscope helped to recognize three-dimensional features. Corner and side tics, photograph and flight line number were marked on each Mylar sheet. We delineated polygons using a 0.5 mm lead pencil. Only the center portion of each aerial photograph was interpreted to minimize the effects of edge distortion. In order to insure completeness and accuracy, digital transfer specialists reviewed all of the interpreted photos for consistency and recommended changes where necessary.

We delineated map classes, derived from the NVC classification, on the photos that were visible on the photography. Photointerpreters applied the preliminary NVC classification to aerial photosignatures to see how many plant associations could be recognized on the photos and the

development of these map classes consisted of an iterative process between the photointerpreter and the ecologist. We addressed problems by using two separate but related classifications: (1) a NVC classification based on the classification relevés and (2) a map class classification for the GIS database.

Digital transfer

The transfer process removes much of an aerial photograph's inherent distortion and ties the interpreted data to real-world coordinates so it can be digitally automated. To accomplish this, RSGIG created an ArcInfo GIS database for WUPA using in-house protocols. The protocols consist of a shell of Arc Macro Language (AML) scripts and menus 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 aerial photographs to a digital, geo-referenced format involves two techniques: (1) scanning the interpreted line work and (2) on-screen digitizing some land use classes. Both techniques require a background image (base map). We used USGS DOQQs as the base maps for this project.

The scanning transfer technique used for WUPA involved a multi-step process whereby the Mylar overlay sheets produced by the photointerpreters were scanned into a digital form. The digital image file (.tif) created from the scanned sheet was then converted to a vector file using RSGIG-developed AMLs. The vector file or 'line coverage' was then geo-referenced to the orthophoto base map. Essential to this process is to match the scale and position of features on the photographs with the scale and position of the same features on the orthophotos. Technicians accomplished this by adjusting the scale of the scanned Mylar between known control points using computer program routines until the adjustment was considered a good fit (Figure 7).

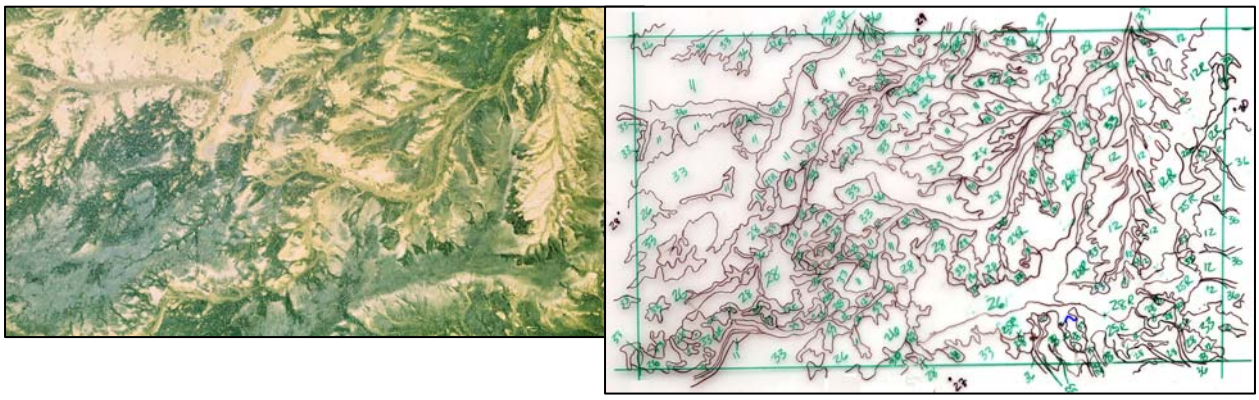


Figure 7. Example of the photointerpretation process using aerial photo 10-009 and corresponding (scanned) Mylar overlay.

Any remaining land use classes not already scanned (such as roads) RSGIG transferred by manually tracing digital lines (using a mouse) on a computer monitor screen with the DOQQ as a background image. The completed line work for each photo was edge matched. Finally, RSGIG created the polygon topology and attribute information added to produce a digital vector (polygon) coverage. All the individual coverages (one per photo) were then combined into a single vegetation coverage.

Each polygon in the final coverage for WUPA was given attributes pertaining to map classes, the corresponding aerial photograph number, NVC information (ecosystem, physiognomy, association, alliance, class, subclass, group, subgroup, formation, and database codes), and other comments related to the distribution and photointerpretation.

RSGIG has developed an efficient automated system of scanning, transferring, and registering interpreted line work using a 'shell' system of AMLs and MENUs. This system greatly increases accuracy and consistency in the development of the digital vegetation map. In addition, in order to accommodate several technicians working on the database at the same time, the work was divided by quarter-quad area (i.e., one vegetation coverage per quarter-quad area). Once all the transfer work was complete, we combined all the individual vegetation coverages into one seamless coverage.

Map Validation

A draft hard copy vegetation map at the 1:12,000 scale was printed and checked against the interpreted aerial photographs. As a final internal accuracy check, RSGIG applied photointerpretation observations and classification relevés over the vegetation map to determine if the polygon labels matched the field data.

Map validation occurred prior to the accuracy assessment. Because of the difficulties in interpreting the vegetation directly from the aerial photographs, we eventually mapped and/or validated much of the project area in the field.

Metadata

Metadata are required for all spatial data produced by the federal government. RSGIG used SIMMS™ software to create the three FGDC-compliant metadata files attached to the spatial databases and to this report. The metadata files explain the vegetation coverage and ancillary coverages created by RSGIG, the plot data coverage created by CPRS, and the accuracy assessment data created by CPRS.

Accuracy assessment

CPRS field staff conducted the formal accuracy assessment of the WUPA vegetation map and vegetation association key. We conducted field surveys from August through October 2002 in two phases. We sampled the western half of the map first, followed by the eastern half. The sampling design was developed to ensure that halves of the map were sampled equally. We used the field observations to create the reference dataset used to assess the accuracy of the map. Accuracy assessment was conducted using both standard criteria for accuracy (exact match) and 'fuzzy' categorization criteria for accuracy (acceptable, understandable, vaguely similar, and complete error).

Prior to selecting reference points for field observations, the topology and data structure for the vegetation coverage were checked by running a check for node errors and label errors. The coverage was also 'dissolved', removing polygon boundaries when adjoining polygons have the same value.

We selected field sampling locations for each map class based on the total cover of each class in the vegetation coverage. Map classes with more cover had more reference points assigned than those with less cover. The required number of polygons to be sampled was determined by applying USGS-NPS vegetation mapping program criteria (Table 1) that considers the number of polygons in each map class and the total area of each map class in the vegetation coverage and seeks to ensure a 90% confidence level and a sample error of 10%. We assigned random numbers to the polygons for each map class and the required numbers of polygons were selected plus 5 to 10 extra polygons in the case that some polygons could not be reached.

Table 1. USGS-NPS vegetation mapping program criteria used for determining sampling numbers in the accuracy assessment.[4]

Scenario	Description	Polygons in class	Area occupied by class	Recommended number of samples in class
A	Abundant. Many polygons that cover a large area.	≥ 30	≥ 50 ha	30
B	Relatively abundant. Class has few polygons that cover a large area.	< 30	≥ 50 ha	20
C	Relatively rare. Class has many polygons, but covers a small area. Many polygons are close to the MMU.	> 30	< 50 ha	20
D	Rare. Class has few polygons, which may be widely distributed. Most or all polygons are close to the MMU.	≥ 5, ≤ 30	< 50 ha	5
E	Very rare. Class has too few polygons to permit sampling. Polygons are close to the MMU.	< 5	< 50 ha	Visit all and confirm

Eight hundred and eighty two accuracy assessment sampling locations were initially determined, including alternate locations in case a targeted point could not be evaluated. We observed 691 locations in the field.

All polygons were included in the sampling design regardless of the size of the polygon. Polygons that were greater than the minimum mapping unit (MMU) had sampling locations randomly assigned in the polygon excluding a 5-meter (16 ft) (buffer from the polygon edge. In

[4] Based on the USGS-NPS park mapping accuracy assessment procedures (http://biology.usgs.gov/npsveg/aa/sect8.html#8.2.1) (USGS-NPS 2000) and TNC-ERSI (1994c) criteria.

polygons that were less than the MMU, we used the centroid of the polygon for the sampling locations to minimize edge effects from adjacent polygons.

Data collection

The CPRS field team had a list of UTM coordinates for each sampling location, the area and perimeter of the polygon encompassing its location, and the shortest distance to the adjacent map class. The team had provided polygon maps for all polygons to be sampled. The field ecologists went to the sampling location indicated by the UTM coordinates and assessed an area around that location no larger than the MMU. Field observations were recorded on a field form, including the following: the plant association/alliance and map class within the sampling location, confidence in the decision according to the descriptions of the association/map classes in the field key (using the following four categories: exact, good or some problems, poor, or none that fit), explanation of confidence less than exact (including alternative map class possibilities), other map classes/associations/alliances that were identified within the polygon, UTM coordinates (easting, northing), altitude, and Global Positioning System (GPS) error (using the Garmin 45XL, Garmin Corporation, 1996). The field ecologists sometimes could not get to a pre-selected sampling location; in these cases, the polygon was assessed remotely if possible or a different polygon was selected for observation from the list of replacement polygons. During the accuracy assessment fieldwork ongoing discussions between the field biologists and project ecologists/botanists allowed for refinement of the NVC plant association or map class key. We accounted for these changes during the accuracy assessment analysis described below.

Accuracy assessment analysis

Accuracy assessment analysis was done by comparing the map class observed in the field (field observation or reference data) with the map class mapped at the same location on the final vegetation map (map class data). We made these comparisons using standard accuracy assessment analysis, identified as part of the USGS-NPS Vegetation Mapping Program (http://biology.usgs.gov/npsveg/aa/toc.html), and a modified 'fuzzy set' accuracy assessment analysis (Klopfer et al. 2002) (Table 2). We overlaid field observations onto the final vegetation map to determine the corresponding map class for each location, except for those places that were remotely assessed in 2002. In these cases, the map class that was identified for the target polygon for the sampling design was assigned to the map class data rather reference map class.

For each standard and fuzzy set comparison, a contingency table was developed to compare the reference data with the map class data. The contingency table lists reference data values in the columns and map class values in the rows. The number of each reference data and map class pair for all sampling locations is indicated at each row/column intersection in the matrix (see Table 7 for an example). Correct mappings are indicated on the table where the row and column values are the same and typically occur on the diagonal on the matrix (yellow highlight on Table 7). The contingency table is used to calculate a variety of statistics describing the map performance: omission accuracy (also known as producer's accuracy), commission accuracy (also known as consumer's accuracy), the overall accuracy, and the Kappa index.

Initial analysis revealed a low overall accuracy and therefore, we examined the errors associated with each observation using a modified 'fuzzy set' analysis to rank the type of error (Klopfer et al. 2002, Falzarano and Thomas In Press). In this assessment, five criteria: exact match,

acceptable error, understandable error, vague similarity, and complete error, are used to assess the fit between the reference data and map class for each sampling location (Table 2).

Table 2. Definitions used in the 'fuzzy set' analysis classifications at WUPA.

Criteria	Descriptions
5	**Exact Match**: The reference data is an exact match to the map class.
4	**Acceptable Error**: If any of the following criteria were met, the case was considered acceptable error: 1) The reference data are the same as a map class in the nearest adjacent polygon and is within 12 meters of that polygon (distance chosen based on project specific considerations), or within National Map Accuracy Standards for horizontal accuracy (Robinson 1984); 2) The reference data has an alternative correct reference label that was described in the field, which was correct for the map class.
3	**Understandable Error**: The map class has similar structural composition and species dominance.
2	**Vague Similarity**: The map class has a similar formation type, but not similar species composition.
1	**Complete Error**: No similarly in the species or structural composition.

A contingency table was created for three criteria: 1) standard or exact match analysis, a correct map class was considered to occur where there was exact match between the reference data and map class data, 2) acceptable error—a correct class was represented by exact (criteria 5) and acceptable (criteria 4) matches between reference data and map class data, and 3) understandable error—a correct class was represented by exact (criteria 5), acceptable (criteria 4) and understandable (criteria 3) matches between reference data and map class data. The standard accuracy assessment uses the same criteria as an exact match in the modified fuzzy set analysis.

An example of acceptable error was the case of a field observation of Wupatki Wash System mapped as Crinklemat/Alkali Sacaton Dwarf Shrubland. In this example, the field observation was 10 meters from the nearest polygon, with a GPS error of 5 meters, and that polygons classified Wupatki Wash System. Due to the close proximity of the field observation to a polygon with a matching map class we believe that the apparent misclassification may actually be a reflection of locational error either on the map or in the field, rather than a photointerpretation misclassification.

Another case of acceptable error was where the field observation was Snakeweed / Galleta Grassland with Moenkopi Sandstone Sparse Vegetation interspersed within the very large polygon and the map classifies the polygon as Moenkopi Sandstone Sparse Vegetation. Since the correct map class was listed on the field sheet as an alternative map class, this observation was considered an acceptable error.

An example of understandable error was where the field observation has a similar species composition and structure as the map class assigned to the polygon containing the observation. For example, Galleta Grassland as the reference label and Galleta Mixed Grasslands as the map class have the same structure and species composition, except that additional grass species occur

in the Galleta Mixed Grassland map class. In this case, it was likely that it was difficult for the photointerpreters to delineate a pure galleta type from a galleta mixed grass type.

Vaguely similar would include the case where the field observation structure was similar to the map class; however, the species composition was not similar, for example a field observation of Black Grama Grassland and map class of Galleta Grassland. An example of complete error was when the reference label (such as Cinder Barren) has no similarity with the map class (such as Fourwing Saltbush Upland Drainage-ways) in terms of structure or species composition.

When the field observation was determined to 'fit' the map class for a particular criteria, the field observation was 'reassigned' to the map class for the purposes of constructing the error matrix. Hence, the diagonals on the error matrix show the sum of all field observation/map class pairs that fit under the particular criteria being applied.

Overall total accuracy for each contingency table criteria described above (standard analysis, acceptable error, and understandable error) was calculated by dividing the total number of correctly classified reference data points by the total number of reference data points. We also assessed individual map class accuracies for each of the criteria described above. To calculate the probability that a reference data observation has been correctly classified (producer's accuracy or omission error), the number of reference data points correctly classified is divided by the total number of reference data points in that map class. To calculate the probability that the mapped vegetation associations represent the associations actually found on the ground (user's accuracy or commission error), the number of correctly classified reference samples is divided by the total number of samples classified or mapped to that vegetation association.

Equations to calculate statistics for each criteria described occur in the program document, Accuracy Assessment Procedures (http://biology.usgs.gov/npsveg/ aa/toc.html) and TNC and ERSI (1994c). Two-tailed, 90% confidence intervals for the binomial distribution were also calculated using JMP statistical software (SAS Institute 1989-2000) using Score Confidence Interval Tables. Score Confidence Interval Tables are known to have better coverage probabilities with smaller sample sizes (Agresti and Coull 1998). To account for correct classifications due to chance, we calculated a Kappa index (Foody 1992; TNC and ERSI 1994c) also using JMP statistical software.

4. RESULTS

Field surveys

We obtained 186 photointerpretation observations and 214 classification relevés for analysis of vegetation communities, interpretation of the aerial photography, and selection of the final map classes (Figure 8).

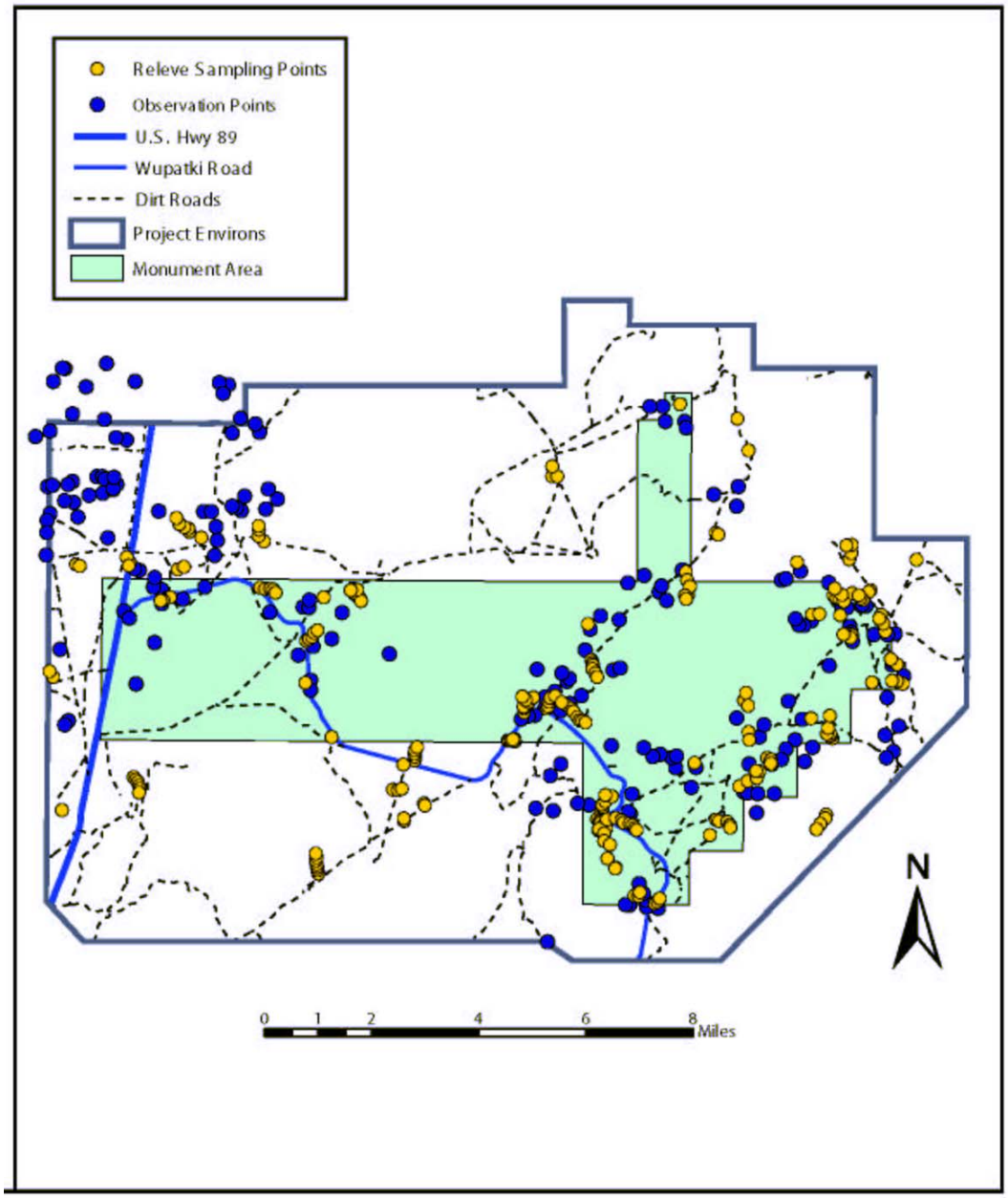


Figure 8. Location of WUPA photointerpretation observations and classification relevés.

Vegetation classification

The NVC classification resulted in a total of 24 alliances, 23 associations, 3 provisional associations, one local vegetation assemblage, and one barren class (Table 3). Full descriptions of the WUPA vegetation associations and provisional associations are located in Appendix F. A listing of all species identified during the course of this study can be found in Appendix G. Three provisional associations and one local vegetation assemblage described during the course of this study needs further sampling on the Colorado Plateau to determine if they represent local vegetation types unique to WUPA or if they are found across the landscape. Ten alliances and 14 associations are newly described in the NVC. The alliances, as grouped by formation, consist of four sparse, eight herbaceous, two dwarf-shrubland, ten shrubland, and one forest formation classes and the associations consist of four sparse, ten herbaceous, one dwarf-shrubland, ten shrubland, and one forest formation classes. The plant associations, provisional associations, local assemblage, Anderson land-use classes, and geologic exposures are related to the aerial photointerpretation map classes and are listed in Appendix H. A field key to both the map classes and alliance/association classification is listed in Appendix E.

Table 3. WUPA National Vegetation Classification assignments.

Formation Class	Assignment	NVC Alliance	NVC Association	Relevé #
Sparse	New Association	PAINTED DESERT SPARSELY VEGETATED ALLIANCE	*Atriplex obovata* Badland Sparse Vegetation	WU-026, WU-040, WU-139B, WU-140, WU-140B, WU-142
Sparse	New Alliance and Association	*EPHEDRA TORREYANA* SPARSELY VEGETATED ALLIANCE	*Ephedra torreyana - (Atriplex canescens, confertifolia*) Sparse Vegetation	WU-004, WU-005, WU-006, WU-007, WU-008B, WU-010, WU-013, WU-014, WU-015, WU-018, WU-024, WU-039, WU-041, WU-049, WU-050, WU-052, WU-168, WU-169
Sparse	New Alliance and Association	*ERIOGONUM CORYMBOSUM* SPARSELY VEGETATED ALLIANCE	*Eriogonum corymbosum* Cinder Sparse Vegetation	WU-072, WU-073, WU-074, WU-075, WU-076, WU-077, WU-078, WU-079
Sparse	New Alliance and Provisional Association	SANDSTONE SPARSELY VEGETATED ALLIANCE	*Atriplex canescens - (Ephedra viridis) / (Muhlenbergia porteri*) Sandstone Sparse Vegetation [Provisional]	WU-038, WU-066, WU-089, WU-090, WU-091, WU-094, WU-097
Herbaceous	New Association	*ANDROPOGON HALLII* HERBACEOUS ALLIANCE	*Andropogon hallii* Colorado Plateau Herbaceous Vegetation	WU-085
Herbaceous	Association	*BOUTELOUA ERIOPODA* HERBACEOUS ALLIANCE	*Bouteloua eriopoda - Pleuraphis jamesii* Herbaceous Vegetation	WU-092, WU-163, WU-207
Herbaceous	New Association	*BOUTELOUA ERIOPODA* XEROMORPHIC SHRUB HERBACEOUS ALLIANCE	*Bouteloua eriopoda* Coconino Plateau Shrub Herbaceous Vegetation	WU-061, WU-062, WU-107, WU-108, WU-109, WU-110, WU-111, WU-112, WU-113, WU-114, WU-115, WU-117, WU-137, WU-146, WU-154, WU-157, WU-172, WU-173, WU-205, WU-206, WU-208

Formation Class	Assignment	NVC Alliance	NVC Association	Relevé #
Herbaceous	New Association	*HESPEROSTIPA COMATA* BUNCH HERBACEOUS ALLIANCE	*Hesperostipa comata - (Bouteloua eriopoda - Pleuraphis jamesii)* Herbaceous Vegetation	WU-081, WU-083, WU-084, WU-118, WU-119, WU-126, WU-127, WU-127B, WU-131, WU-132, WU-133, WU-134, WU-145, WU-147, WU-148, WU-150, WU-151, WU-153, WU-155, WU-174, WU-175
Herbaceous	New Alliance and Association	*JUNIPERUS MONOSPERMA* WOODED HERBACEOUS ALLIANCE	*Juniperus monosperma* Cinder Wooded Herbaceous Vegetation	WU-120, WU-121, WU-122, WU-123, WU-123B, WU-129, WU-130, WU-176, WU-177, WU-178, WU-179, WU-180, WU-181, WU-182, WU-183, WU-184, WU-185, WU-192, WU-193, WU-194, WU-198, WU-199, WU-200, WU-201, WU-202B, WU-203, WU-204
Herbaceous	New Association	*PLEURAPHIS JAMESII* SHRUB HERBACEOUS ALLIANCE	*Gutierrezia sarothrae / Sporobolus airoides - Pleuraphis jamesii* Shrub Herbaceous Vegetation	WU-033, WU-143, WU-149, WU-158, WU-159
Herbaceous	Association	*PLEURAPHIS JAMESII* SHRUB HERBACEOUS ALLIANCE	*Ericameria nauseosa / Pleuraphis jamesii - (Hesperostipa comata)* Shrub Herbaceous Vegetation	WU-001, WU-027, WU-030, WU-064, WU-124, WU-125, WU-128, WU-135, WU-136, WU-152
Herbaceous	Alliance	*PLEURAPHIS JAMESII* SHRUB HERBACEOUS ALLIANCE	No Association	WU-116
Herbaceous	Association	*PLEURAPHIS JAMESII* HERBACEOUS ALLIANCE	*Pleuraphis jamesii - Sporobolus airoides* Herbaceous Vegetation	WU-028, WU-165, WU-166, WU-167, WU-170
Herbaceous	Association	*PLEURAPHIS JAMESII* HERBACEOUS ALLIANCE	*Pleuraphis jamesii* Herbaceous Vegetation	WU-008, WU-031, WU-059, WU-067, WU-068, WU-080 WU-082, WU-101, WU-156, WU-160, WU-161, WU-162, WU-164, WU-202A
Herbaceous	Association	*SPOROBOLUS AIROIDES* HERBACEOUS ALLIANCE	*Sporobolus airoides* Herbaceous Vegetation	WU-009, WU-011, WU-022, WU-025, WU-035, WU-141B, WU-142B, WU-171
Dwarf-shrubland	Provisional Association	*TIQUILIA LATIOR* DWARF-SHRUBLAND ALLIANCE	*Tiquilia latior / Sporobolus airoides* Dwarf-shrubland [Provisional]	WU-012
Dwarf-shrubland	New Alliance	*GUTIERREZIA SAROTHRAE* DWARF-SHRUBLAND ALLIANCE	No Association	WU-144
Shrubland	New Alliance and Association	*ALHAGI MAURORUM* SEMI-NATURAL SHRUBLAND ALLIANCE	*Alhagi maurorum* Semi-natural Shrubland	WU-188
Shrubland	New Association	*ARTEMISIA FILIFOLIA* SHRUBLAND ALLIANCE	*Artemisia filifolia - Ephedra (torreyana, viridis)* Shrubland	WU-021, WU-036, WU-037, WU-042, WU-043, WU-046, WU-047, WU-054, WU-088, WU-095, WU-096, WU-098, WU-099, WU-100
Shrubland	Association	*ATRIPLEX CANESCENS* SHRUBLAND ALLIANCE	*Atriplex canescens / Sporobolus airoides* Shrubland	WU-019, WU-020

Formation Class	Assignment	NVC Alliance	NVC Association	Relevé #
Shrubland	Provisional Association	*ATRIPLEX CANESCENS* SHRUBLAND ALLIANCE	*Atriplex canescens* Desert Wash Shrubland [Provisional]	WU-048, WU-053, WU-093, WU-096
Shrubland	New Alliance and Association	*BRICKELLIA CALIFORNICA* SHRUBLAND ALLIANCE	*Brickellia californica - Rhus trilobata* Shrubland	WU-032, WU-086, WU-087
Shrubland	New Alliance and Association	*EPHEDRA TORREYANA* SHRUBLAND ALLIANCE	*Ephedra torreyana - Achnatherum hymenoides* Hummock Shrubland	WU-069, WU-070, WU-071
Shrubland	New Alliance and Association	*FALLUGIA PARADOXA* SHRUBLAND ALLIANCE	*Fallugia paradoxa - (Atriplex canescens - Ephedra torreyana)* Cinder Shrubland	WU-029, WU-044, WU-045, WU-051, WU-055, WU-056, WU-057, WU-058, WU-060, WU-063, WU-065, WU-102, WU-103, WU-104, WU-105, WU-106, WU-209
Shrubland	New Alliance and Association	*POLIOMINTHA INCANA* SHRUBLAND ALLIANCE	*Poliomintha incana / (Pleuraphis jamesii)* Shrubland	WU-002, WU-003, WU-016, WU-017, WU-138, WU-139
Shrubland	Association	*SALIX (EXIGUA, INTERIOR)* TEMPORARILY FLOODED SHRUBLAND ALLIANCE	*Salix exigua* / Barren Shrubland	WU-186
Shrubland	Association	*TAMARIX SPP.* SEMI-NATURAL TEMPORARILY FLOODED SHRUBLAND ALLIANCE	*Tamarix* spp. Temporarily Flooded Shrubland	WU-187, WU-189, WU-190, WU-191, WU-195, WU-196
Forest	Association	*POPULUS FREMONTII* TEMPORARILY FLOODED FOREST ALLIANCE	*Populus fremontii / Salix exigua* Forest	WU-197
Unique	Local Assemblage	RIVER COBBLES – HILLTOPS (small area, included in the Monekopi Shale Sparse Vegetation map class)		WU-023
Barren	Surficial Geology	BARREN (small area, included in the Galleta Mixed Shrubland map class)		WU-141

Unvegetated geologic landforms to sparsely vegetated badlands, cinder, Moenkopi sandstone, and Moenkopi shale are common in the project area. The unvegetated landform classes consist of cinder barrens and active river channels with less than 5% total vegetation cover. These barren types cover less than 1% (960 ac/388 ha) of the total area mapped. Although we classified only four vegetation associations and alliances as sparsely vegetated (typically with < 15% total vegetation), many of our grassland and shrubland relevés contain less than 25% total vegetation cover. These relevés were placed into shrubland and herbaceous formations based on their floristic similarity with associations with higher vegetative cover, rather than their total vegetative cover. Sparse vegetation associations cover approximately 16% (17,262 ac/6,986 ha) of the total area mapped. Painted Desert sparse vegetation occurs throughout the eastern section of the project area and commonly includes mound saltbush (*Atriplex obovata*), Torrey's joint-fir

(*Ephedra torreyana*), four-wing saltbush (*Atriplex canescens*), and shadscale saltbush (*Atriplex confertifolia)*. Cinder substrate often supports a sparse annual community, crispleaf buckwheat (*Eriogonum corymbosum*), and Apache plume (*Fallugia paradoxa*). Sparse sandstone vegetation often contains a sparse shrub community of four-wing saltbush, Mormon tea (*Ephedra viridis*), and bush muhly (*Muhlenbergia porteri*) growing in the shrubs.

Grasslands are the most common formation type in WUPA; they consist of pure stands (herbaceous vegetation), mixed grass/shrub steppe vegetation (shrub herbaceous vegetation), and as understory in wooded types (wooded herbaceous vegetation). Herbaceous vegetation types cover 48% (51,388 ac/20,796 ha) of the project area. Half of all the herbaceous associations described during the course of the project were newly described in the NVC. Black grama (*Bouteloua eriopoda*), galleta (*Pleuraphis jamesii*), alkali sacaton (*Sporobolus airoides*), and needle-and-thread (*Hesperostipa comata*) are the four most common grasses in the project area. Pure stands of galleta and alkali sacaton were identified in the project area. Small stands of sand bluestem (*Andropogon hallii*) also occur in less than 12 ac (5 ha) of the project area. Mixed stands of galleta and alkali sacaton, black grama and galleta, and needle-and-thread, black grama, and galleta all occur in the project area. Black grama also occurs as a steppe type, with various shrubs in the canopy. Galleta steppe vegetation typically contains rabbitbrush (*Ericameria nauseosa*) and snakeweed (*Gutierrezia sarothrae*) in the shrub layer. One-seed juniper (*Juniperus monosperma*) typically occurs in a savanna structure in the southern section of the project area with black grama and galleta as the dominant species in the understory. We classified this association as one-seed juniper "cinder" wooded herbaceous vegetation, due to the open savanna structure with a cinder substrate; graminoid cover is not necessarily present in all of these relevés.

Two alliances and one association were classified as a dwarf-shrubland. Only one of the associations, Crinklemat / Alkali Sacaton Dwarf-Shrubland, was mapped and it covers less than 1% (245 ac/99 ha) of the project area. This association consists of crinklemat (*Tiquilia latior*), a small caespitose dwarf-shrub, and alkali sacaton; it only occurs on basalt lava flows adjacent to the Little Colorado River. This association is defined as a provisional association and will need additional data collected prior to inclusion in the NVC. The other dwarf-shrubland alliance identified during our classification is a newly defined pure snakeweed dwarf-shrubland alliance. This alliance occurred in an area of sandstone cobbles, with no recent sign of human disturbance, despite this species frequently occurring in higher abundance in areas of disturbance. The range of this alliance on the Colorado Plateau will require additional sampling to determine its extent.

Shrublands occur throughout the project area in washes, riparian corridors, flats, and on a variety of geologic substrates and cover less than 12% (12,644 ac/5,117 ha) of the project area. More than half of the shrubland associations and alliances were newly described or included as a provisional NVC association. Shrublands on the Little Colorado River included a provisional invasive camelthorn (*Alhagi maurorum*) association, an invasive saltcedar (*Tamarisk* spp.) association, and a native coyote willow (*Salix exigua*) association. All of these associations are fairly limited to the corridor of the Little Colorado River. A large portion of the project area consists of a mixed shrub association with sand sage (*Artemisia filifolia*) as an indicator species and either Torrey's joint-fir and Mormon tea frequently co-occurring. Other shrubs typical to this association include four-wing saltbush and Apache plume. Four-wing saltbush with alkali

sacaton in the understory commonly occurs as a shrubland in washes or areas with sheet flow, and as well as pure stands of dense four-wing saltbush occur in these same environments. California brickellbush (*Brickellia californica*) and skunkbush sumac (*Rhus trilobata*) form a restricted shrub association that occurs only in basalt rock outcrops. A unique hummock, cinder dune, shrubland association occurs with Torrey's joint-fir and Indian ricegrass (*Achnatherum hymenoides*) as indicators of this unique association with other shrubs, typically co-occurring with Apache plume and crispleaf buckwheat. An Apache plume association occurs in cinder substrate, with four-wing saltbush and Torrey's jointfir occasionally co-dominating. A unique, newly defined association, occurring on sand dunes in the eastern section of the project area, has the indicator shrub frosted mint (*Poliomintha incana*) with galleta grass often occurring in the understory.

Only one forested association, and no woodland associations, were characterized at WUPA. In the forest association, we obtained only one classification relevé. Our classification relevé had a total cover of only 20%, much less than a typical forest association (>75% total vegetation). With additional data, we believe that this assemblage will be included in NVC as a woodland. However, with only one relevé collected it was included into an existing association, with the same species composition. The forested association consists of a Fremont cottonwood (*Populus fremontii*) canopy with a coyote willow (*Salix exigua*) shrub understory. We also had a co-dominance of saltcedar (*Tamarix* spp.) in the shrub understory.

Map classes and aerial photography interpretation

The WUPA mapping project used a total of 35 map classes, of which 26 were vegetation based, two were geomorphologic based and seven were Anderson Level II land-use units. The final map classes were selected by CPRS, NPS and RSGIG personnel at a meeting held in December 2001 and adjusted slightly following map verification in February 2002. The units reflect the combination of fieldwork, photointerpretation, and the NVC vegetation classification developed by the CPRS. A crosswalk between map classes and the NVC vegetation classification is shown in table 4. The final map classes deviated from NVC standards when either 1) a NVC vegetation association could not be distinguished on the aerial photos as in the case of some of the grasslands, or 2) when special units were requested by monument staff to aid with their management.

Table 4. WUPA map classes and their NVC components.

Map Code	Map Class	Map Class NVC Name
1	Cinder Barren	- none (Land Cover Class)
2	Basalt Outcrop Shrubland	*Brickellia californica - Rhus trilobata* Shrubland
3	Active River Channel	- none (Land Cover Class)
4	Mound Saltbush Badlands Sparse Vegetation	*Atriplex obovata* Badland Sparse Vegetation
5	Moenkopi Sandstone Sparse Vegetation	*Atriplex canescens - (Ephedra viridis / Muhlenbergia porteri)* Sandstone Sparse Vegetation
6	Moenkopi Shale Sparse Vegetation	*Ephedra torreyana - (Atriplex canescens, confertifolia)* Sparse Vegetation
7	Sand Bluestem Grassland	*Andropogon hallii* Colorado Plateau Herbaceous Vegetation
8	Black Grama Grassland	*Bouteloua eriopoda* Coconino Plateau Shrub Herbaceous Vegetation

Map Code	Map Class	Map Class NVC Name
9	Needle-and-Thread Grassland	*Hesperostipa comata - (Bouteloua eriopoda-Pleuraphis jamesii)* Herbaceous Vegetation
10	Galleta Grassland	*Pleuraphis jamesii* Herbaceous Vegetation
11	Galleta Mixed Grasslands	*Bouteloua eriopoda - Pleuraphis jamesii* Herbaceous Vegetation, *Pleuraphis jamesii - Sporobolus airoides* Herbaceous Vegetation
12	Crinklemat/Alkali Sacaton Dwarf Shrubland	*Tiquilia latior / Sporobolus airoides* Dwarf Shrubland
13	Snakeweed/Galleta Grassland	*Gutierrezia sarothrae / Sporobolus airoides - (Pleuraphis jamesii)* Shrub Herbaceous Vegetation, *Gutierrezia sarothrae* Dwarf-Shrub Alliance
14	Galleta Mixed Shrublands	*Pleuraphis jamesii* Shrub Herbaceous Alliance
15	Crispleaf Buckwheat Cinder Shrubland	*Eriogonum corymbosum* Cinder Sparse Vegetation
16	Black Grama Coconino Plateau Mixed Shrubland	*Bouteloua eriopoda* Coconino Plateau Shrub Herbaceous Vegetation
17	Rabbitbrush Shrubland	*Ericameria nauseosa / Pleuraphis jamesii - (Hesperostipa comata)* Shrub Herbaceous Vegetation
18	Fourwing Saltbush Upland Drainageways	*Atriplex canescens* Desert Wash Shrubland
19	Sand Sagebrush Shrubland	*Artemisia filifolia - Ephedra (torreyana, viridis)* Shrubland
20	Mormon Tea Cinder Dune Shrubland	*Ephedra torreyana - Achnatherum hymenoides* Hummock Shrubland
21	Apache Plume Cinder Shrubland	*Fallugia paradoxa - (Atriplex canescens - Ephedra torreyana)* Cinder Shrubland
22	Frosted Mint Shrubland	*Poliomintha incana / (Pleuraphis jamesii)* Shrubland
23	Unclassified Mixed Shrubland	[N/A][1] Unique Stand
24	Wupatki Wash System	*Sporobolus airoides* Herbaceous Vegetation, *Artemisia filifolia - Ephedra (torreyana, viridis)* Shrubland, *Atriplex canescens / Sporobolus airoides* Shrubland, *Atriplex canescens* Desert Wash Shrubland, *Fallugia paradoxa - (Atriplex canescens - Ephedra torreyana)* Cinder Shrubland
25	Sandbar Willow Shrubland	*Salix exigua* / Barren Shrubland
26	Little Colorado River Invasive Riparian Shrubland	*Tamarix spp.* Temporarily Flooded Shrubland, *Alhagi maurorum* Semi-natural Shrubland
27	Oneseed Juniper Woodland	*Juniperus monosperma* Cinder Wooded Herbaceous Vegetation
28	Fremont Cottonwood Woodland	*Populus fremontii / Salix exigua* Forest
29	Transportation Route	- none (Anderson Land Use class)
30	Facilities	- none (Anderson Land Use class)
31	Commercial Development	- none (Anderson Land Use class)
32	Residential Land	- none (Anderson Land Use class)
33	Stock Tanks and Dams	- none (Anderson Land Use class)
34	Strip Mines, Quarries and Gravel Pits	- none (Anderson Land Use class)
35	Corrals	- none (Anderson Land Use class)

[1] A NVC vegetation association was not determined during the course of the study; however, this community was identified as a unique map class during the photointerpretation process.

The final map class list for WUPA contains four categories of map classes:

1. NVC associations represented by a unique photo-signature and topographic position.
2. Aggregations of NVC associations that together are represented by a unique signature.
3. Stands of vegetation that are not addressed by the NVC, but are seen as management concerns for WUPA and could be recognized on the aerial photography.
4. Geologic formations/exposures and land-use classes that are not addressed by the NVC.

Each map class for WUPA can be crosswalked to their NVC association using the aggregations described below:

One Map Class to One Plant Association

These map classes were developed by directly translating a NVC vegetation association into a map class onto the aerial photography.

Map Code	Map Class NVC Plant Association
4	Mound Saltbush Badlands Sparse Vegetation *Atriplex obovata* Badland Sparse Vegetation
5	Moenkopi Sandstone Sparse Vegetation *Atriplex canescens – (Ephedra viridis) / (Muhlenbergia porteri*) Sandstone Sparse Vegetation [Provisional]
6	Moenkopi Shale Sparse Vegetation *Ephedra torreyana - (Atriplex canescens, confertifolia)* Sparse Vegetation
7	Sand Bluestem Herbaceous Vegetation *Andropogon hallii* Colorado Plateau Herbaceous Vegetation
8	Black Grama Grassland *Bouteloua eriopoda* Coconino Plateau Shrub Herbaceous Vegetation
9	Needle-and-Thread Grassland *Hesperostipa comata - (Bouteloua eriopoda-Pleuraphis jamesii)* Herbaceous Vegetation
10	Galleta Grassland *Pleuraphis jamesii* Herbaceous Vegetation
12	Crinklemat/Alkali Sacaton Dwarf Shrubland *Tiquilia latior / Sporobolus airoides* Dwarf Shrubland

14 Galleta Mixed Shrublands
Pleuraphis jamesii Shrub Herbaceous Alliance

15 Crispleaf Buckwheat Cinder Shrubland
Eriogonum corymbosum Cinder Sparse Vegetation

16 Black Grama Coconino Plateau Mixed Shrubland
Bouteloua eriopoda Coconino Plateau Shrub Herbaceous Vegetation

17 Rabbitbrush Shrubland
Ericameria nauseosa / Pleuraphis jamesii - (Hesperostipa comata) Shrub Herbaceous Vegetation

18 Fourwing Saltbush Upland Drainageways
Atriplex canescens Desert Wash Shrubland

19 Sand Sagebrush Shrubland
Artemisia filifolia - Ephedra (torreyana, viridis) Shrubland

20 Mormon Tea Cinder Dune Shrubland
Ephedra torreyana - Achnatherum hymenoides Hummock Shrubland

21 Apache Plume Cinder Shrubland
Fallugia paradoxa - (Atriplex canescens - Ephedra torreyana) Cinder Shrubland

22 Frosted Mint Shrubland
Poliomintha incana / (Pleuraphis jamesii) Shrubland

25 Sandbar Willow Shrubland
Salix exigua / Barren Shrubland

27 Oneseed Juniper Woodland
Juniperus monosperma Cinder Wooded Herbaceous Vegetation

28 Fremont Cottonwood Woodland
Populus fremontii / Salix exigua Forest

Multiple Associations-to-One Map Class

NVC associations and local assemblages identified in the aerial photography were too intermixed to identify as unique photosignatures. NVC associations were aggregated with ecologically similar NVC associations to form mosaics.

Map Code	Map Class NVC Plant Association/Alliance
11	Galleta Mixed Grasslands *Bouteloua eriopoda - Pleuraphis jamesii* Herbaceous Vegetation *Pleuraphis jamesii - Sporobolus airoides* Herbaceous Vegetation
13	Snakeweed/Galleta Grassland *Gutierrezia sarothrae / Sporobolus airoides - (Pleuraphis jamesii)* Shrub Herbaceous Vegetation *Gutierrezia sarothrae* Dwarf-Shrub Alliance
24	Wupatki Wash System *Sporobolus airoides* Herbaceous Vegetation *Artemisia filifolia - Ephedra (torreyana, viridis)* Shrubland *Atriplex canescens / Sporobolus airoides* Shrubland *Atriplex canescens* Desert Wash Shrubland *Fallugia paradoxa - (Atriplex canescens - Ephedra torreyana)* Cinder Shrubland
26	Little Colorado River Invasive Riparian Shrubland *Tamarix* spp. Temporarily Flooded Shrubland *Alhagi maurorum* Semi-natural Shrubland

Park Special Map Classes

Two map classes at WUPA are considered park specials. The first map class was developed based a NVC association and expanded to include all basalt outcrops. The second map class was developed based on a unique shrubby area identified only during the photointerpretation process.

Map Code	Map Class NVC Plant Association
2	Basalt Outcrop Shrubland *Brickellia californica - Rhus trilobata* Shrubland
23	Unclassified Mixed Shrubland

RSGIG interpretation of the aerial photographs for WUPA relied heavily on direct observation in the field. The usual aids to interpretation (color, shape, and texture, landscape position and substrate) were less helpful in this case, partly because the abundance of cinder created a black substrate that hid the vegetation signature on the color infrared photos. A brief description of each map class follows. The number in parentheses indicates the map code. An illustrated guide to the map classes appears in Appendix H.

Cinder Barren (1). Openings of unvegetated black cinder occur primarily on the plateaus in the southern part of the project area, and on the slopes that lead from the plateaus to the Wupatki

Basin. Although these areas may support communities of ephemeral spring annual plants, they appear uniformly pitch black on the aerial photos.

Basalt Outcrop Shrubland (2). Cliffs and steep slopes of broken basalt mark the rim of the high plateaus in the southern part of the mapping area. West of Highway 89, mounds of basalt blocks are scattered throughout the grasslands and support a similar vegetation. The rough basalt supports a unique suite of species, including three-leaf sumac, Mormon tea, sideoats grama (*Bouteloua curtipendula*), fourwing saltbush, and blue grama.

Active River Channel (3). Bare sand and basalt areas occur in the active channels of the Little Colorado River and its tributaries, and reflect zones that are scoured at least annually. On the aerial photos these areas appear unvegetated, although they may support ephemeral communities of annual plants that were dormant at the time the photos were taken.

Mound Saltbush Badlands Sparse Vegetation (4). This map class describes a large area in the northeastern part of the mapping area where long-term sheep grazing and poor soils have created an extremely sparsely-vegetated, dwarf desert shrubland of *Atriplex obovata* and little else. The photosignature is very similar to shale barrens badlands (map code 6) west of the Little Colorado River: pale reddish brown with little evident texture.

Moenkopi Sandstone Sparse Vegetation (5). The Moenkopi Formation consists of two major units: a lower sandstone unit and an upper siltstone unit. The two units support different plant associations. The sandstone unit supports a sparse shrubland community characterized by plates of sandstone on the surface and the presence of fourwing saltbush. The signature is a pale orange-red, smooth in texture. In areas where black cinders are mixed with the sandstone, the signature is a much darker red-black.

Moenkopi Shale Sparse Vegetation (6). The lower shale unit of the Moenkopi is exposed east and north of the sandstone unit, although the boundary is difficult to distinguish on the aerial photos due to the similar signature. The photosignature ranges from pale orange red to a medium red to a red-gray, depending on the amount of vegetation present and the presence of surface dust.

Sand Bluestem Grassland (7). This is a very minor type at WUPA, but is unusual enough that we mapped it when we encountered it in the field. All polygons of this type are much smaller than the minimum mapping unit of 0.5 ha and too small to be recognizable on the aerial photos. The type is restricted to canyon rims and cinder dunes within roughly a two-mile (3.2 km) radius of the Visitor Center.

Black Grama Grassland (8). This map class describes large areas in the southwest corner of the mapping area and a few small slopes just east of Highway 89 that support nearly pure stands of black grama. The even size and spacing of the grass clumps contributes to the distinctive smoothness of the photosignature. The color is a medium to light beige.

Needle-and-Thread Grassland (9). This map class is relatively rare, and is restricted to the grassy limestone plateaus in the southern and western parts of the mapping area. The class

consists of nearly pure stands of needle-and-thread grass occurring as regularly spaced clumps. The irregular spacing of grass clumps and the large amount of oxidized litter associated with this class contribute to its unique photosignature. Stands of this type appear as dark grayish-green patches with scattered small white speckles within a lighter gray-green grassland matrix (usually map codes 10 or 11). The speckles resemble prairie dog holes, but instead are small areas of no vegetation where the white limestone chips in the soil are revealed.

Galleta Grassland (10). This type is largely restricted to slopes below basalt rims in the western part of the project area. The signature is very similar to that of Black Grama Grassland (8), appearing as a very smooth, unbroken pale beige. We mapped much of this type from field observations.

Galleta Mixed Grasslands (11). This is the major grassland map class. Because the composition and substrate in the area vary, the signature also is variable. In general, it is a solid pale color with occasional speckles. Many of the mapping area's prairie dog towns occur in this map class.

Crinklemat/Alkali Sacaton Dwarf Shrubland (12). This type is restricted to a shelf of older basalt exposed along the edge of the Little Colorado River in the vicinity of Black Falls Crossing. The photosignature, like many others, is a nearly pure black. We mapped this type primarily mapped in the field.

Snakeweed/Galleta Grassland (13). This type occurs primarily in the employee housing area, in areas where Moenkopi silts and shales have washed into the valley floor. Other polygons of this type occur on Antelope Mesa on limestone. Accordingly, the aerial photosignature is variable. We mapped this type primarily from field observations.

Galleta Mixed Shrublands (14). This map class includes a number of plant associations; it is really a galleta grassland with any of a number of shrubs occurring in several different habitats. The photosignature is variable and we mapped this type primarily in the field.

Crispleaf Buckwheat Cinder Shrubland (15). This map class describes an unusual shrubland type restricted to cinder slopes descending from the highest mesas south of the Visitor Center. The photosignature is a smooth black punctuated by tiny, even-sized white dots that represent the buckwheat shrubs. A few occurrences of rabbitbrush shrubland on cinder slopes were included in this map class.

Black Grama Coconino Plateau Shrubland (16). During the late Pleistocene and early Holocene, streams running from the San Francisco Peaks into the Little Colorado River left deposits of rounded pebbles that now cap isolated hills within the Wupatki Basin. These caps appear as smooth white or dark gray patches on the aerial photographs and tend to support a community of Torrey's joint fir and black grama. Other examples of this map class contain different shrub species and appear with many different signatures. This unit was mapped primarily from field observations.

Rabbitbrush Shrubland (17). This map class represents a community that is widespread on top of the major mesas in the southern part of the mapping area. The most common species are

rabbitbrush, galleta, and Mormon tea. It appears as smooth to slightly speckled, very light beige on the aerial photographs.

Fourwing Saltbush Upland Drainageways (18). Paths of intermittent surface flow are clearly visible on the nearly level limestone plateaus of the southern and western part of the mapping area. Water will pond occasionally in these areas, and the vegetation is distinct and easily recognizable on the aerial photos. This map class appears with a pebbly texture similar to that of rabbitbrush shrublands, but much darker in color. The dark color is not the result of vegetation, but rather of small cinder fragments that wash across the plateau in these floodways.

Sand Sagebrush Shrubland (19). This unit occurs primarily on the flats between the WUPA visitor's center and Wukoki Ruin. Sand sagebrush is always present, but is not always the dominant shrub. We mapped this type primarily from field observations, as it has a variable photosignature.

Mormon Tea Cinder Dune Shrubland (20). This map class describes level areas where thick cinder deposits have been scoured by wind, leaving mounds two to four ft (0.6-1.2 m) high where shrubs are present to hold the cinders. This map class is easily recognizable on aerial photos; it appears as long narrow polygons, predominantly black in color and oriented southwest to northeast (the direction of the prevailing winds in this area).

Apache Plume Cinder Shrubland (21). This is one of the major shrub map classes at WUPA, and the dominant map class in non-wooded areas covered with volcanic cinders. The aerial photosignature is predominantly black, with pinhead-sized, irregularly-shaped dark green speckles that represent the Apache plume shrub clumps.

Frosted Mint Shrubland (22). This rare type is restricted to hills and slopes of relict sands deposited by the same stream(s) that left the pebble veneer described under map code 11. These hills occur in the lower parts of the Wupatki Basin near the Little Colorado River. They have a distinct signature, appearing as pale beige or light gray on the aerial photos. Polygons of this map class are usually associated with relict river cobble polygons.

Unclassified Mixed Shrubland (23). The one polygon of this type is located in the lower Antelope Wash area, where the drainage spreads out into many channels and the vegetation changes every ten feet (3 m) as you cross the area. The mix of many different vegetation types makes this area impossible to classify. It is predominantly a shrubland with all the important WUPA species represented, interspersed with narrow belts of alkali sacaton or galleta.

Wupatki Wash System (24). This map class contains a number of different plant associations, which have in common only the fact that they occur in the bottom of drainages throughout the project area. In the upper reaches of many drainages, cinder is a major constituent of the substrate and Apache plume is a common shrub. In areas where the substrate lacks cinder and most of the soil is sand, sand sagebrush, rabbitbrush and snakeweed are common shrubs. Alkali sacaton is consistent throughout all drainage-based shrublands, and occasionally forms dominant stands in the drainage bottoms. Because of the diversity of substrate and vegetation, the identifying characteristic of this map class on the aerial photos is the appearance of a dendritic

flow pattern. This pattern appears in areas that are not otherwise recognizable as drainages; that is, they lack banks and distinct channels visible from the ground.

Sandbar Willow Shrubland (25). This map class is rare within the project area, occurring only along the Little Colorado River in very narrow belts adjacent to the active river channel. Sandbar willow stands are difficult to distinguish from stands of young tamarisk (map code 26) on the aerial photos, but can be recognized by the slightly brighter red color, the distinctive narrow, linear distribution pattern, and proximity to the river bed. We identified this type mostly from direct field observation.

Little Colorado River Invasive Riparian Shrubland (26). This is the predominant riparian vegetation type along the river corridor, and extending slightly up the mouths of major tributary streams such as Deadman Wash and Antelope Wash. It consists of dense, even-aged stands of tamarisk with little understory. This map class appears dark red with a slightly rough texture, occurring in bands that parallel the margins of the floodplain.

Oneseed Juniper Woodland (27). One-seed juniper woodland occupies the higher plateaus within the southern and western parts of the mapping area and gradually thins out and disappears with falling elevation to the north and east. It is easily recognizable; the juniper crowns appearing as black dots in a matrix of pale, smooth grassland/limestone, black cinder, or rough-textured rabbitbrush shrubland. Woodland polygons have been given additional attribute of crown density, broken down into four density classes: <10%, 11-25%, 26-60%, >61%.

Fremont Cottonwood Woodland (28). Dense tamarisk (map code 26) has replaced most of the cottonwood stands along the Little Colorado River; there are a few scattered relict groves of cottonwood on inactive terraces in the river corridor. Each grove consists of a few mature trees, generally with an understory of exotic species and rabbitbrush. The groves are easily recognizable on the aerial photography because of the relative height of the cottonwoods and the bright red of their crowns.

Transportation Route (29). Mapped roadways include Highway 89, the monument's paved access roads as well as major county dirt roads. We gave two-track roads within the mapping area a vegetation code that best described the vegetation through which the road passes, as well as a secondary code of "T" (in the COMMENTS field in the database) to indicate a transportation corridor.

Facilities (30). This map class includes the Visitor Center, employee residential areas, the sewage ponds and other aboveground developments associated with operation of the monument.

Commercial Development (31). There are several commercial developments located along Highway 89. They were distinguished from rural residential developments by direct observation in the field.

Residential Land (32). Ranch buildings occur both along Highway 89 and on privately owned lands adjacent to the monument.

Stock Ponds and Tanks (33). These developments are scattered throughout the non-NPS lands within the project area. They are easily recognizable because of their triangular or circular shapes, location in or near a waterway, and the presence of a distinct berm to retain water.

Strip Mines, Quarries and Gravel Pits (34). Cinder quarries and gravel pits occur primarily in association with Highway 89, but a few occur within the project area as well, on private and U.S. Dept. of Agriculture – Forest Service (USDA-FS) lands.

Corrals (35). Corrals for short-term retention of livestock are scattered around the lands surrounding the monument. They appear as small rectangles or squares, usually with a two-track road leading to them.

GIS database and maps

The WUPA GIS database consists of ten coverages and imagery with associated metadata in ArcInfo format and is archived on a CD (Appendix A) accompanying this report. The coverages are:

a. Accuracy assessment observation points
b. Classification relevé points
c. DOQQ boundary and USGS Quad maps for Sunset Crater, Wupatki, and Walnut Canyon National Monuments
d. DOQQ imagery for WUPA
e. Flightline boundary for Sunset Crater, Wupatki, and Walnut Canyon National Monuments
f. WUPA park boundary
g. Photointerpretative observation points
h. Project boundary
i. Vegetation map clipped to the National Monument boundary
j. Vegetation map for the entire project area. This main product coverage consists of 6,113 classified polygons covering a total area of approximately 106,460 ac (43,083 ha). This coverage includes several polygon attributes, described in the corresponding metadata on the project CD. Table 5 shows the total number of polygons and hectares per map class in the project area.

A readme file (Appendix A) further describes these coverages.

A hard copy map was created of the vegetation coverage with a legend identifying the color of each map class. For clarity, the map code was printed only on polygons with an area greater than 5000 m^2 (0.5 ha). The hard copy map is presented in a folder sleeve (Appendix I).

Table 5. Map class occurrence in Wupakti National Monument and environs.

Map Code	Map Class Common Names	Monument		Environs	
		Polygons	Hectares	Polygons	Hectares
1	Cinder Barren	89	37	212	125
2	Basalt Outcrop Shrubland	78	24	249	96
3	Active River Channel	6	26	11	200
4	Mound Saltbush Badlands Sparse Vegetation	--	--	29	1,337
5	Moenkopi Sandstone Sparse Vegetation	543	733	146	290
6	Moenkopi Shale Sparse Vegetation	274	2,029	125	2,596
7	Sand Bluestem Grassland	5	4	4	1
8	Black Grama Grassland	13	93	22	652
9	Needle-and-Thread Grassland	44	295	77	336
10	Galleta Grassland	24	25	94	236
11	Galleta Mixed Grasslands	374	2942	427	8,913
12	Crinklemat/Alkali Sacaton Dwarf Shrubland	8	88	3	12
13	Snakeweed/Galleta Grassland	60	96	131	268
14	Galleta Mixed Shrublands	255	532	107	491
15	Crispleaf Buckwheat Cinder Shrubland	14	82	37	61
16	Black Grama Coconino Plateau Shrubland	211	1,160	167	944
17	Rabbitbrush Shrubland	274	1,786	274	2,025
18	Fourwing Saltbush Upland Drainageways	8	17	9	31
19	Sand Sagebrush Shrubland	80	764	8	17
20	Mormon Tea Cinder Dune Shrubland	17	139	59	301
21	Apache Plume Cinder Shrubland	576	1,000	374	977
22	Frosted Mint Shrubland	8	89	1	4
23	Unclassified Mixed Shrubland	1	3	1	5
24	Wupatki Wash System	182	560	123	380
25	Sandbar Willow Shrubland	5	1	28	8
26	Little Colorado River Invasive Riparian Shrubland	8	31	74	718
27	Oneseed Juniper Woodland	290	1,716	266	7,554
28	Fremont Cottonwood Woodland	2	1	12	5
29	Transportation Route	3	67	4	72
30	Facilities	3	1	1	0
31	Commercial Development	1	0	3	7
32	Residential Land	1	1	3	1
33	Stock Tanks and Dams	1	0	14	9
34	Strip Mines, Quarries and Gravel Pits	4	6	24	57
35	Corrals	6	4	4	4
	Total	**3,468**	**14,350**	**3,123**	**28,733**

Accuracy assessment

Six hundred and ninety-one accuracy assessment observations were included into the reference data (Figure 9). We assigned accuracy assessment observations that did not match any map classes as "other" in the reference data. This value and map classes 3, 17, 22, and 23 were not included in calculation of the error statistics in order to satisfy the assumptions for calculating the Kappa statistic (Carletta 1996). Although none of these map classes were included in the Kappa index calculation, all of these classes were retained on the contingency tables, see Tables 7, 8, and 9. The total number of reference data points used to calculate overall exact match accuracy was 687, acceptable accuracy was 687, and understandable accuracy was 688 for the final accuracy assessment analysis. The final number of reference data points analyzed for each map class was representative of the relative percent cover of each map class except for map classes with high percentage of occurrence on private land (i.e. land use classes). In these cases, the number of reference points sampled was less than the number suggested for the accuracy assessment analysis (Table 1).

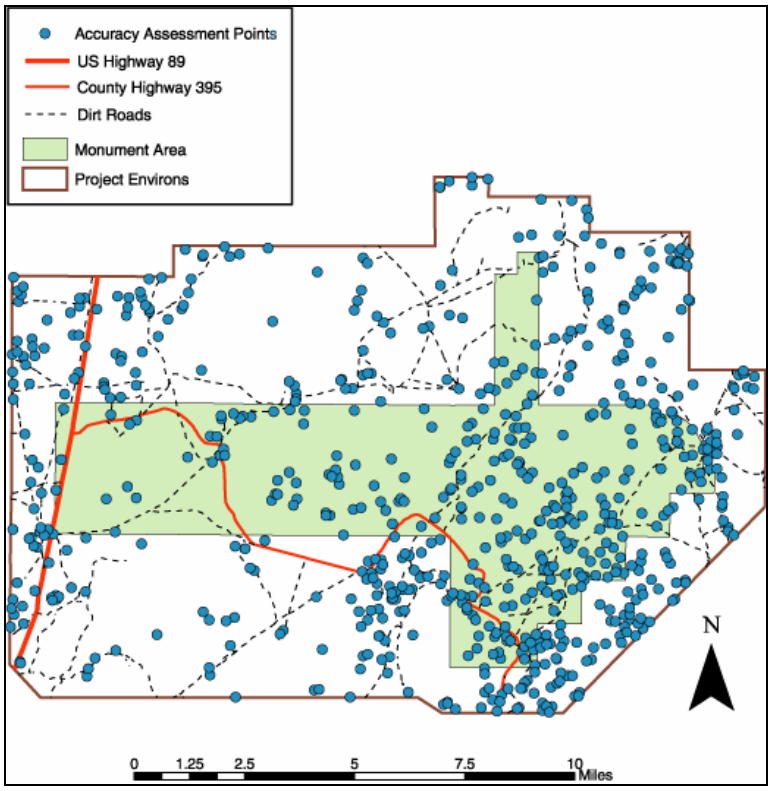


Figure 9. Location of accuracy assessment field observations collected in 2002.

Standard analysis of map accuracy criteria 5, exact match suggested that overall accuracy was low, 59.1% (90% confidence interval of 57.2% to 61.0%) and a Kappa index of 57.3%, (Table 7). For criteria 4 acceptable error, overall accuracy of the map is 69.7% (90% confidence interval of 67.9% and 71.5%) and Kappa index of 68.5% (Table 8). Criteria 3, understandable error, accuracy is 92.2% (90% confidence interval of 91.1% and 93.3%) and a Kappa index of 91.8%

(Table 9). Omission and commission accuracies for each individual map class, including two-tailed, 90% confidence intervals, are also shown for each in each contingency table.

Evaluation of the performance of each map class provides insight on map error. For each map class, we report in Table 6 the criteria at which the class was assessed to meet the standard of 80% or greater for commission and omission accuracy.

Table 6. Map class performance.

Map Code	Map Class	Commission Accuracy (Criteria and %)	Omission Accuracy (Criteria and %)	Comments
1	Cinder Barren	Exact 83%	Exact 80%	This type is considered adequate as mapped.
2	Basalt Outcrop Shrubland	Exact 83%	Exact 96%	This type is considered adequate as mapped.
3	Active River Channel	Exact 92%	Exact 85%	This type is considered adequate as mapped.
4	Mound Saltbush Badlands Sparse Vegetation	Understandable 100%	Understandable 91%	This map class is restricted to the project environs and had little photointerpretation reconnaissance work due to a lack of accessibility to the Navajo Nation. Therefore, many map classes in these areas appeared to be aggregated within this map class and were often misclassified as Wupatki Wash System.
5	Moenkopi Sandstone Sparse Vegetation	Understandable 94%	Understandable 83%	When labeled incorrectly, this class was confused with Moenkopi Shale Sparse Vegetation.
6	Moenkopi Shale Sparse Vegetation	Understandable 83%	Understandable 71%	When labeled incorrectly, this class was confused with other sparse map classes (Mound Saltbush Badlands Sparse Vegetation, Moenkopi Sandstone Sparse Vegetation) as well as classes with semi-sparse grasslands on similar substrate.
7	Sand Bluestem Grassland	Understandable 60%	Exact 100%	This class did not meet the commission accuracy even using understandable criteria. Only 5 polygons were selected for the accuracy assessment sampling design. These polygons are all smaller than the minimum mapping unit and were often misclassified as other grassland types.
8	Black Grama Grassland	Acceptable 85%	Understandable 77%	When labeled incorrectly, this class was confused with Needle-and-Thread and Galleta Grasslands (commission error).
9	Needle-and-Thread Grassland	Understandable 73%	Understandable 92%	This map class does not meet the commission criteria even using understandable criteria. It was often misidentified as Galleta, Black Grama, or Wupakti Wash System (commission error). This type was often confused on the aerial photography with Galleta Mixed Grassland (omission error), which

Map Code	Map Class	Commission Accuracy (Criteria and %)	Omission Accuracy (Criteria and %)	Comments
				includes a mixed grassland type similar in structure to this map class.
10	Galleta Grassland	Understandable 73%	Understandable 88%	In the field areas where it was found, this class was mapped as Black Grama Grassland and Rabbitbrush Shrubland (commission error). On the map it was misclassified as areas of Needle-and-Thread Grassland, Galleta Mixed Grasslands, and Galleta Mixed Shrublands (omission error).
11	Galleta Mixed Grasslands	Understandable 84%	Understandable 84%	In the field areas where it was found, this class was mapped as Needle-and-Thread Grassland and as Black Grama Grassland (commission error). On the map it was misclassified as Black Grama Coconino Plateau Shrubland (omission error).
12	Crinklemat/Alkali Sacaton Dwarf Shrubland	Exact 86%	Exact 100%	This type is considered adequate as mapped.
13	Snakeweed/Galleta Grassland	Understandable 83%	Acceptable 92%	When labeled incorrectly, this class was confused with many different map classes, including Galleta Mixed Shrublands and Wupatki Wash System (commission error).
14	Galleta Mixed Shrublands	Understandable 93%	Understandable 93%	In the field areas where it was found, this map class was mapped as Moenkopi Shale Sparse Vegetation, Galleta Grassland, and Unclassified Mixed Shrubland (commission error). On the map it was misclassified as Snakeweed/Galleta Grassland (omission error).
15	Crispleaf Buckwheat Cinder Shrubland	Acceptable 87%	Exact 85%	This type is considered adequate as mapped.
16	Black Grama Coconino Plateau Shrubland	Understandable 84%	Understandable 84%	This type was often misclassified on the map as Galleta Mixed Grasslands (commission error). In the field areas where it was found, it was mapped as Needle-and-Thread Grassland and Rabbitbrush Shrubland (omission error).
17	Rabbitbrush Shrubland	Understandable 93%	Understandable 88%	This map class was mapped as Black Grama Coconino Plateau Shrubland and Galleta Grassland where it was found in the field (commission error). On the aerial photographs Galleta Grassland, Crispleaf Buckwheat Cinder Shrubland, and Mormon Tea Cinder Dune Shrubland were often interpreted as this class (omission error).
18	Fourwing Saltbush Upland	Understandable 50%	Understandable 100%	This map class was considered a unique stand within the monument and six

Map Code	Map Class	Commission Accuracy (Criteria and %)	Omission Accuracy (Criteria and %)	Comments
	Drainageways			polygons out of nine mapped were sampled. However, only one of the sampled polygons was mapped correctly using the exact match criteria.
19	Sand Sagebrush Shrubland	Understandable 100%	Acceptable 85%	This map class was mapped as Apache Plume Cinder Shrubland and Unclassified Mixed Shrubland where it was found in the field (commission error). On the map it was misclassified as Snakeweed/Galleta Grassland (omission error).
20	Mormon Tea Cinder Dune Shrubland	Acceptable 84%	Acceptable 91%	This type is considered adequate as mapped.
21	Apache Plume Cinder Shrubland	Understandable 93%	Understandable 96%	In the field areas where it was found, this map class was mapped as various map classes adjacent to the polygon, including Mormon Tea Cinder Dune Shrubland (commission error). On the map it was misclassified as Cinder Barren and Sand Sagebrush Shrubland (omission error).
22	Frosted Mint Shrubland	Understandable 100%	Understandable 100%	In the field it was identified as Moenkopi Shale Sparse Vegetation (commission error) and on the map as various shrubland map classes (omission error).
23	Unclassified Mixed Shrubland	Understandable 100%	Understandable 100%	On the map this type was misclassified as Moenkopi Shale Sparse Vegetation (omission error). In the field areas where this map was found, this class was mapped as Snakeweed/Galleta Grassland, Galleta Mixed Shrublands and Sand Sagebrush Shrubland (commission error).
24	Wupatki Wash System	Understandable 97%	Understandable 90%	This map class was confused with many other grassland and shrubland types both when mapped and in the field.
25	Sandbar Willow Shrubland	Acceptable 80%	Exact 100%	This type is considered adequate as mapped.
26	Little Colorado River Invasive Riparian Shrubland	Exact 80%	Acceptable 81%	This type is considered adequate as mapped.
27	Oneseed Juniper Woodland	Exact 90%	Exact 96%	This type is considered adequate as mapped.
28	Fremont Cottonwood Woodland	Exact 80%	Exact 100%	This type is considered adequate as mapped.
29	Transportation Route	Exact 100%	Exact 80%	This type is considered adequate as mapped.
30	Facilities	Acceptable 100%	Exact 100%	This type is considered adequate as mapped.
31	Commercial Development	Exact 100%	Exact 100%	This type is considered adequate as mapped.
32	Residential Land	Exact	Exact	This type is considered adequate as

Map Code	Map Class	Commission Accuracy (Criteria and %)	Omission Accuracy (Criteria and %)	Comments
		100%	100%	mapped.
33	Stock Tanks and Dams	Exact 100%	Acceptable 80%	This type is considered adequate as mapped.
34	Strip Mines, Quarries, and Gravel Pits	Exact 89%	Exact 100%	This type is considered adequate as mapped.
35	Corrals	Exact 80%	Exact 100%	This type is considered adequate as mapped.

Table 7. Accuracy assessment contingency table (criteria 5, exact match) and statistical analysis of reference data with map class data.

		Reference Data (Field Accuracy Assessment Observation)																																					Total	Commission Error	90% Confidence Intervals	
	Map Code[1]	Other[2]	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	N	(% Correct)	-	+
Map Class Data	1		24																		1		4															29	83	69	91
	2		1	25								3																1										30	83	70	92
	3				11																							1										12	92	70	98
	4					15									1									1		3					1							21	71	54	84
	5		1				18	2				1			1			1	1			1	1		1	3												31	58	43	71
	6					2	3	15		1	1	2	1			1		1						1	1	1												30	50	36	64
	7	1	1						1								1					1																5	20	58	64
	8									15		1	3						1																			20	75	57	87
	9						3			4	4	4	3		1	1		3	1							6												30	13	61	27
	10	2								5		18	1			1		1	3																			31	58	47	75
	11						1	4		1	8	7	4			1		1								3												30	13	61	27
	12												2	6												1												7	86	55	97
	13						2			3			2		6	4		1			3		1		2	5									1			30	20	11	34
	14						1	3		1		5	2			10			1		2			1	3	1												30	33	21	48
	15															1	22		3			3	2															31	71	56	82
	16						3	3		1		1	8		1	1		9							1	3												31	29	18	44
	17					1				2	1	3	2			2	1	3	14				1															30	47	24	61
	18		2					1												1	1					1												6	17	4	50
	19						2	1								2				1	17		3		4													30	57	42	70
	20																1		4		1	23	1												1			31	74	60	85
	21		1					1				1	1				1	1		1	1	2	18		1													29	62	47	75
	22							2														1		6														9	67	40	86
	23							1																	0													1	0	N/A	N/A
	24					1		1								1			1	1	1		2			20		1										29	69	54	81
	25				2																						10	8										20	50	33	67
	26					2													1					1		2		24										30	80	66	89
	27										1		1										1						27									30	90	77	96
	28																											1		4								5	80	44	95
	29																														4							4	100	60	100
	30			1																												3						4	75	36	94
	31																																3					3	100	53	100
	32																																	4				4	100	60	100
	33																																		4			4	100	60	100
	34																												1						1	17		19	89	73	97
	35																									1											4	5	80	44	95
Total	N	3	30	26	13	21	33	34	1	33	15	46	28	6	10	25	26	21	30	4	27	31	34	10	13	50	10	36	28	4	5	3	3	4	7	17	4	**Total Sampling Points: 687[3]**			
Omission Error	(% Correct)		80	96	85	71	55	44	100	45	27	39	14	100	60	40	85	43	47	25	63	74	53	60	0	40	100	67	96	100	80	100	100	100	57	100	100	**Total Correct: 406**			
																																						Overall Accuracy: 59.1%			
90% Confidence Intervals	-		66	85	63	54	41	31	27	32	13	28	7	69	35	26	70	27	33	58	47	60	39	35	N/A	29	79	53	86	60	46	53	53	60	25	86	60	**Kappa Index: 57.3%**			
																																						90% Confidence Interval:			
	+		89	99	95	84	68	58	100	60	48	51	28	100	81	56	93	60	61	64	76	85	66	81	N/A	52	100	78	99	100	95	100	100	100	75	100	100	**57.2-%, 61.0+%**			

[1] See Table 5 for list of map codes and classes
[2] Other was recorded in cases where none of the map classes available adequately described the vegetation
[3] Total Sampling Points excludes undescribed (map class other) and Unclassified Mixed Shrublands (map class 23) that do not satsify the Kappa statistic assumption

Table 8. Accuracy assessment contingency table (criteria 4, acceptable accuracy) and statistical analysis of reference data with map class data.

	Reference Data (Field Data for Accuracy Assessment)																																					Total	Commission Error	90% Confidence Intervals	
	Map Code[1]	Other[2]	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	N	(% Correct)	-	+
Map Class Data	1		28																				1															29	97	86	99
	2		1	27								1																1										30	90	77	96
	3				11																							1										12	92	70	98
	4					16									1									1		3												21	76	59	88
	5						21	1				1						1	1			1	1		1	3												31	68	53	80
	6					2	3	15		1	1	2	1			1		1						1	1	1												30	50	36	64
	7	1							2								1					1																5	40	14	73
	8									17			2						1																			20	85	68	94
	9						3			4	7	4	1			1		3	1							6												30	23	13	38
	10	2								4		20	1			1		1	2																			31	65	50	77
	11						1	4		1	8	7	4			1		1								3												30	13	6	27
	12													7																								7	100	72	100
	13						2			3			1		10	4					1		1		2	5									1			30	33	21	48
	14							2		1		3	1			15			1		2			1	3	1												30	50	36	64
	15															1	27		1			1	1															31	87	74	94
	16						3	3		1		1	2		1	1		15							1	3												31	48	34	63
	17									2		3				1		2	21				1															30	70	55	82
	18		2					1												2						1												6	33	12	65
	19															2				1	22		1		4													30	73	59	84
	20																1		2		1	26													1			31	84	70	92
	21							1				1	1				1	1				2	21		1													29	72	57	84
	22							1														1		7														9	78	50	92
	23							1																	0													1	0	N/A	N/A
	24					1		1								1			1	1	1		2			21												29	72	57	84
	25																										16	4										20	80	62	91
	26					2													1					1		1		25										30	83	70	92
	27										1																		29									30	97	86	99
	28																													5								5	100	65	100
	29																														4							4	100	60	100
	30																															4						4	100	60	100
	31																																3					3	100	53	100
	32																																	4				4	100	60	100
	33																																		4			4	100	60	100
	34																																			19		19	100	88	100
	35																									1											4	5	80	44	95
Total	N	3	31	27	11	21	33	30	2	34	17	43	14	7	12	29	30	25	32	4	27	32	29	11	13	48	16	31	29	5	4	4	3	4	6	19	4	**Total Sampling Points: 687[3]**			
Omission Error	(% Correct)		90	100	100	76	64	53	100	50	53	49	43	100	92	62	90	60	66	75	85	91	72	73	0	44	100	81	100	100	100	100	100	100	67	100	100	**Total Correct: 479**			
90% Confidence Intervals	-		78	91	80	59	49	36	43	36	24	35	14	72	60	37	77	44	51	18	67	68	57	39	N/A	32	86	67	91	65	60	60	53	60	35	88	60	**Overall Accuracy: 69.7%**			
	+		96	100	100	88	76	64	100	64	61	59	51	100	94	66	96	74	78	82	91	90	84	82	N/A	55	100	90	100	100	100	100	100	100	88	100	100	**Kappa Index: 68.5%**			
																																					90% Confidence Interval: 67.9-%, 71.5+%			

[1] See Table 5 for list of map codes and classes
[2] Other was recorded in cases where none of the map classes available adequately described the vegetation
[3] Total Sampling Points excludes undescribed (map class other) and Unclassified Mixed Shrublands (map class 23) that do not satisfy the Kappa statistic assumption

Table 9. Accuracy assessment contingency table (criteria 3, understandable accuracy) and statistical analysis of reference data with map class data.

	Reference Data (Field Data for Accuracy Assessment)																																					Total	Commission Error	90% Confidence Intervals	
	Map Code[1]	Other[2]	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	N	(% Correct)	-	+
Map Class Data	1		29																																			29	100	92	100
	2			28								1																1										30	93	82	98
	3				12																																	12	100	82	100
	4					21																																21	100	89	100
	5						29											1					1															31	94	82	98
	6							25		1	1	2	1																									30	83	70	92
	7	1							3													1																5	60	27	86
	8									20																												20	100	88	100
	9						3				22					1		3	1																			30	73	59	84
	10	2										26						1	2																			31	84	70	92
	11						1	4					22													3												30	73	59	84
	12													7																								7	100	72	100
	13						2			2					25						1																	30	83	70	92
	14							1		1						28																						30	93	82	98
	15															1	30																					31	97	87	99
	16							3				1	1					26																				31	84	70	92
	17									2									28																			30	93	82	98
	18		2					1												3																		6	50	22	78
	19																				30																	30	100	92	100
	20																					31																31	100	92	100
	21											1	1										27															29	93	81	98
	22																							9														9	100	77	100
	23																								1													1	100	27	100
	24							1																		28												29	97	86	99
	25																										20											20	100	88	100
	26					2													1									27										30	90	77	96
	27										1																		29									30	97	86	99
	28																													5								5	100	65	100
	29																														4							4	100	60	100
	30																															4						4	100	60	100
	31																																3					3	100	53	100
	32																																	4				4	100	60	100
	33																																		4			4	100	60	100
	34																																			19		19	100	88	100
	35																																				5	5	100	65	100
Total	N	3	31	28	12	23	35	35	3	26	24	31	25	7	25	30	30	31	32	3	31	32	28	9	1	31	20	28	29	5	4	4	3	4	4	19	5	**Total Sampling Points: 688[3]**			
Omission Error	(% Correct)	N/A	94	100	100	91	83	71	100	77	92	84	88	100	100	93	100	84	88	100	97	97	96	100	100	90	100	96	100	100	100	100	100	100	100	100	100	**Total Correct: 634**			
90% Confidence Intervals	-	N/A	82	91	82	77	70	58	53	61	78	70	74	72	90	82	92	70	75	53	87	87	86	77	27	78	88	86	92	65	60	60	53	60	60	88	65	**Overall Accuracy: 92.2%**			
	+	N/A	98	100	100	97	91	82	100	88	97	92	95	100	100	98	100	92	94	100	99	99	99	100	100	96	100	99	100	100	100	100	100	100	100	100	100	**Kappa Index: 91.8%**			
																																						90% Confidence Interval: 91.1-%, 93.3+%			

[1] See Table 5 for list of map codes and classes
[2] Other was recorded in cases where none of the map classes available adequately described the vegetation
[3] Total Sampling Points excludes undescribed (map class other) and Unclassified Mixed Shrublands (map class 23) that do not satisfy the Kappa statistic assumption

5. DISCUSSION

The vegetation at WUPA includes sparsely vegetated badlands, riparian vegetation along river corridors, grasslands, shrublands, and savanna woodlands. The variety in vegetation types and surficial geology posed several challenges to mapping, including the need to identify new vegetation associations, problems in photointerpretation of sparsely vegetated areas, and masked photosignatures due to the strong geologic spectral signatures. Since the vegetation and geology at WUPA can be highly patchy, about half of the project area had polygons delineated at a scale less than the MMU. The photointerpreter in some areas was unable to distinguish vegetation associations and thus developed mosaics of vegetation associations with similar signatures for map units. Another challenge in mapping occurred due to the time lag between aerial photo acquisition, field data collection, community analysis, photointerpretation, and accuracy assessment. These challenges are summarized below:

1) Sparse vegetation is difficult to classify to the association level. In relevés with less than 15% vegetative cover, we had inconsistent species composition and cover due to the depauperate nature of these communities. We developed vegetation associations and map classes to represent the sparse communities based on the presence of indicator species. Also, many of these vegetation community types are characterized by a specific landform and geologic signature that indicate the map class better than the species composition included in the map class name.

2) Surficial geology, such as basaltic soils, cinder barrens, and lava flows, can mask the vegetation photosignature. Where this was observed ground truthing was preformed and the photointerpreter was required to walk the entire areas to verify the polygon delineation. Black substrates such as the volcanic cinder and basalt that cover much of the southern part of the mapping area reflect black on CIR film. Even a small amount of cinder mixed with soils derived mainly from sandstone, limestone or shale causes the photosignature to darken significantly, and in many cases obscures the texture. Yet small amounts of cinder do not necessarily cause changes in vegetation, with the result that a single vegetation type may have several photosignatures, and at the same time a very dark photosignature may conceal any of several plant associations/mapping classes. A number of examples of this problem are illustrated in Appendix H.

3) Areas on the landscape that consist of tightly woven mosaics of vegetation were difficult to photointerpret to the association level. Two vegetation map classes that occur in washes and along riparian corridors, Wupatki Wash System and Little Colorado River Invasive Riparian Shrubland, consisted of several different vegetation associations that were not distinguishable on the photography. These associations were combined into single map classes that were based on landform, rather than the species composition.

4) Small polygon sizes can confound the ability of the field team to ensure that they are sampling the correct polygons. Almost half of the polygons (48%) were delineated below the MMU. Although this level of detail provides extra information to the park on the distribution of the map classes, it makes accurate positioning within the polygon more

difficult to achieve without sophisticated GPS processing and more field time to collect signal. These small polygons may have contributed to apparent misclassification of map classes during the accuracy assessment. We considered possible location errors during the accuracy assessment analysis; however, it is likely that map users may also experience the same problems with determining exact locations. It may have been beneficial to use the polygon centroid instead of a buffer of five meters to ensure that the field crew was assessing the correct polygon, particularly for polygons less than the minimum mapping unit. Correct placement of the field crew within the polygon is confounded when the polygon has dimensions that are smaller than the location accuracy of the GPS equipment. Real time differential correction would also be useful to ensure adequate georeferencing small or linear polygons, typically those less than 0.5 ha. MMU. Use of such equipment was not within the initial scope of the project. In addition, we recommend that field crews use a Pocket PC to digitally view the placement of the accuracy assessment point in relation to the vegetation polygons on the map. This would also help ensure the positional accuracy of the field points.

5) The 1996 aerial photograph acquisition, 1999-2002 photointerpretation observations and photointerpretation, 2000 classification relevés and 2001 community classification, and 2002 accuracy assessment may be each describing land cover characteristics that have temporal variability. Plants that were dormant when the aerial photography was flown in October 1996 were growing when the field data were collected in the summer of 2000 and 2002. This difference can cause ecologists in the field and photointerpreters to give the same vegetation type different names. Changes to the land cover could include increased recreational activities, change in the fire frequency, non-native plant invasions, native plant increases or decreases, and changes in the annual plant community composition on the Little Colorado River and its tributaries. These map class changes may occur frequently enough to result in misclassified polygons and therefore decrease the measured total accuracy assessment.

Vegetation classification and map class development

Ten new alliances, 15 new associations, three provisional associations, one local vegetation assemblage, and one barren type were newly defined during the course of this project; the other vegetation types were described primarily using existing NVC community classification. More than half of all the alliances and associations described during this project were newly identified or included as a provisional type in the NVC. More than half of the total associations are herbaceous and shrubland formations. In all of the sparse, shrubland, and dwarf-shrubland associations, there were no shared alliances. The lack of overlap in alliances between these formations is probably an artifact of little data previously collected for these types on the Colorado Plateau; with additional data collected on the Colorado Plateau, alliance designations may be re-evaluated. In addition, the provisional associations and local assemblages, if significantly described elsewhere, may eventually be included as confirmed associations within the NatureServe Explorer database.

Twenty of the 30 associations and alliances described were directly translatable into map classes; the remaining associations and alliances were combined to form complexes of vegetation as a single map class. Map class complexes occurred in areas with mosaics of vegetation associations, particularly in areas with similar species composition and photosignatures. Although 20 of the associations have a one-to-one relationship to the map classes, in many cases

the photointerpretive concept included a broader scope than defined in the vegetation descriptions. Map classes that were not adequately described during the vegetation classification, but noted during photointerpretation were labeling using the vegetation classification relevés as a modal type and with the concept expanded to include a broader range of photosignatures. The photointerpretative signature key is explained (Appendix H) and the crosswalk between map classes and the NVC vegetation associations and alliances is described in the vegetation key (Appendix E).

Four sparse associations were described and represented a major portion of the eastern section of the mapping area. The association concepts were all directly translated into map classes that were defined on substrate (Moenkopi Shale, Moenkopi Sandstone, cinder, badlands) rather than the vegetation. Although the vegetation was included in the key as the indicator species of their particular map class, these species did not have to occur to be included in the map class. In sparse areas, geology and landform were delineated with the assumption the vegetation association characterized in the relevés occurs within these types. Sparse vegetation needs to be re-addressed in the NVC, since many of the relevés' mean total vegetation cover represented within the grassland, dwarf-shrubland, and shrubland formations contained less than 25% total vegetation cover, which is the upper break point for sparse classes in the FGDC. In our study, the total vegetation cover was not the main decision factor of where a specific association should be designated. If a association or alliance was defined for a specific formation class with a similar floristic composition and cover to relevés with less than 25% total cover in our project, those relevés were generally assigned to that association or alliance. Further sampling on the Colorado Plateau will need to occur to determine if many of these alliances and associations should be re-defined to be included within the sparse formation.

Ten associations were described in the herbaceous formation class. Of these ten, one association is a wooded herbaceous association and three are shrub herbaceous association. We directly translated all of these associations into a map class, except for two where the photosignatures were not identifiable. Mixed galleta (*Pleuraphis jamesii*) grassland associations were combined into a Galleta Mixed Grasslands map class and pure stands of snakeweed (*Gutierrezia sarothrae*) were combined with mixed snakeweed / galleta steppe into a Snakeweed / Galleta Grassland map class.

Two dwarf-shrubland alliances and one dwarf-shrubland association were described. One of these associations we directly mapped and the other we combined with an herbaceous formation class. Only two relevés were described as occurring in the dwarf-shrubland formation class, each of these representing a different alliance. The extent of these dwarf-shrubland types is patchy and localized.

Ten alliances and associations are in the shrubland formation. Each alliance described has a one association, with over half of these associations newly defined during the course of this project. Shrublands include pure stands of shrubs, ranging in density from sparse to high vegetative cover, to mixed grass shrub types, with higher cover of shrubs to grasses. Three of the shrub associations, depending on the area, have shrubs that act as indicators of the association. These associations include *Artemisia filifolia – Ephedra* (*torreyana, viridis*) Shrubland, *Ephedra*

torreyana – Achnatherum hymenoides Shrubland, and *Poliomintha incana* / (*Pleuraphis jamesii*) Shrubland.

One forest association was described. This type has low total vegetation cover (~20%) and would be considered a woodland formation class if a woodland association had been defined previously. Currently, with only one relevé described with this species composition, it was included with a previously defined association. Additional data collection of this association, would likely result in the re-classification of this association into a woodland formation class.

The USGS-NPS vegetation mapping projects are designed to produce both a vegetation classification and a set of map classes. Typically, the NVC classification and the map classes are very similar, but sometimes there is not a strict one-to-one correspondence between them. Photographic interpretation centers around the ability to accurately and consistently delineate map classes based on complex signatures. Vegetation characteristics that can be seen on aerial photography are not necessarily the same as those apparent on the ground. Map verification work in the field aided enormously in developing the map classes and discerning the inherent variability of each photographic signature.

Accuracy assessment

The USGS-NPS park mapping program has the standard of 80% for overall map accuracy and for each class. The map meets this standard using the understandable accuracy criteria. Understandable accuracy allows for all of the acceptable errors as well as mistakes in interpretation in communities with similar species dominance and structure that are often very sparse, patchy, and difficult to distinguish in the photography. We believe the map is usable as long as the assessments for each individual map class are reviewed and are kept in mind when the map is being used for management purposes. Most acceptable error in the map can be directly attributed to known sources and not to avoidable misclassification in photointerpretation.

Applications

The vegetation map is ready for use with the knowledge that some of the map classes are below the desired 80% accuracy using the acceptable error criteria. These map classes may need to be aggregated to the NVC alliance level or to the lifeform depending on the desired accuracy needed for a particular project.

This map will provide the baseline vegetation data that will allow for better resource management of the park. As with other USGS-NPS park management programs, it is possible that this map will assist with many different aspects of planning activities, including fire management planning, habitat modeling, field sampling for threatened and endangered species, research of particular species and their habitats, education and interpretation, and trail maintenance. This study will also help to compare habitats across management boundaries and hopefully to assist in the joint-agency management of the lands studied in the project environs. Ultimately, the vegetation map will help to monitor impacts on vegetation health as well as the overall ecosystem health of the area.

6. BIBLIOGRAPHY

Agresti, A. & Coull, B.A. 1998. Approximate is better than exact for interval estimation of binomial proportions. The American Statistician. 52: 119-126.

Anderson, J., E. Hardy, J. Roach, and R. Witmer. 1976. A Land Use and Land Cover Classification System for use with Remote Sensor Data. Geological Survey Professional Paper 964. U.S. Government Printing Office. Washington, D.C.

Bateman, G.C. 1976. Natural resource survey and analysis of Sunset Crater and Wupatki National Monuments, final report. Report to National Park Service. Department of Biological Sciences, Northern Arizona University, Flagstaff.

Bateman, G.C. 1978. Natural resource survey and analysis of Sunset Crater and Wupatki National Monuments, final report (phase II). Report to National Park Service. Department of Biological Sciences, Northern Arizona University, Flagstaff.

Bateman, G.C. 1980. Natural resource survey and analysis of Sunset Crater and Wupatki National Monuments, final report (phase III). Report to National Park Service. Department of Biological Sciences, Northern Arizona University, Flagstaff.

Carletta, J. 1996. Assessing the agreement on classification tasks: the Kappa statistic. Computation Linguistics. 22(2): 1-6. Internet Site: http://www.cogsci.ed.ac.uk/~jeanc/squib.pdf Accessed 2003.

Cordasco, W. S., Thybony, and K. Thomas. 1998. Babbitt Ranches Biological Assessment of the Coconino Plateau. Babbitt Ranches. Flagstaff, AZ.

Falzarano, S. and K. Thomas. In Press. Fuzzy set and spatial analyses of thematic accuracy of a land cover map. In R. Lunnetta and J.G. Lyon, editors, Proceedings of the Remote Sensing and GIS Accuracy Assessment Symposium, Las Vegas, NV, Dec 11-13, 2001.

FGDC [Federal Geographic Data Committee]. 1997. Vegetation classification standard, FGDC-STD-005 (http://www.fgdc.gov/Standards/Documents/Standards/Vegetation). United States Geological Survey, Reston, Virginia 22092 USA.

Foody, G. M. 1992. On the Compensation for Chance Agreement. In Image Classification Accuracy Assessment. *Photogrammetric Engineering and Remote Sensing,* 58 (10): 1459-1460.

Grossman, D. H., D. Faber-Langendoen, A.S. Weakley, M. Anderson, P. Bourgeron, R. Crawford, K. Goodin, S. Landaal, K. Metzler, K. Patterson, M. Pyne, M. Reid, and L. Sneddon. 1998. International Classification of Ecological Communities: Terrestrial Vegetation of the United States. Volume I. The National Vegetation Classification

System: Development, Status, and Applications. The Nature Conservancy, Arlington Virginia, USA.

Hoffmeister, D.J. 1986. Mammals of Arizona. University of Arizona Press, Tucson.

Jennings M., O. Loucks, D. Glenn-Lewin, R. Peet, D. Faber-Langendoen, D. Grossman, A. Damman, M. Barbour, R. Pfister, M. Walker, S. Talbot, J. Walker, G. Hartshorn, G. Waggoner, M. Abrams, A. Hill, D. Roberts, and D. Tart. 2003. Guidelines for Describing Associations and Alliances of the U.S. National Vegetation Classification, version 2.0. The Ecological Society of America, Vegetation Classification Panel. Internet Site: http://vegbank.nceas.ucsb.edu/vegbank/panel/esa_guidelines_v2.pdf.

Klopfer, S.D., A. Olivero, L. Sneddon, and J. Lundgren. 2002. Final Report of the NPS Vegetation Mapping Program Fire Island National Seashore. Conservation Management Institute, GIS & Remote Sensing Division. Virginia Tech. Blackburg, Virginia, 24061.McCune, B. and M.J. Mefford. 1999. Multivariate analysis of ecological data. Version 4.01. MjM Software. Gleneden Beach, Oregon.

Muller-Dombois, D. and H. Ellenberg. 1974. Aims and Methods of Vegetation Ecology. New York, NY: Wiley & Sons.

NPS [National Park Service]. 2002. General Management Plan. Final Environmental Impact Statement, General Management Plan, Wupatki National Monument, Arizona. U. S. Department of Interior.

NOAA [National Oceanic Atmospheric Administration]. 1997. Internet Site: National Climatic Data Center weather data. http://www.ncdc.noaa.gov/ol/climate/online/coop-precip.html. Accessed 1997-2003.

Nowak, E.M., T.B. Persons, and A.J. Monatesti. 2003. 2002 Progress report on herpetofauna inventories of southern Colorado Plateau national parks. Report to Southern Colorado Plateau Inventory and Monitoring Network. USGS Colorado Plateau Field Station, Flagstaff, Arizona.

Persons, T.B. 2001. Distribution, activity, and road mortality of amphibians and reptiles at Wupatki National Monument, Arizona. Report to National Park Service. USGS Colorado Plateau Field Station, Flagstaff, Arizona.

Priest, S.S., W.A. Duffield, K. Malis-Clark, J.W. Hendley II, and P.H. Stauffer. 2001. The San Francisco Volcanic Field, Arizona. U.S. Geological Survey Fact Sheet 017-01. Internet Site: http://geopubs.wr.usgs.gov/fact-sheet/fs017-01/.

Reid, M.S., K.A. Schulz, P.J. Comer, M.H. Schindel, D.R. Culver, D.A. Sarr, and M.C. Damm. 1999. Descriptions of vegetation alliances of the coterminous western United States. The Nature Conservancy, Boulder, Colorado, USA.

Robinson, A. H., R. D. Sale, J. L. Morrison, and P. C. Muehrcke. 1984. *Elements of Cartography,* 5th ed. New York: John Wiley & Sons (pp 64-66, Appendix B). Retrieved from September 12, 2003, from Texas Natural Resource Conservation Commission. 2003. Horizontal Accuracy Standards for TCEQ GIS Positional Data. Internet Site: http://www.tnrcc.state.tx.us/gis/geocoord.html. Accessed 2003.

Rosenstock, S.S. 1999. Effects of juniper woodland expansion on breeding birds in grasslands of northern Arizona. Technical Guidance Bulletin No. 1, Arizona Game and Fish Department, Phoenix.

SAS Institute 1989-2000. JMP Statistical Discovery Software. Version 4. Cary, NC.

TNC and ESRI [The Nature Conservancy and Environmental Research Systems Institute]. 1994a. NBS/NPS Vegetation Mapping Program: Field Methods for Vegetation Mapping. Arlington, VA. Available on-line at: http://biology.usgs.gov/npsveg/standards.html

_____. 1994b. NBS/NPS Vegetation Mapping Program: Standardized National Vegetation Classification System. Arlington, VA. Available on-line at: http://biology.usgs.gov/npsveg/standards.html

_____. 1994c NBS/NPS Vegetation Mapping Program: Accuracy Assessment Procedures. Arlington, VA. Available on-line at: http://biology.usgs.gov/npsveg/standards.html

USDA NRCS [U.S. Department of Agriculture, National Resource Conservation Service]. 1999. Internet Site: The PLANTS database. National Plant Data Center, Baton Rouge, LA. http://plants.usda.gov/plants. Accessed 2003.

USGS-NPS [U.S. Geological Survey – National Park Service]. 2000. Internet Site: USGS - NPS Vegetation Mapping Program. http://biology.usgs.gov/npsveg/. Accessed 1998-2003.

Zion Natural History Association. 1985. Geologic Cross Section of the Grand Canyon - San Francisco Peaks - Verde Valley Region. ISBN 0-915630-02-8. NPS-Zion National Park. Springdale, UT.

7. GLOSSARY

The following people contributed to this glossary: Alan Bell, Jack Butler, Daniel Cogan, Janet Coles, Doug Crawford, Dave Eckhardt, Monica Hansen, and Tom Owens.

This glossary refers to terms as they are used in USGS-NPS vegetation mapping projects. Some terms may not appear in this report.

7.5-Minute Quadrangle. Informally known as a 'quad' map. A USGS paper map product at 1:24,000 scale covering 7.5 minutes of latitude and 7.5 minutes of longitude. Features shown include elevation contours, roads, railroads, water bodies, buildings, urban developments, wooded cover, permanent ice fields, and wetlands. This is a basic layer of information for many ecological and natural resource applications. A digital version of a 7.5-minute quad is called a Digital Raster Graphic (DRG).

Accuracy. The closeness of results of observations, computations, or estimates to the true values or to values that are accepted as being true (ASP 1984). See also Error.

Accuracy Assessment (AA). The process of determining the thematic accuracy of the vegetation map. An unaffiliated ecologist tests map accuracy after the vegetation mapping and classification are complete. (Stadelmann et al. 1994).

Accuracy Assessment Point. A location where accuracy assessment data are collected. See "Producing rigorous and consistent accuracy assessment procedures" at http://biology.usgs.gov/npsveg/aa/aa.html for more information.

Aerial Photography. Photography taken from an airplane (not satellite) mounted with specially designed photographic equipment. Ideally, the lens and the film are parallel to the surface being photographed. A sequence of aerial photographs along a flight line will have a certain amount of overlap so that the photos can be viewed with a stereoscope. "Sidelap" refers to overlap between flight lines (ASP 1984). Print size is usually 9"x9" and are photos that may use true color or color infrared film.

Alliance. A physiognomically uniform group of associations sharing one or more diagnostic (dominant or indicator) species that usually occur in the uppermost stratum of the vegetation (FGDC 1997). This is the second finest level in the NVCS hierarchy.

Anderson Classification System.
A classification system developed for use with remote sensing systems in the 1970s adopted for the National Vegetation Classification to map cultural and water features (Anderson et al. 1976).

Level I	Level II
Urban or Built-up Land	Residential
	Commercial and Services
	Industrial
	Transportation, Communications, and Utilities
	Industrial and Commercial Complexes
	Mixed Urban or Built-up Land
	Other Urban or Built-up Land
Agricultural Land	Cropland and Pasture
	Orchards, Vineyards, and Ornamental Horticultural Areas
	Confined Feeding Operations
	Other Agricultural Lands
Water (non-vegetated portion)	

	Streams and Canals
	Lakes
	Reservoirs
	Bays and Estuaries
Barren Land	
	Dry Salt Flats
	Beaches
	Sandy Areas other than Beaches
	Strip Mines, Quarries, and Gravel Pits
	Transitional Areas
	Mixed Barren Lands

ArcInfo. A geographic information software used to view and analyze data.

Association. The finest level of the NVCS classification hierarchies. A physiognomically uniform group of stands of vegetation that share one or more diagnostic overstory and understory species. These elements occur as repeated patterns of assemblages across the landscape, and are generally found under similar habitat conditions (FGDC 1997).

Attribute (digital data). A numeric, text, or image data field in a relational database table (such as a GIS) that describes a spatial feature such as a point, line, polygon, or cell (ESRI 1994).

Automation. The process of entering data into a computer (see also Digitize).

Base map. The control to which all spatial data is georeferenced. Interpreted photo data are transferred to a base map to rectify and register the data. In this project the base maps are USGS DOQQs.

Bureau of Reclamation (USBR, BOR). A U.S. Department of Interior agency created in 1902 and charged with developing environmentally and economically sound irrigation and hydropower projects in 17 Western States. The Remote Sensing and GIS Group of the BOR manages a number of park projects for the USGS-NPS Vegetation Mapping Program.

Biological Resources Discipline (BRD). A USGS discipline housing the Center for Biological Informatics. The BRD's mission is to work with others to provide the scientific understanding and technologies needed to support the sound management and conservation of our Nation's biological resources. Formerly, the National Biological Service (NBS).

Center for Biological Informatics (CBI). A USGS Science Center. CBI serves as the operating agent for the National Biological Information Infrastructure. In addition, CBI manages the USGS-NPS Vegetation Mapping Program along with other national data collection programs that complement and strengthen its role within the NBII.

Class. The level in the NVCS hierarchies based on the structure of the vegetation. Class is determined by the relative percentage of cover and the height of the dominant, uppermost life forms (Grossman et al. 1998).

Classification Accuracy. How closely the map classes match the vegetation found on the landscape. This is determined by accuracy assessment protocols. See "Producing rigorous and consistent accuracy assessment procedures" at http://biology.usgs.gov/npsveg/aa/aa.html for more information.

Color Infrared (CIR) Film. A three-layer color film sensitized to green, red, and near-infrared portions of the spectrum. CIR films emphasize differences in infrared reflectance from surfaces and are some of the most use-

ful aerial films currently available for use in agricultural and vegetation surveys. The images are sharper and have better contrast than conventional color photos because they are less susceptible to atmospheric light scattering. Furthermore, CIR has a high transmission component through green leaves, meaning that it can detect layers of leaves lower in the canopy. In true-color photography, the photosynthetic pigments within leaves quickly absorb visible light, and the film records information about nothing below the uppermost leaf layer. Color differences recorded on CIR film are used to differentiate among vegetation types. Generally, in spring and summer, healthy deciduous trees and other vegetation photographs as magenta or red, while healthy evergreens photograph more as a brownish red. CIR film can only be used in daylight.

Commission Accuracy. See Producer's Accuracy.

Community. An assemblage of species that co-occur in defined areas at certain times and have the potential to interact with one another (Grossman et al. 1998). In the NVCS, Association and Community are synonyms.

Community Element Global (CEGL). NatureServe's unique plant association coding system in their central biodiversity database; also known as Elcode.

Community Type. See Association or Type.

Complex. A group of associations that are not distinguishable from one another on aerial photography and so are grouped into a map class. Compare with Mosaic.

Confusion Matrix. See Contingency Table.

Contingency Table. A table that is used in accuracy assessment to determine the degree of misclassification that has occurred. The table compares the classes derived from accuracy assessment relevés to the classes derived from photointerpretation. Also referred to as Error Matrix, Confusion Matrix, or Misclassification Matrix.

Coordinate System. A reference system that represents horizontal and/or vertical locations and distances on a map. A geographic coordinate system is the latitude and longitude with respect to a reference spheroid. A local coordinate system is one that is not aligned with the Earth's surface. Most coordinate systems are based on projections of the earth's surface onto a plane. All spatial data in this project uses the Universal Transverse Mercator (UTM) coordinate system.

Cover. The area of ground covered by the vertical projection of the aerial parts of vegetation (FGDC 1997).

Cover Type. A designation based upon the plant species forming a plurality of composition within a given area (e.g., Oak-Hickory) (FGDC 1997). It is roughly equivalent to an Alliance in the NVCS classification hierarchy.

Coverage. A data theme in a geographic information system with vector and polygon topology and attribute data related to that topic. Also, the file format used by Arc/Info software for vector spatial data.

Cowardin Classification. A wetland classification system used as the FGDC standard for wetland classification (Cowardin et al. 1979).

Crosswalk. The relationship between the elements of two classification systems. For

example, this project includes a crosswalk between Map Classes and units of the NVCS. In a database, the crosswalk is in a Lookup Table (LUT).

Cultural Vegetation. Vegetation planted or actively maintained by humans such as annual croplands, orchards, and vineyards. Contrast with Natural Vegetation.

Datum. A mathematical model that describes the shape of the earth. The earth is not a sphere but is rather an ellipsoid distorted by rotation about its axis, bulging at the equator and flattened at the poles. Because of the distribution of continents and seas, the distortion is not uniform around the globe and there are datums for different parts of the earth based on different measurements (Snyder 1982). The datum used by this project is NAD83.

Datum (horizontal-control). The position on the spheroid of reference assigned to the horizontal control of an area. A datum may extend over an entire continent or be limited to a small area (referred to as 'local datum'). This project used the North American Datum of 1983 (NAD83) (ASP 1984).

Density. Density is the relationship between the area covered by the vegetation and the total area of a polygon in which the community is found. The USGS-NPS Vegetation Mapping Program uses a series of arbitrarily defined density classes to separate vegetation units: Closed/Continuous > 60 %, Discontinuous 40-60%, Dispersed 25-40%, Sparse 10-25%, Rare 2-10%. Compare with Pattern and Height.

Diagnostic Species. A species generally considered to indicate (i.e., diagnose) a specific set of environmental conditions. For example, the presence of *Vaccinium stamineum* var. *stamineum* (gooseberry) beneath a canopy of chestnut oak, black oak, and Virginia pine indicates that the site is dry. The trees can inhabit a wide range of sites, wet to dry, but the gooseberry understory is the indicator of a drier habitat. Sometimes also called Indicator Species (FGDC 1997).

Dichotomous Field Key. A document that identifies plant associations or map classes on the basis of pairs of exclusive characteristics such as "forested" versus "non-forested". This key is an important product of each vegetation-mapping project. Also known as Vegetation Field Key and Vegetation Key.

Digital Orthophoto Quadrangle (DOQ). A USGS digital product derived from high altitude aerial photography. Each DOQ is rectified and registered to locations on the earth and covers the same area as a 7.5 minute quad. These are often used as base maps to register photointerpreted data. See also Quarter Quadrangle.

Digital Raster Graphic (DRG). A scanned image of a paper USGS topographic quadrangle map. The geographic information is georeferenced to the UTM projection with the same accuracy and datum as the original map. The minimum scanning resolution is 250 dots per inch.

Digitize. The process of converting lines on a map or image into a computer file. The basic technique involves tracing a line with a device connected to a computer that sends a stream of x-y coordinates corresponding to the traced line into a computer file. Synonymous with Automation.

Division. The highest level in the NVCS hierarchy, separating the earth's surface into vegetated and non-vegetated categories (FGDC 1997). (See NVCS).

Dominance. The extent to which a given species or life form dominates in a community because of its size, abundance or cover. The ecological assumption is that dominant species can affect the fitness of associated species (FGDC 1997).

Dominant Life Form. An organism, group of organisms, or taxon that by its size, abundance, or coverage exerts significant influence upon an association's biotic and abiotic conditions (FGDC 1997).

Ecological Groups. Non-NVCS categories of vegetation based on plant assemblages, physical environments, and dynamic processes useful for conservation planning. These groups are classified on total floristic composition, physiognomy (vertical structure), distribution (horizontal structure), physical environment (slope, rainfall), chemical variables (soil pH), and disturbance regimes. Some factors are difficult to measure directly, and must be inferred from knowledge of species ecology, spatial patterns, and ecological processes.

Edge Distortion. In reference to aerial photographs, lens distortion increases with distance from the center of the photograph. Because of this, photointerpreters work only with the center third of each aerial photograph.

Error. The numeric distance of results of observations, computations, or estimates from the values that are accepted as being true. Also refers to the misclassification of thematic data. Contrast with Accuracy.

Error Matrix. See Contingency Table.

Existing Vegetation. The plant species existing at a location at the present time. The USGS-NPS Vegetation Mapping Program classifies and maps existing vegetation. Contrast with Potential Vegetation

Federal Geographic Data Committee (FGDC). Coordinates the development of the National Spatial Data Infrastructure (NSDI). The NSDI encompasses policies, standards, and procedures for agencies to produce and share geographic data. The 17 federal agencies that make up the FGDC are developing the NSDI in cooperation with state, local, and tribal governments, the academic community, and the private sector.

Field Reconnaissance. Preliminary field visits by photointerpreters and vegetation ecologists to gain an overview of the vegetation of the project area and how it relates to the NVC.

Flight Line. A line connecting the principal points of sequential vertical aerial photographs. Designated on the film as 'flight line number – photo number' (ASP 1984).

Floristics. The kinds, number and distribution of plant species in a particular area.

Formation. A level in the NVCS hierarchies that represents veg-etation types sharing a definite physiog-nomy or structure within broadly defined environmental factors, relative landscape positions, or hydrologic regimes (Grossman et al. 1998).

Frequency. The number of occurrences of an item of interest.

Georeference. The process of converting a map or image into real-world coordinates. A non-georeferenced map or image is said to be in ‘digitizer-inches’ or ‘scanner-inches’, i.e., it has no real-world coordinates.

Geographic Information System (GIS). An organized database of geographically referenced information (ESRI 1994).

Global Positioning System (GPS). A system of satellites, ground receiving stations and handheld receivers that allow accurate location of features on the earth's surface. GPS receivers are used to locate field relevés, reconnaissance points, and accuracy assessment points.

Gradsect. Gradient directed transect sampling. The gradsect sampling design is intended to provide a description of the full range of biotic variability (e.g., vegetation) in a region by sampling along the full range of environmental variability. This approach is based on the distribution of vegetation along environmental gradients. Transects that contain the strongest environmental gradients in a region are selected in order to optimize the amount of information gained in proportion to the time and effort spent during the vegetation survey (Grossman et al. 1994).

Ground photograph. An image recorded with the photographer standing on the ground (See Aerial Photography).

Ground truth. The process of taking aerial photographs into the field to see how particular photographic signatures compare with the vegetation on the ground.

Group. The level in the NVCS hierarchies based on leaf characters and identified and named in conjunction with broadly defined macroclimatic types to provide a structural-geographic orientation (Grossman et al. 1998).

Habitat. The combination of environmental or site conditions and ecological processes influencing a plant community.

Habitat Type. 1. A collective term for all parts of the land surface supporting, or capable of supporting, the same kind of climax plant association (Daubenmire 1978). 2. An aggregation of land areas having a narrow range of environmental variation and capable of supporting a given plant association (Gabriel and Talbot 1984).

Hectare. A metric unit of measure equal to 10,000 m^2 or approximately 2.471 acres.

Height. Height of the overstory of a plant community. One of the physiognomic modifiers classified in the USGS-NPS Vegetation Mapping Program. Vegetation polygons are attributed by height class: < 0.5 m, 0.5-2 m, 2-5 m, 5-15 m, 15-35 m, 35-50 m, >50 m. Compare with Density and Pattern.

Indicator Species. See Diagnostic Species.

Infrastructure. Human-built systems that include structures such as roads and bridges, water supply systems, and electric, gas or telephone lines.

Integrated Taxonomic Information System (ITIS). A comprehensive, standardized reference for the scientific names, synonyms and common names for all the plants and animals of North America and the surrounding oceans. This database is accessible over the Internet (http://www.itis.usda.gov/). The PLANTS database is an important ITIS partner providing plant taxonomic information to ITIS.

Land Cover Classification.
A classification of the cultural, physical, and vegetation features that cover the earth, commonly used with remote sensing technology. The Anderson Classification System is a land cover/land use classification.

Vegetation classification is a subset of land cover classification.

Land Use Classification. A classification of the earth's surface that defines the human use the land is providing. Commonly used with remote sensing technology, and usually combined with land cover classification. Natural vegetation may be classified as "vacant", "forest", or "grazing".

Large-scale. Refers to a map or image with a large-scale denominator (e.g., 1:100,000). Large-scale maps cover a broad area, are usually low in detail, and images usually have low resolution (e.g., 30m per pixel).

Look-Up Table (LUT). A computer file that is a list of standard elements that may be entered in a field in the database. In the context of these vegetation-mapping projects, LUT relates the elements of one classification to another in a crosswalk. The values of a map classification could be related to the associations of the NVCS in a park project.

Map Accuracy. A measure of the maximum error allowed in horizontal location and elevation on maps. For example, the USGS map accuracy standards for 1:24,000-scale maps are that 90% of well-defined objects should appear within 40 ft (12.2 m) of their true location. See United States National Map Accuracy Standards.

Map Attribute. See Attribute.

Map Class. Plant communities and non-vegetated elements that can be discerned on an aerial photograph. If individual plant associations cannot be distinguished on an aerial photograph, map classes lumping related plant associations must be developed. For example, at Devils Tower National Monument there were five associations in the Ponderosa Pine Woodland Alliance, but it was necessary to create two ponderosa pine map classes because the associations could not be distinguished on the photography. Also known as Map Unit.

Map Code. The map class code number related to the map class. For example, map class Black Grama Grassland has a map code of 8.

Map Scale. The relationship between a distance portrayed on a map and the same distance on the earth's surface (Dana 1999). A scale of 1 inch = 1000 feet can also be expressed as 1:12,000 (i.e., 1 inch on the map equals 12,000 inches on the earth). When a map is reproduced in a different size, the scale reference (1:12,000) is no longer valid but the scale bar on the map is still valid.

Map Projection. A systematic conversion of locations on the Earth's surface from spherical coordinates to planar coordinates (ESRI 1994).

Map Unit. See Map Class.

Map Validation. The process of field checking photointerpretation. This step is completed prior to accuracy assessment.

Metadata. A text file describing how a spatial database was created. Metadata files document how the data were created, their content, quality, condition, and other characteristics. Metadata's purpose is to help organize and maintain an organization's internal investment in spatial data, provide information about an organization's data holdings to data catalogues, clearing-houses, and brokerages, and provide information to process and interpret data received through a transfer from an external source (FGDC 1997). The FGDC sets the content standards

for metadata. The NBII has developed software to aid in creating metadata and commercial software programs are also available.

Minimum Mapping Unit (MMU). The smallest area that is consistently delineated during photointerpretation. The MMU for the USGS-NPS Vegetation Mapping Program is 0.5 hectares.

Mosaic (Biology). An intermixing of plant associations in an area that has a unique photosignature but is too intricate for individual associations to be delineated. Compare with Complex.

Mosaic (Image). An image composed of an assemblage of edge-matched, overlapping aerial photographs.

National Biological Information Infrastructure (NBII). A broad, collaborative program to provide access to data and information relating to the Nation's biological resources. The NBII links diverse, high-quality biological databases, and analytical tools maintained by NBII partners in government agencies, academic institutions, nongovernmental organizations, and private industries.

National Biological Service (NBS). See Biological Resources Discipline.

National Map Accuracy Standards. See US National Map Accuracy Standards.

National Park Service (NPS). A U.S. Department of Interior agency created in 1916 and charged with preserving the natural and cultural resources of the national park system for the enjoyment, education, and inspiration of this and future generations. NPS manages the National Parks and the Inventory and Monitoring Program and works closely with USGS to coordinate the USGS-NPS Vegetation Mapping Program.

National Vegetation Classification (NVC). A vegetation classification system developed and maintained by NatureServe. It is based on the National Vegetation Classification Standard (NVCS). The NVC can be examined on their on-line NatureServe Explorer database (http://www.natureserve.org/explorer/).

National Vegetation Classification Standard (NVCS). The Federal Geographic Data Committee's vegetation classification model. It has been adapted to the formation level (as of June 2001); adoption of standards for finer levels is expected in the spring of 2004 with the adoption of the Ecological Society of America's 'Guidelines For Describing Associations and Alliances of the U.S. National Vegetation Classification'.

Natural Heritage Programs. Operate throughout much of the western hemisphere gathering, managing, and distributing detailed information about the biological diversity found within their jurisdiction. Most programs are part of government agencies such as fish and wildlife departments, although some are run by universities or nongovernmental organizations.

Natural Resources Conservation Service (NRCS). A USDA agency that is the lead federal agency for conservation on private land and is a partner in land conservation with private land managers, conservation districts; resource conservation and development (RC&D) councils; state and local conservation agencies; state, local, and Tribal governments; rural communities; businesses; and others. The NRCS produces the nation's Soil Survey reports.

Natural Vegetation. Plant life of an area that appears to be substantially unaltered by human activities. Most existing vegetation has been subjected to some human modification, so a clear distinction between natural and cultural vegetation may sometimes be difficult (Grossman et al. 1998).

NatureServe. A non-profit organization dedicated to developing and providing knowledge about the world's natural diversity. In cooperation with the Natural Heritage Network, NatureServe collects and develops authoritative information about the plants, animals, and ecological communities of the Western Hemisphere. NatureServe maintains databases to support the National Vegetation Classification (NVC) and the relevé data that it is based on. NatureServe's role in this project was to help develop the vegetation community classification. Formerly known as ABI (Association for Biodiversity Information).

North American Datum (NAD). The standard cartographic reference for map projections and coordinates throughout North America (see also Datum). Usually associated with a version, such as 1927 or 1983. This project used the 1983 North American datum (NAD83), which is consistent with satellite location systems. The 1983 datum uses the GRS 80 spheroid whereas the 1927 datum uses the Clarke 1866 spheroid (ESRI 1994).

Observation Point. Field data used to support map class and vegetation classification development. These points are collected during reconnaissance and verification field work.

Omission Errors. See Producer's Accuracy.

Order. The 2nd highest level in the NVCS hierarchy (FGDC 1997). An order is generally defined by dominant life form (tree, shrub, dwarf shrub, herbaceous, or non-vascular)

Ortho Image. An aerial photograph that has had the distortions common to aerial photography removed and has been registered to locations on the earth. A digital ortho image can be placed in a GIS and have other layers, such as vegetation, overlain on it. A DOQQ is an ortho image. Also sometimes called an ortho-photo.

Pattern. Describes the distribution of vegetation features across a landscape. Some examples include: Evenly Dispersed, Clumped/Bunched, Gradational/Transitional, or Alternating. Compare with Density and Height.

Photointerpretation. The art and science of identifying and delineating objects and conditions on an aerial photograph.

Photointerpretation Key. A description, often accompanied by pictures of examples, of the visual elements that make up the photographic signature of each map class.

Photointerpretation Modifiers. Codes used to describe special features that are not part of the NVC. For example, an agency may be interested in eagle nests, beaver dams, prairie dog towns, and forest blowdown areas.

Photosignature. See Signature.

Physiognomic Modifiers. Modifiers used to describe the physiognomic structure of the vegetation found within a mapped polygon (e.g., cover, density, pattern, height).

Physiognomy. The structure and life form of a plant community (FGDC 1997).

Plant Association. See Association.

Plant Community. See Community.

PLANTS database. A database maintained by the Natural Resource Conservation Service. This database focuses on vascular plants, mosses, liverworts, hornworts, and lichens of the U.S. and its territories. The PLANTS Database includes names, checklists, automated tools, identification information, species abstracts, distributional data, crop information, plant symbols, plant growth data, plant materials information, links, references, and other information. This is the database that maintains the current list of accepted scientific names. See http://plants.usda.gov/.

Plot. A defined location of a certain size where the data necessary to classify the vegetation is collected. Plots are generally located non-randomly and plot size varies depending on the vegetation being sampled. See: http://biology.usgs.gov/npsveg/fieldmethods. Plot data are entered into a database for storage and analysis. Also referred to as vegetation relevés.

Polygon. A multisided figure that represents area on a map. A polygon is defined by the lines that consist of the boundary and the label point within its boundary used for identification. Polygons have attributes that describe the geographic feature they represent.

Positional Accuracy. How close a point in a spatial database is to its actual location on the earth's surface. The National Map Accuracy Standard for horizontal positional accuracy at the 1:24,000 scale is 1/50 of an inch (40 ft/12.2 m) of an object's actual location.

Potential Vegetation. The vegetation that would become established if succession were completed without interference under the present climatic and edaphic conditions. Contrast with Existing Vegetation.

Precision Lightweight GPS Receiver (PLGR). A small handheld, global positioning system (GPS) receiver developed for the military and featuring anti-spoofing and anti-jamming capability.

Producer's Accuracy. The probability that a reference sample (the ground data) has been classified correctly, also known as error of omission. This quantity is computed by dividing the number of samples that have been classified correctly by the total number of reference samples in that class (Story and Congalton 1986). Compare with User's Accuracy.

Projection. A two-dimensional representation of data located on a curved surface. Projections always involve distortion, so the cartographer must choose which characteristics (distance, direction, scale, area, or shape) will be emphasized at the expense of the other characteristics (Snyder 1982). In this project, all spatial data use the Universal Transverse Mercator (UTM) coordinate system that is based on the transverse mercator projection applied between 84 degrees north and 80 degrees south latitude.

Quadrangle. A USGS 7.5 minute topographic map.

Quarter Quad(rangle). A map or image that includes ¼ of a 7.5-minute quadrangle map. Quarter quadrangles are organized in geographic quadrants of the original map:

northeast, northwest, southeast, and southwest.

Rectify. To remove distortions from aerial photographs in the process of transferring interpreted photographs into a spatial database. Distortions on photographs are due to topographic relief on the ground, radial distortion in the geometry of the aerial photography, tip and tilt of the plane, and differences in elevation of the airplane from its nominal scale. This process may be separate or included in the registration process, depending on the technology used.

Reference Data. The field data that is collected for the accuracy assessment.

Register. The process of relating objects on an aerial photograph to the surface of the earth. This is necessary to be able to place vegetation data in a GIS with other spatial data such as roads, topography, or soils. This process may be separate or may be included in the rectification process, depending on the technology used. See also Transfer.

Relevé. See Plot.

Sample Data. Sample data are the map classes that were photo-delineated as occurring on the vegetation map. The sample data is compared to the reference data (see reference data) to compute map accuracy.

Scale. The relationship between a distance portrayed on a map and the same distance on the Earth (Dana 1999). A map scale can be defined by a fraction (e.g., 1 unit on map / 12,000 units on ground) or by a graphic scale bar.

Signature. The unique combination of color, texture, pattern, height, physiognomy, and position in the landscape used by photointerpreters to identify map classes on an aerial photograph. Or, characteristics of an item on a photograph by which the item may be identified (ASP 1984).

Small-scale. Refers to a map or image with a relatively small-scale denominator (e.g. 1:1,000). Small-scale maps cover a small area, have fine detail, and the images have high resolution (e.g. 0.5m per pixel).

Spatial. Refers to features or phenomena distributed in geographic space and having physical, measurable dimensions.

Special Modifiers. See Photointerpretation Modifiers.

Stratum. A horizontal layer of vegetation. A stratum may be defined by the life form of the vegetation (tree, shrub, herbaceous), its relative position in the community (understory) or its actual height.

Structure (Vegetation). The spatial distribution pattern of life forms in a plant community, especially with regard to their height, abundance, or coverage within the individual layers. Synonymous with Physiognomy.

Subclass. The level in the NVCS hierarchies based on growth form characteristics (Grossman et al. 1998).

Subgroup. The level in the NVCS hierarchies that divides each group into either a "natural/semi-natural" or "cultural" (planted/cultivated) subgroup (Grossman et al. 1998).

The Nature Conservancy (TNC). A non-profit conservation organization founded in 1951. Working with communities, businesses and people, TNC protects millions of acres of valuable lands and waters world-

wide. TNC was the original caretaker of the NVC, but those responsibilities have been spun off to NatureServe. TNC no longer has an active role with the USGS-NPS Vegetation Mapping Program.

Thematic Accuracy. The correctness of the map classes in relation to the vegetation on the ground. This is determined through standardized accuracy assessment procedures. The program standard is 80% accuracy for each map class within 90% confidence intervals. See Accuracy Assessment, Producer's Accuracy, and User's Accuracy.

Thematic Map. A map that displays the spatial distribution of a single attribute or a specific topic, such as land-cover and land-use classes.

Topology. The explicit definition of how map features represented by points, lines and areas are related. Specifically, accounting for issues of connectivity and adjacency of features.

Topographic Quads. USGS paper maps showing the topography of an area as well as roads, railroads, water bodies, buildings, urban developments, and wetlands. These come in a variety of scales, but commonly refer to 1:24,000-scale 7.5-minute quads. Informally referred to as topo quads.

Transfer. The process of entering data from interpreted aerial photo overlays into a digital database. The data is usually registered and rectified into real-world geographic coordinates. This process varies depending on the type of technology used. See also Transformation.

Transform(ation). The process of converting coordinates (map or image) from one coordinate system to another. This involves scaling, rotation, translation, and warping (images) (ESRI 1994).

Transition Zone. An area where the vegetation composition and structure is intermediate between two associations. The transition zone may be narrow as associations abruptly change due to a significant change in a major habitat factor, such as a cliff, or it may be broad when the physical environment changes gradually. Transition zones may be challenging to classify or map.

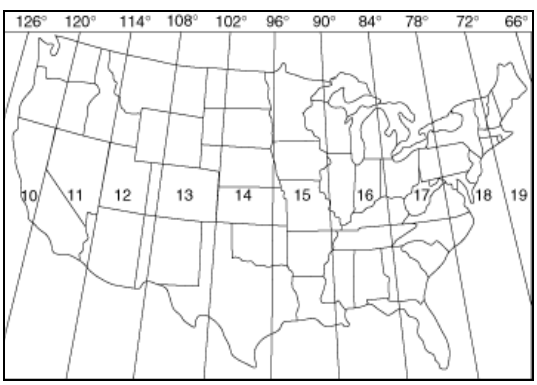
Type. A generic term that can mean any vegetation level in the NVCS, whether an association, alliance, formation, etc, or even a combination of levels. It is a vague but useful term. It is correctly used when the focus is not on a specific unit of vegetation, but rather when used loosely to explain some other point (e.g., "We do not have a good grasp of how vegetation types at Acadia link to the map classes."). Also known as Vegetation Type.

United States Geological Survey (USGS). Established in 1879, the USGS is the natural science agency for the Department of the Interior. The USGS is one of the host agencies, along with the National Park Service, for the USGS-NPS Vegetation Mapping Program.

United States National Map Accuracy Standards. Defines accuracy standards for published maps, including horizontal and vertical accuracy, accuracy testing method, accuracy labeling on published maps, labeling when a map is an enlargement of another map, and basic information for map construction as to latitude and longitude boundaries. The table below shows the standard for some common map scales. Note that the conversion of paper maps into digital data usually creates additional error.

Scale	Engineering Scale	Accuracy Standard
1:1,200	1"=100'	+/- 3.33 feet
1:2,400	1"=200'	+/- 6.67 feet
1:4,800	1"=400'	+/- 13.33 feet
1:9,600	1"=800'	+/- 26.67 feet
1:10,000		+/- 27.78 feet
1:12,000	1"=1000'	+/- 33.33 feet
1:24,000	1"=2000'	+/- 40.00 feet
1:63,360	1"=one mile	+/- 105.60 feet
1:100,000		+/- 166.67 feet

Universal Transverse Mercator (UTM). A map coordinate system (not a map projection) that is defined by the Transverse Mercator projection which has a set of zones defined by a central meridian as shown in the figure below for the United States (ESRI 1994):



User's Accuracy. In assessing the thematic accuracy of a vegetation map, the probability that a sample from the mapped data actually represents that category on the ground, also known as error of commission. This quantity is computed by dividing the number of correctly classified samples by the total number of samples that were classified as belonging to that category (Story and Congalton 1986). Compare with Producer's Accuracy.

Vector Data. Spatial (usually digital) data that consists of using coordinate pairs (x, y) to represent locations on the earth. Features can take the form of single points, lines, arcs or closed lines (polygons).

Vegetation. The plant cover over an area (FGDC 1997).

Vegetation Characterization. The detailed description of a plant association's diagnostic and dominant species, structure, and/or ecological processes. See: http://biology.usgs.gov/npsveg/agfo/descript.pdf

Vegetation Classification. The process of categorizing vegetation into recognizable and consistent elements. Also a document that lists and organizes the vegetation communities in an area. An example of a vegetation classification can be found at http://biology.usgs.gov/npsveg/agfo/methods.pdf classification.

Vegetation Community.
See Community.

Vegetation Description.
See Vegetation Characterization.

Vegetation (Field) Key.
See Dichotomous Field Key.

Vegetation Mapping. The process of identifying, labeling, and locating vegetation communities using real world coordinates.

Vegetation Structure. See Structure.

Vegetation Type. See Type.

Vertical Aerial Photography.
See Aerial Photography.

Wetland. A community or landscape type that is characterized by either hydric soils or hydrophytic plants or both. A wetland may be vegetated or non-vegetated.

Glossary Literature Cited

ASP [American Society of Photogrammetry]. 1984. Multilingual Dictionary of Remote Sensing and Photogrammetry. Rabchevsky, G.A. (Editor). Falls Church, VA.

Anderson, J.R., E.E. Hardy, and J.T. Roach. 1976. "Land Use and Land Cover Classification System for Use with Remote Sensing Data." Geological Survey Professional Paper 964. A revision of the land use classification system as presented in US. Geological Circular 671. Washington, D.C: U. S. Government Printing Office.

Cowardin, L. W., V. Carter, F.C. Golet, and E. T. LaRoe. 1979. Classification of Wetlands and Deepwater Habitats of the United States. Biological Service Program, U.S. Fish and Wildlife Service, FWS/OBS 79/31. Office of Biological Services, Fish and Wildlife Service, U.S. Department of Interior, Washington, D.C., USA.

Dana, P.H. 1999. Map Projection Overview. http://www.colorado.edu/geography/gcraft/notes/mapproj/mapproj_f.html.

Daubenmire, R.F. 1978. Plant Geography, with Special Reference to North America. New York, New York.

ESRI [Environmental Systems Research Institute, Inc.]. 1994. Understanding GIS: The Arc/Info Method. Redlands, CA.

FGDC [Federal Geographic Data Committee]. 1997. Vegetation Classification Standard. http://biology.usgs.gov/fgdc.veg/standards/vegstd.html.

Gabriel, H.W. and S.S. Talbot. 1984. "Glossary of Landscape and Vegetation Ecology for Alaska." Alaska Technical Report 10. Washington, D.C.: Bureau of Land Management, U.S. Department of the Interior.

Grossman, D.H., D. Faber-Langendoen, A.S. Weakley, M. Anderson, P. Bourgeron, R. Crawford, K. Goodin, S. Landal, K. Metzler, K. Pattterson, M. Pyne, M. Reid, and L. Sneddon. 1998. International classification of ecological communities: terrestrial vegetation of the United States. Volume I. Arlington, VA. The Nature Conservancy.

Grossman, D.H., K.L. Goodin, X. Li, D. Faber-Langendoen, M. Anderson, and R. Vaughan. 1994. Establishing standards for field methods and mapping procedures. Prepared for the USGS-NPS Vegetation Mapping Program by The Nature Conservancy, Arlington VA, and Environmental Science Research Institute, Redlands, CA.

Snyder, John P. 1982. Map Projections Used by the U.S. Geological Survey. 2nd Edition. Washington, D.C.: United States Government Printing Office.

Stadelmann, M., A. Curtis, R. Vaughan, and M. Goodchild. 1994. Producing rigorous and consistent accuracy assessment procedures. Prepared for the USGS-NPS Vegetation

Mapping Program by The Nature Conservancy, Arlington VA, and Environmental Systems Research Institute, Redlands, CA.

Storey, M. and R. G. Congalton. 1986. Accuracy assessment: A user's perspective, *Photogrammetric Engineering and Remote Sensing.*

APPENDIX A

A. CD-Rom Readme Text and CD-Rom

(Included as Readme.doc file on the CD-ROM)

The following is the text of the Readme.doc document for the CD-Rom that accompanies this report. This CD-Rom contains all coverages and GIS data developed for the WUPA vegetation map, databases for vegetation classification relevés and accuracy assessment observations, field photos, report files, and associated metadata. The associated metadata describes the attributes in all of the coverages and databases. We also include a list of appropriate citations below each of the coverages or databases to be used when citing these sources.

The files are arranged on the CD-Rom as follows:

readme.doc – This file

1. Ancillary_Data - This folder contains 4 subfolders with information on the park, project, and imagery boundary files. Each subfolder contains a coverage in Arc/Info export format (.e00), a shapefile, a coverage, and associated metadata:

   a. Flightline_bndry- Flightline boundaries used to develop the aerial photography
   Citation:
   U.S. Bureau of Reclamation Remote Sensing and GIS Group. 2004. Flight Line Coverage: Wupatki National Monument. A digital spatial database (ArcInfo). U.S. Geological Survey.
   b. Park_bndry- Boundary of Wupatki National Monument
   Citation:
   Flagstaff Area National Monuments. 2004. Boundary: Wupatki National Monument. A digital spatial database (ArcInfo). U.S. Geological Survey.
   c. Proj_bndry- Boundary for vegetation map for Wupatki National Monument
   Citation:
   U.S. Bureau of Reclamation Remote Sensing and GIS Group. 2004. Project Boundary: Wupatki National Monument. A digital spatial database (ArcInfo). U.S. Geological Survey.
   d. Quad_Doqq_bndry- Boundary of the USGS topographic quadrant maps and the digital orthophoto quarter quads boundaries used for the development of the vegetation map for Wupatki National Monument
   Citation:
   U.S. Bureau of Reclamation Remote Sensing and GIS Group. 2004. Boundary: Flagstaff Area National Monuments USGS Quadrangle and DOQQs. A digital spatial database (ArcInfo). U.S. Geological Survey.

2. Basemap folder – This folder contains the MrSid compressed mosaic of the DOQQs and associated metadata for Wupatki National Monument. The MrSid images can be viewed as images in ArcView using the MrSid extension.
   Citation:
   U.S. Geological Survey. 2004. DOQQ Basemap: Wupatki National Monument. Digital orthophotoquads. U.S. Geological Survey.

3. Ground Photos (.tif/.jpeg) - This folder contains photos for each relevé collected for the vegetation classification. Each photo is listed as "WU-***a/b/c" where the WU stands

for Wupatki, the *** indicates the relevé number, and either a, b, or c is listed after the prefix corresponding sequentially to the number of photos taken at each relevé point. For example, at relevé number WU-032 two photos were taken and are listed as WU-032a and WU-032b. For additional information on the aspect and time of the photo taken at each relevé refer to the Vegetation Relevé Database described below.

4. Map_Demo – This folder contains an ArcView project file (.apr), associated data that was used to create the final vegetation map, and a readme.txt file. To open the project, a copy of this folder must be placed on your hard drive. You will also need the ArcPress extension. Start ArcView and then navigate to the project file (WUPA_veg.apr). Further information can be found in the included readme.txt file.

5. Project_Report - The folder contains the entire report (WUPA_Final_Report.pdf) in an Adobe Acrobat .pdf format.

6. Vegetation_Data – This folder contains all the spatial data (final vegetation GIS cover including a vegetation map clipped to the park boundary, observation points cover, seeps and springs cover, accuracy assessment points cover and classification relevé cover) and databases (Vegetation Relevé Database and Accuracy Assessment Database) used to create the final vegetation map as well as associated metadata.
   a. Accuracy Assessment
      1. Database- Microsoft access database named WUPA_AAdatabase.mdb with all the information for accuracy assessment points
         Citation:
         Hansen, M. and K. Thomas. 2004. Wupatki National Monument: Accuracy Assessment Database. A MS Access database. U.S. Geological Survey.
      2. Metadata-All associated metadata for the spatial data and database
      3. Spatial data- A coverage and shapefile of the accuracy assessment points used in the accuracy assessment analysis
      4. wupa_aa_pts.e00-An Arc/Info export format (.e00) of the accuracy assessment points
         Citation:
         Dale, B., M. Hansen, and K. Thomas. 2004. Accuracy Assessment Points: Wupatki National Monument. A digital spatial database (ArcInfo). U.S. Geological Survey.
   b. Clip_Veg
      1. Metadata- Associated metadata for the spatial data
      2. Spatial data- A coverage and shapefile of the vegetation map clipped to the Wupatki National Monument boundary
      3. wupa_clip_veg.e00-An Arc/Info export format (.e00) of the cover of vegetation map clipped to the Wupatki National Monument boundary
         Citation:
         U.S. Bureau of Reclamation Remote Sensing and GIS Group. 2004. Clipped Vegetation Coverage: Wupatki National Monument. A digital spatial database (ArcInfo). U.S. Geological Survey.

c. Observation_Points

1. Metadata- Associated metadata for the spatial data
2. Spatial data- A coverage and shapefile of the observation points used to help with the photointerpretative work
3. wupa_obs.e00-An Arc/Info export format (.e00) of the observation points collected in the field to help with the photointerpretative work

   Citation:
   U.S. Bureau of Reclamation Remote Sensing and GIS Group. 2004. Observation Point Coverage: Wupatki National Monument. A digital spatial database (ArcInfo). U.S. Geological Survey.

d. Releve_Plots

1. Database- Microsoft access database named WUPA_FieldReleve_database.mdb with all the information collected in the field at each field relevé

   Citation:
   Hansen, M. and K. Thomas. 2004. Wupatki National Monument: Field Relevé Plots. A MS Access database. U.S. Geological Survey.
2. Metadata- Associated metadata for the database and spatial data
3. Spatial data- A coverage and shapefile of the field relevés
4. wupa_releve.e00-An Arc/Info export format (.e00) of the cover of field relevé points sampled in the Wupatki project boundary

   Citation:
   Hansen, M. and K. Thomas. 2004. Field Relevé Plots: Wupatki National Monument Vegetation Mapping Project. A digital spatial database (ArcInfo). U.S. Geological Survey.

f. Vegetation_Map

1. Metadata- Associated metadata for the spatial data
2. Spatial data- A coverage and shapefile of the vegetation map for Wupakti National Monument and the project environs
3. wupa_veg.e00-An Arc/Info export format (.e00) of the cover of the vegetation map coverage

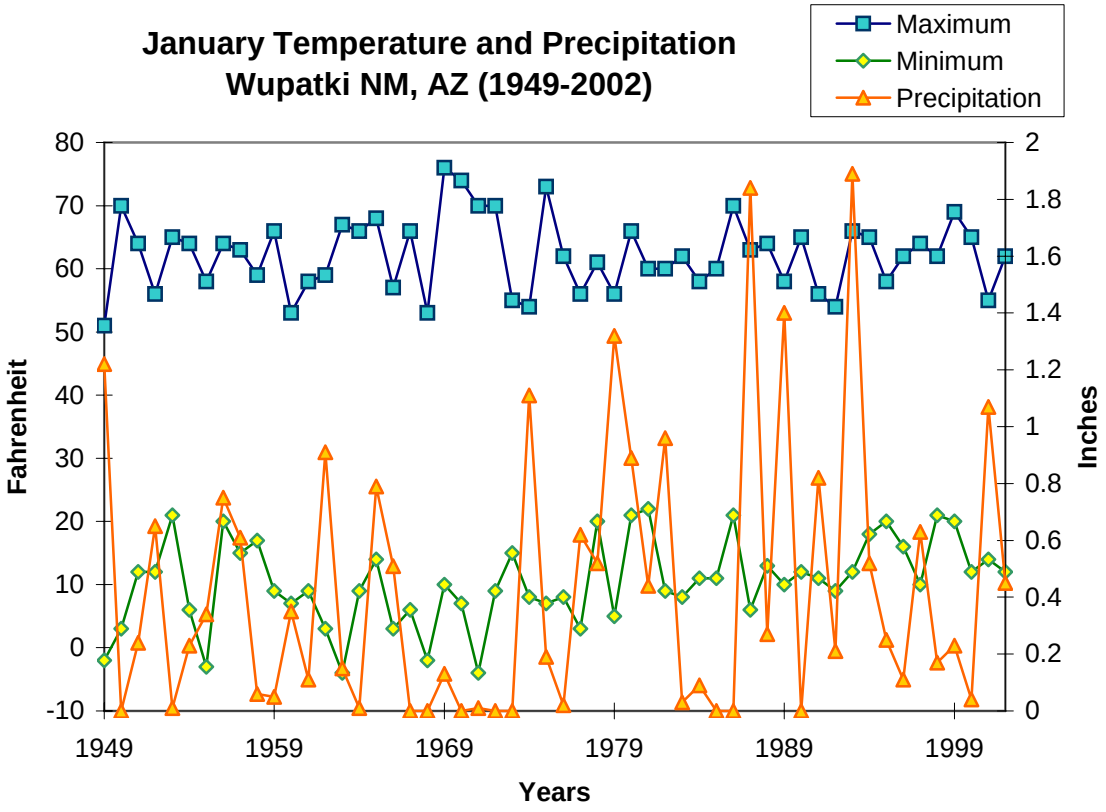
   Citation:
   U.S. Bureau of Reclamation Remote Sensing and GIS Group. 2004. Vegetation Map: Wupatki National Monument. A digital spatial database (ArcInfo). U.S. Geological Survey.

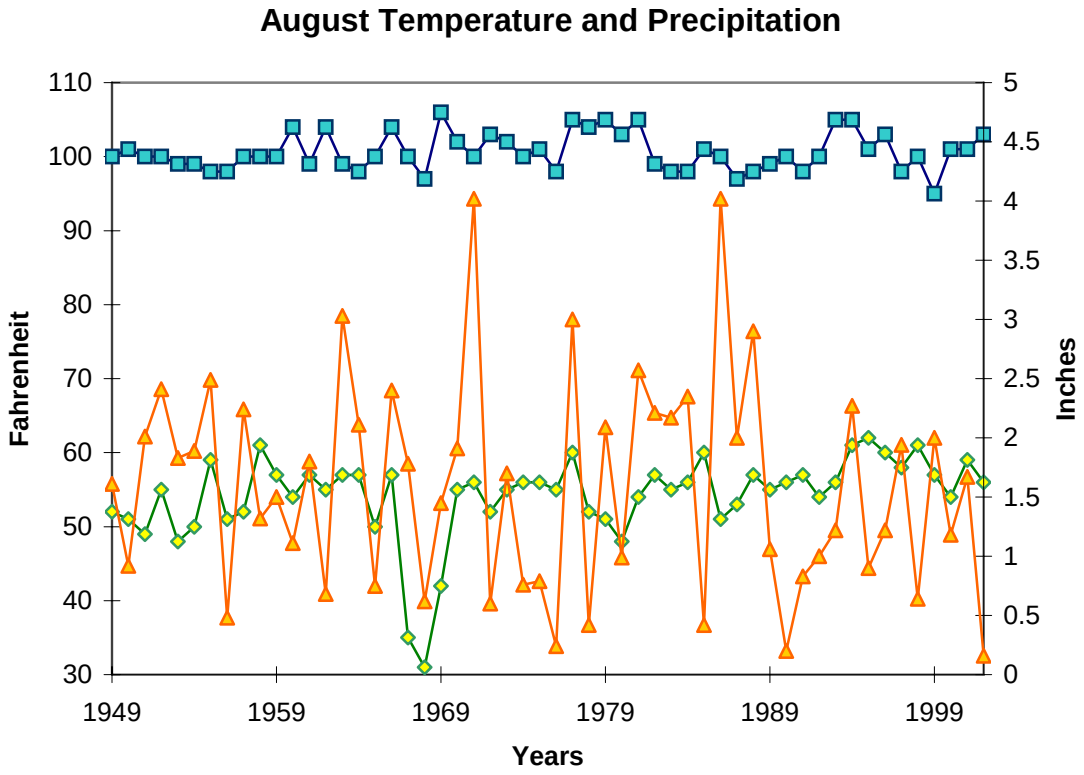
APPENDIX B

B. Precipitation and Temperature Averages for Wupatki National Monument (August and January 1949 –2002)

Precipitation data from http://lwf.ncdc.noaa.gov/oa/ncdc.html
for the Wupatki National Monument reporting station.

Temperature data from www.ncdc.noaa.gov/ol/climate/climatedata.html for the Flagstaff area.

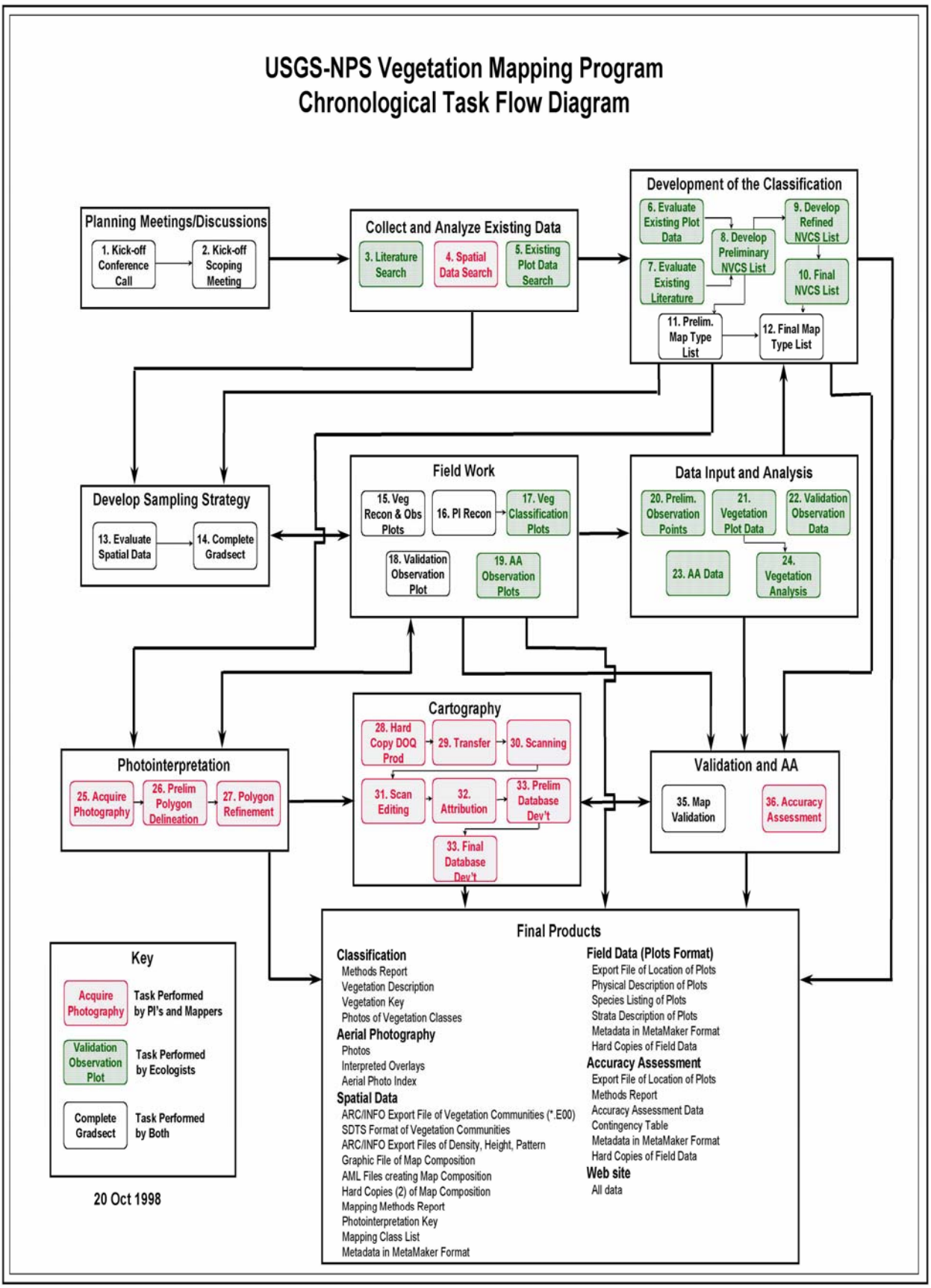

January Temperature and Precipitation
Wupatki NM, AZ (1949-2002)
Maximum
Minimum
Precipitation
Fahrenheit
Inches
Years
80
70
60
50
40
30
20
10
0
-10
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1949
1959
1969
1979
1989
1999


August Temperature and Precipitation
Fahrenheit
Inches
Years
110
100
90
80
70
60
50
40
30
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
1949
1959
1969
1979
1989
1999

APPENDIX C

C. Flowchart of USGS-NPS National Parks Vegetation Mapping Program

(Created by Tom Owens, USGS)


USGS-NPS Vegetation Mapping Program
Chronological Task Flow Diagram
Planning Meetings/Discussions
1. Kick-off Conference Call
2. Kick-off Scoping Meeting
Collect and Analyze Existing Data
3. Literature Search
4. Spatial Data Search
5. Existing Plot Data Search
Development of the Classification
6. Evaluate Existing Plot Data
7. Evaluate Existing Literature
8. Develop Preliminary NVCS List
9. Develop Refined NVCS List
10. Final NVCS List
11. Prelim. Map Type List
12. Final Map Type List
Develop Sampling Strategy
13. Evaluate Spatial Data
14. Complete Gradsect
Field Work
15. Veg Recon & Obs Plots
16. PI Recon
17. Veg Classification Plots
18. Validation Observation Plot
19. AA Observation Plots
Data Input and Analysis
20. Prelim. Observation Points
21. Vegetation Plot Data
22. Validation Observation Data
23. AA Data
24. Vegetation Analysis
Photointerpretation
25. Acquire Photography
26. Prelim Polygon Delineation
27. Polygon Refinement
Cartography
28. Hard Copy DOQ Prod
29. Transfer
30. Scanning
31. Scan Editing
32. Attribution
33. Prelim Database Dev't
33. Final Database Dev't
Validation and AA
35. Map Validation
36. Accuracy Assessment
Key
Acquire Photography
Task Performed by PI's and Mappers
Validation Observation Plot
Task Performed by Ecologists
Complete Gradsect
Task Performed by Both
20 Oct 1998
Final Products
Classification
Methods Report
Vegetation Description
Vegetation Key
Photos of Vegetation Classes
Aerial Photography
Photos
Interpreted Overlays
Aerial Photo Index
Spatial Data
ARC/INFO Export File of Vegetation Communities (*.E00)
SDTS Format of Vegetation Communities
ARC/INFO Export Files of Density, Height, Pattern
Graphic File of Map Composition
AML Files creating Map Composition
Hard Copies (2) of Map Composition
Mapping Methods Report
Photointerpretation Key
Mapping Class List
Metadata in MetaMaker Format
Field Data (Plots Format)
Export File of Location of Plots
Physical Description of Plots
Species Listing of Plots
Strata Description of Plots
Metadata in MetaMaker Format
Hard Copies of Field Data
Accuracy Assessment
Export File of Location of Plots
Methods Report
Accuracy Assessment Data
Contingency Table
Metadata in MetaMaker Format
Hard Copies of Field Data
Web site
All data

APPENDIX D

D. Photointerpretation Observations, Classification Relevés, and Accuracy Assessment Observations Forms

NATIONAL PARK VEGETATION MAPPING PROGRAM: PHOTOINTERPRETATION OBSERVATION FORM

IDENTIFIERS/LOCATORS

Plot Code_____ Polygon Code_____ _____

Provisional Community Name_____

State ___ Park Name _____ Park Site Name _____

Quad Name_____ Quad Code_____

GPS file name_____ Field UTM X___ ___ ___ ___ ___ ___ m E Field UTM Y___ ___ ___ ___ ___ ___ ___ m N
please do not complete the following information when in the field
Corrected UTM X___ ___ ___ ___ ___ ___ m E Corrected UTM Y___ ___ ___ ___ ___ ___ ___ m N UTM Zone____

Survey Date_____ Surveyors_____ _____

ENVIRONMENTAL DESCRIPTION

Elevation _____ Slope _____Aspect_____

Topographic Position

Landform

Cowardin System	Hydrologic Regime		Salinity/Halinity Modifiers
	Non-Tidal		
___Upland	___Permanently Flooded	___Saturated	___Saltwater
___Riverine	___Semipermanently Flooded	___Temporarily Flooded/Saturated	___Brackish
___Palustrine	___Seasonally Flooded	___Intermittently Flooded	___Freshwater
___Lacustrine			

Environmental Comments:	Unvegetated Surface: *(please use the cover scale below)*
	___ Bedrock __ Litter, duff ___ Wood (> 1 cm)
	___ Large rocks (cobbles, boulders > 10 cm)
	___ Small rocks (gravel, 0.2-10 cm)
	___ Sand (0.1-2 mm) ___ Bare soil
	___ Other:_____

VEGETATION DESCRIPTION

Leaf phenology (of dominant stratum)	Leaf Type (of dominant stratum)	Physiognomic class	Cover Scale for Strata & Unvegetated Surface		Height Scale for Strata	
<u>Trees and Shrubs</u> ___Evergreen ___Cold-deciduous ___Drought-deciduous ___Mixed evergreen - cold-deciduous ___Mixed evergreen - drought-deciduous <u>Herbs</u> ___Annual ___Perennial	___Broad-leaved ___Needle-leaved ___Mixed broad-leaved/Needle leaved ___Microphyllous ___Graminoid ___Forb ___Pteridophyte	___Forest ___Woodland ___Shrubland ___Dwarf Shrubland ___Herbaceous ___Nonvascular ___Sparsely Vegetated	01	5%	01	<0.5 m
			02	10%	02	0.5-1m
			03	20%	03	1-2 m
			04	30%	04	2-5 m
			05	40%	05	5-10 m
			06	50%	06	10-15 m
			07	60%	07	15-20 m
			08	70%	08	20-35 m
			09	80%	09	35 - 50 m
			10	90%	10	>50 m
			11	100%		

Strata	Height	Cover Class	Dominant species (mark any known diagnostic species with a *)	Cover Class
T1 Emergent	_____		_____	
T2 Canopy	_____		_____	
T3 Sub-canopy	_____		_____	
S1 Tall shrub	_____		_____ _____	
S2 Short Shrub	_____		_____	
S3 Dwarf-shrub	_____		_____	
H Herbaceous	_____		_____	
N Non-vascular	_____		_____	

V Vine/liana _____ _____

_____

E Epiphyte _____ _____

_____

please see the table on the previous page for height and cover scales for strata

Other Comments

Cover Scale for Species

01 <1%
02 1-5%
03 5-25%
04 25-50%
05 50-75%
06 75-100%

CLASSIFICATION RELEVÉ FORM

SURVEY AND SITE INFORMATION

Park Name:_____ Date:_____
Surveyors_____

Plot Code_____
Provisional Alliance/Association Name_____

Zone 12 **Datum NAD 83**
USGS Quad_____ 7.5 or 15' Environ-Code_____

Air Photo #_____ Polygon Code_____
UTM E_____m UTM N_____m Way Point _____ Error =+/-_____
Landowner(check one):NPS___ Forest Service ___ Private(owner if known) _____
State Lands: Game and Fish ____.

Plot length_____ m Plot width_____ m Plot Shape: (square, rectangle, triangle, circle)
Circle Diameter=35.6m for 1000m^2, Diameter=25.2 for 500m^2
Directions to Plot_____
_____
_____

Plot Photos (Y/N)_____ Roll #_____ Frame #_____ Direction_____
Date_____ Time_____

ENVIRONMENTAL DESCRIPTION

Elevation_____ (m.) Slope_____ % Aspect_____

Topographic position:_____Landform:_____Rock/Sediment Composition_____(enter number from Code Sheet)

Community Type:_____ (Wetland (W) or Upland (U) (if W then:)

Cowardian System:
__Estuarine
__Riverine
__Palustrine
__Laustrine

Hydrologic Modifiers:
__Semi-permanently Flooded
__Seasonally Flooded
__Saturated
__Temporarily Flooded
__Intermittently Flooded
__Permanently Flooded
__Permanently Flooded-tidal
__Tidally Flooded
__Artificially Flooded

Salinity/Halinity Modifiers:
__Saltwater
__Brackish
__Freshwater

VEGETATION DESCRIPTION
Vegetation Group:_____(from the three columns below**)**

Leaf phenology:	**Leaf Type:**	**Physiognomic class:**
Trees and Shrubs	1__Broad-leaved	1__Forest
1__Evergreen	2__Needle-leaved	2__Woodland
2__Cold-deciduous	3__Microphyllous	3__Shrubland
3__Drought-deciduous	4__Graminoid	4__Dwarf shrubland
4__Mixed evergreen-cold-deciduous	5__Broad-leaved herbaceous	5__Herbaceous (grassland and forb)
5__Mixed evergreen drought-deciduous	6__Pteridophyte	6__Nonvascular
Herbs	7__Mixed broad and needle-leaved	7 _Sparsely vegetated
		8_Steppe
6__Annual	8__Extremely xeromorphic	
7__Perennial	9__Hydromorphic	

Additional Comments:

3 Flagstaff Park's Vegetation Mapping Field Form

Plot #_____ Date:_____

Cover Class Intervals: 1(<1%), 2(1-5%), 3(>5-10%), 4(>10-25%), 5(>25-50%), 6(50-75%), 7(>75%)
G=Ground(<0.5m), S-Shrub(0.5-3.0m), T-Tree(>3.0m)

Layer

G	S	T	Vascular plant name	Final determination	Cover Class	%

(Fill data only once per field plot!)
Total Vegetation Cover(Class):_____Total Tree_____Total Shrub_____Total Ground_____Total Non-native_____
% _____ _____ _____ _____

Cover Scale for Strata, Sensitive Species, Exotics, Biotic Surfaces and Unvegetated Surface:

01	<1%	03	>5-10%	05	>25-50%	07	>75%
02	>1-5%	04	>10-25%	06	>50-75		

Unvegetated Surface	Bare Soil	Sand (0.1-2mm)	Gravel (2mm-6.4cm)	Cobble (6.4-19cm)	Stone (>19-61cm)	Boulder (>61 cm)	Bedrock	Litter, duff	Biotic Crust (cryptograms, moss, lichens)
Cover Class									

Environmental Comments:

Soil Taxon/Description:

Strata	Moss/Lichen	0-25cm	25-50cm	0.5-1m	1-3m	3-5m	5-10m	10-20m	20-30m	>30m
Cover Class										

Sensitive Species:

Genus	Species	% Cover	Cover Class

Exotic Species:

Genus	Species	% Cover	Cover Class

DBH Table

Species	Diameter	Species	Diameter

3-Flagstaff Park's Code Sheet for Classification Relevés

MACRO TOPOGRAPH

00	INTERFLUVE(crest, summit, ridge): linear top of ridge, hill, or mountain; elevated area between two fluves
01	HIGH SLOPE(shoulder slope, upper slope, convex creep slope): the top of a slope, convex
02	HIGH LEVEL(mesa): top of plateau
03	MIDSLOPE(transportational midslope, middle slope): intermediate slope
04	BACKSLOPE(dipslope): subset of midslopes which are steep, linear, and cliff segments
05	STEP IN SLOPE(ledge, terracetee): nearly level shelf interrupting a steep slope, rock wall, or clifffface
06	LOWSLOPE(lower slope, foot slope, colluvial footslope): inner gently inclined surface at the base of a slope, concave
07	TOESLOPE(alluvial toeslope): outermost gently inclined surface at base of slope, commonly gentle and linear
08	LOW LEVEL(terrace): valley floor or shoreline representing the former position of an alluvial plain, lake or shore
09	CHANNEL WALL(bank): sloping side of a channel
10	CHANNEL BED(narrow valley bottom, gully arroyo): bed of single or braided watercourse commonly barren of vegetation
11	BASIN FLOOR(depression): nearly level to gently sloping, bottom surface of a basin

LANDFORM

20 **Rockpile**=uplands composed primarily of jointed and efoliating granitic outcrops
21 **Bajada**=alluvial slopes of fans that accumulate at the base of a desert mountain or mountain canyons that are interrupted by the trenching of minor water sources
22 **Drainage Channel**=bottom not side slope of a drainage confined by banks or a canyon
23 **Valley Bottom Fill**=usually level places
24 **Playa**=Pleistocene dried lakebed often with some surface water
25 **Side Slope**=side of drainage channels
26 **Lower Slope**=lower better watered portion of a slope
27 **Mid Slope**=central portion of a slope
28 **Upper Slope**=the upper driest portion of a slope
29 **Interfluve**=the area between small drainage channels
30 **Ridge**=high ground between two opposing slopes
31 **Slick Rock**=large exposed expanses of bedrock
32 **Terrac**e=level or gently sloping shelf perched on a slope, often caused by down-cutting rivers
33 **Mesa**=level or gently sloping ground surrounded on 3 or more sides by steep down slopes and capped
34 **Butte**=similar to a mesa, except with a top that does not have a flat configuration
35 **Cliff**=very steep rock slopes
36 **Talus**=unsorted material resulting from mass wasting of steep mountain slopes
37 **Sand Dune/Sand Sheet**=large accumulations of sand, may be stable or unstable (moving)
38 **Plains**=any flat, lowland area, large or small, at a low elevation.
39 **Plateau**=flat area of great extent and elevation; specifically an extensive land region considerably elevated (more than 100 meters) above adjacent lower-lying terrain

Cowardin System:	**Hydrologic Modifiers:**	
Estuarine=includes deepwater tidal and tidal wetlands	Semi-permanently Flooded=surface water persists throughout the growing season	Intermittently Flooded=substrate is usually exposed, but surface water can be present for variable periods
Riverine=includes all wetlands and deepwater habitats contained within a channel, excluding wetlands dominated by vegetation	Seasonally Flooded=surface water is present for the majority of the growing season except for the end	Permanently Flooded=water covers the land surface at all times of the year in all years
Palustrine=includes all nontidal wetlands dominated by vegetation	Saturated=surface water is seldom present, but is saturated to surface for extended period	Permanently Flooded-Tidal/Tidally Flooded= not present in this area
Laustrine =includes all wetlands and deepwater habitats in a topo depression, lacking vegetation, and area exceeds 20 ac (8 ha)	Temporarily Flooded=surface water present for brief periods during the growing season	Artificially Flooded=amount and duration of flooding is controlled by means of pumps or siphons with dams or dikes, leakage resulting from man-made impoundment

Leaf penology:	**Leaf Type: (more than 50%)**	**Physiognomic class:**
Trees and Shrubs	1__Broad-leaved	1 Forest=trees with crowns overlapping (60-100%)
1__Evergreen=75% is never without green foliage	2__Needle-leaved	2__Woodland=trees with crowns not touching (25-60%), trees may be <25% where exceeds shrubs, herb and non-vascular cover
2__Cold-deciduous=75% sheds foliage due to winter frost	3__Microphyllous	3__Shrubland=shrubs generally greater than .5m, clumps overlapping/touching, shrubs may be <25% where it exceeds all other veg. types
3__Drought-deciduous=75% sheds foliage due to drought	4__Graminoid	4__Dwarf shrubland=shrubs <.5m, clumps overlapping/not touching, dwarfshrubs may be <25% where it exceeds all other veg. types
4__Mixed evergreen-cold-deciduous=25-75% of both mixed	5__Broad-leaved herbaceous	5__Herbaceous (grassland and forb)=herbs dominant, may be <25% when dominant
5__Mixed evergreen drought-deciduous=25-75% of both admixed	6__Pteridophyte	6__Nonvascular=bryophytes, lichens, algae
6_Perennial-herbaceous vegetation composed of more than 50% perennial species	7__Mixed broad and needle-leaved	7__Sparsely vegetated=abiotic substrate dominant, veg. cover <25%
7_Annual-herbaceous vegetation composed of more than 50% annual species	8__Extremely xeromorphic	
	9__Hydromorphic	

ROCK/SEDIMENT COMPOSITION

50 Basaltic
51 Lava Flow
52 Black Cinders
53 Red Cinders
54 Sandy Loam
55 Sand
56 Sandstone
57 Limestone
58 Clay
59 Badland Clay
60 Pleistocene Riverine Cobbles

ACCURACY ASSESSMENT OBSERVATION FORM

SURVEY AND SITE INFORMATION

Park Name:_____ Date:_____
Surveyors_____ Plot Code_____

Zone 12 **Datum NAD 83**
USGS Quad_____ 7.5
UTM E_____ UTM N_____ Way Point_____
Error =+/-_____ Elevation _____(m)

PLEASE CIRCLE CLOSEST MAP CLASS REPRESENTING SITE:

Vegetation
Apache Plume Cinder Shrubland
Basalt Outcrop Shrubland
Black Grama Coconino Plateau Shrubland
Black Grama Grassland
Crinklemat / Alkali Sacaton Dwarf Shrubland
Crispleaf Buckwheat Cinder Shrubland
Fremont's Cottonwood Woodland
Frosted Mint Shrubland
Galleta Grassland
Galleta Mixed Grasslands
Galleta Mixed Shrublands
Little Colorado River Invasive Riparian Shrubland
Moenkopi Sandstone Sparse Vegetation
Moenkopi Shale Sparse Vegetation
Mormon Tea Cinder Dune Shrubland
Needle-and-Thread Grassland
Mound Saltbush Badlands Sparse Vegetation
One-seed Juniper Cinder Woodland
Rabbitbrush Shrubland
Sand Sagebrush Shrubland
Sandbar Willow Shrubland
Snakeweed / Galleta Grassland
Unclassified Mixed Shrubland
Wupatki Wash System

Land Use
Commercial Development
Corrals
Quarries and Gravel Pits
Park Facilities
Stock Ponds and Tanks
Rural Residential Development
Transportation Route

Geomorphology
Cinder Barren
Active River Channel

PLEASE ALSO CIRLCLE IF THE MODIFIER OR PARK SPECIAL ALSO CHARACTERIZES THE SITE:

Modifiers
Communication/Utility Corridor
Prairie Dog Colony

Park Special
Sand Bluestem Grassland
Fourwing Saltbush Upland Drainageways

CONFIDENCE: Exact Good (Some problems) Poor None that fit
Please list other map classes that were identified within the polygon_____
_____

Please explain all reasons for Good, Poor or None Confidence

PLEASE CIRCLE CLOSEST ASSOCIATION/ALLIANCE REPRESENTING SITE:

Alhagi maurorum Semi-natural Shrubland	*Eriogonum corymbosum* Cinder Sparse Vegetation
Andropogon hallii Colorado Plateau Herbaceous Vegetation	*Fallugia paradoxa – (Atriplex canescens – Ephedra torreyana*) Cinder Shrubland
Artemisia filifolia – Ephedra spp. Shrubland	*Gutierrezia sarothrae* Dwarf Shrub Alliance
Atriplex canescens – (*Ephedra viridis/ Muhlenbergia porteri*) Sandstone Sparse Vegetation	*Gutierrezia sarothrae / Pleuraphis jamesii – (Sporobolus airoides*) Shrub Herbaceous Vegetation
Atriplex canescens – Sporobolus airoides Shrubland	*Hesperostipa comata – (Bouteloua eriopoda-Pleuraphis jamesii*) Herbaceous Vegetation
Atriplex canescens Desert Wash Shrubland (Provisional)	*Juniperus monosperma* Cinder Wooded Herbaceous Vegetation
Atriplex obovata Badland Sparse Vegetation	*Pleuraphis jamesii – Sporobolus airoides* Herbaceous Vegetation
Bouteloua eriopoda - Pleuraphis jamesii Herbaceous Vegetation	*Pleuraphis jamesii* Herbaceous Vegetation
Bouteloua eriopoda Coconino Plateau Shrub Herbaceous Vegetation	*Pleuraphis jamesii* Shrub Herbaceous Alliance
Bouteloua eriopoda Herbaceous Vegetation	*Poliomintha incana*/ *Pleuraphis jamesii* Shrubland
Brickellia californica – Rhus trilobata Shrubland	*Populus fremontii / Salix exigua* Temporarily Flooded Woodland
Ephedra torreyana – (Atriplex canescens, confertifolia) Sparse Vegetation	*Salix exigua* / Barren Shrubland
Ephedra torreyana – Achnatherum hymenoides Hummock Shrubland	*Sporobolus airoides* Herbaceous Vegetation
Ericameria nauseosa / Pleuraphis jamesii – (Hesperostipa comata) Shrub Herbaceous Vegetation	*Tamarix* spp. Temporarily Flooded Shrubland
	Tiquilia latior / Sporobolus airoides Dwarf Shrubland

CONFIDENCE: Exact Good (Some problems) Poor None that fit
Please list other associations that were identified within the polygon_____

_____

Please explain all reasons for Good, Poor or None Confidence

APPENDIX E

E. Field Key for the Wupatki National Monument Vegetation Community Descriptions and Map Classes

How to Use this Key---

On the following pages, associations, alliances, and/or map classes are arranged in dichotomous couplets with corresponding field descriptions of the associations, alliances, and/or map classes. Starting with "1.1" read the statements and choose the best fit subheading that is demarked by bold and capital letters such as "1.a **LAND USES**". Follow this subheading to "1.a.1" and continue to follow the key to select the "best fit" association occurring at the bottom of the description demarked by italicized species names such as "*Ephedra torreyana – Achnatherum hymenoides* Hummock Shrubland" and map classes demarked by bolded lower case letters such as "**Mormon Tea Cinder Dune Shrubland**". In some cases it may be necessary to read through several couplets before reaching the best answer.

In many cases, the map classes and the vegetation associations do not have 100% correspondence. This may be due to difficultly in photointerpretation of the vegetation class and/or high variability in the vegetation community. If the map class consists of a group of associations or alliances, the map class will appear twice in the key because two separate vegetation descriptions represent the same map class. In other cases, the association description located in Appendix F will not match the map class description in which the association occurs due to differences in the ability to photointerpret the photosignature and the vegetation descriptions for the association as standardized by NatureServe. However, the key will lead you to the correct map class; but, it may be possible that it will not lead to the same association defining characteristics depending on the range of variability in the vegetation descriptions. For a full description of each association please read Appendix F. It is important when using this key that the vegetation types are surveyed larger or equal to the minimum mapping unit (≥ 0.5 ha). If smaller scales are used it is likely that the community types will not correspond with the map classes or vegetation descriptions recorded in the key.

Sites characterized by land uses, non-vegetated areas, substrate, or exotic invasive species:

1.a Land use (human infrastructure) or prairie dog colonies **LAND USES (1.a.1)**
1.b No or sparse vegetation (< 5%) **UNVEGETATED (1.b.1)**
1.c Diagnostic substrate characterized by cinder, basalt, river cobbles, sand dunes, sandstone, or badlands with vegetation ranging from sparse to low vegetation (2-20%) **SUBSTRATE (1.c.1)**
1.d Dominance of an invasive species (saltcedar, Russian thistle, camel thorn) **EXOTIC INVASIVE SPECIES (1.d.1)**

Sites not characterized by land uses, non-vegetated areas, substrate, or exotic invasive species:

2.1 Vegetation cover generally greater than 10% and herbs and grasses the dominant lifeform. (Or vegetation has a 'steppe-like' expression with shrub cover occasionally higher or equal in cover to the herbaceous species. In these cases shrub cover must be less than two times the herbaceous cover.)
- 2.a Shrub cover less than 10% **HERBACEOUS VEGETATION**
- 2.b Shrub cover greater than 10% and is 'steppe-like' in its expression **SHRUB HERBACEOUS VEGETATION**

3.1 Vegetation cover generally greater than 10% with shrub or dwarf-shrub cover greater than 10% and the dominant lifeform
SHRUBLAND

4.1 Vegetation cover generally greater than 10% with tree cover greater than 10% (trees includes large shrubs such as saltcedar and one-seed juniper that may be treated elsewhere as shrubs)
WOODLAND

LAND USES

1.a.1 Site characterized by land use
1. **Commercial Development**
2. **Corrals**
3. **Strip Mines, Quarries and Gravel Pits**
4. **Facilities**
5. **Residential Land**
6. **Stock Tanks and Dams**
7. **Transportation Route (paved roads)**

(if dirt roads or tracks, continue key to vegetation association)

UNVEGETATED

1.b.1 Site characterized by a diagnostic substrate.
1. **Cinder Barren**
2. Sandstone, shale, basalt, or other diagnostic substrate continue key to **SUBSTRATE** (1.c.1)

1.b.1 Site characterized by river channel. **Active River Channel**

SUBSTRATE

1.c.1 Sites characterized by cinder. (1.c.4)
1.c.1 Sites characterized by other geologic substrates. (1.c.2)

1.c.2 Sites characterized by basalt. (1.c.7)
1.c.2 Sites characterized by other geologic substrates. (1.c.3)

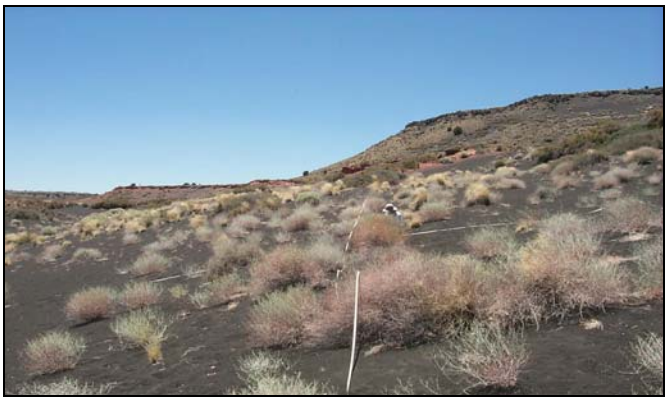
1.c.3 Sites characterized by sandstone or sand dunes. (1.c.8)
1.c.3 Sites characterized by badlands or river cobbles. (1.c.9)

1.c.4 Sites characterized by dunes/hummocks often with Torrey's joint-fir or Apache plume dominant or co-dominant shrubs. *Ephedra torreyana – Achnatherum hymenoides* Hummock Shrubland (see picture below).
(MAP CLASS: **Mormon Tea Cinder Dune Shrubland**)

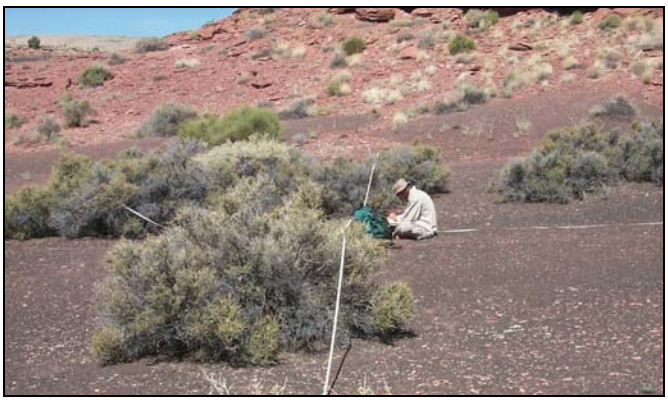
1.c.4 Sites characterized by flat areas or slopes. (1.c.5)

1.c.5 Sites dominated by shrubs other than oneseed juniper. (1.c.6)
1.c.5 Sites dominated by oneseed juniper with sparse to moderate cover. Grasses such as black grama and galleta may be present depending on cinder dept. Locally grasses may have higher cover than oneseed juniper but vegetation is characterized by overall presence of oneseed juniper on cinder. *Juniperus monosperma* Cinder Wooded Herbaceous Vegetation (see picture below).
(MAP CLASS: **Oneseed Juniper Woodland**)

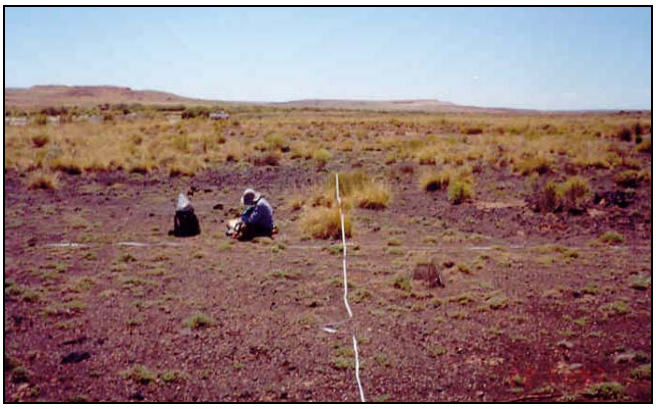
1.c.6 Crispleaf buckwheat is an indicator for this type. Apache plume, brickelbush, and other shrubs may be present at higher cover; however, crispleaf buckwheat must be present with at least 2% absolute cover on cinder. *Eriogonum corymbosum* Cinder Sparse Vegetation (see picture below). (MAP CLASS: **Crispleaf Buckwheat Cinder Shrubland**)



1.c.6 Apache Plume is the characteristic dominant species although rabbitbrush, fourwing saltbush, or Torrey's joint-fir may dominate in smaller patches. Occurs on black and red cinder substrate. *Fallugia paradoxa – (Atriplex canescens – Ephedra torreyana)* Cinder Shrubland (see picture below).
(MAP CLASS: **Apache Plume Cinder Shrubland** or MAP CLASS: **Wupatki Wash System** (if occurring in washes))



1.c.7 Sites characterized by basalt pebble/cobble plains near the Little Colorado River. Crinklemat is an indicator for this type with the grass alkali sacaton often occurring in these areas. *Tiquilia latior / Sporobolus airoides* Dwarf-Shrubland (see picture below).
(MAP CLASS: **Crinklemat / Alkali Sacaton Dwarf Shrubland**)



1.c.7 Sites characterized by basalt outcrops, sometimes containing brickelbush or skunkbush. *Brickellia californica – Rhus trilobata* Shrubland (see picture below).
(MAP CLASS: **Basalt Outcrop Shrubland**)

1.c.8 Sites characterized by sandstone bluffs and outcrops. Vegetation often includes shrubs such as fourwing saltbush, Mormon tea, and snakeweed and sometimes the bush Muhly grass. *Atriplex canescens – (Ephedra viridis) / (Muhlenbergia porteri)* Sandstone Sparse Vegetation (see picture below).
(MAP CLASS: **Moenkopi Sandstone Sparse Vegetation**)

1.c.8 Sites dominated by sand dunes and sand sheets. Frosted mint is an indicator for this type although shrubs such as Whiting's dalea, snakeweed, or sand sagebrush may occur in higher abundance. Galleta grass is often present in this type. *Poliomintha incana – (Pleuraphis jamesii)* Shrubland (see picture below).
(MAP CLASS: **Frosted Mint Shrubland**)

1.c.9 Sites characterized by clay badland soils. Vegetation is sparse to low with either mound saltbush or Russian thistle present often even in very low cover. Since Russian thistle is an annual its presence could be masked due to seasonal variation. *Atriplex obovata* Badland Sparse Vegetation (see picture below).
(MAP CLASS: **Mound Saltbush Badlands Sparse Vegetation**)

1.c.9 Sites characterized by Moenkopi shale badlands or areas with Pleistocene river cobbles. Basalt, clay, and sandstone soils may occur in smaller patches in this type. Torrey's joint-fir is an indicator for this type and is always present even at very low cover (<1%). Other shrubs may occur in higher cover such as fourwing saltbush, shadscale, and crispleaf buckwheat. In areas where Pleistocene river cobbles dominant the substrate, grass cover may occasionally be >10% with black grama, three-awn, or galleta dominating. *Ephedra torreyana – (Atriplex canescens, confertifolia)* Sparse Vegetation (see picture below).
(MAP CLASS: **Moenkopi Shale Sparse Vegetation**)

EXOTIC INVASIVE SPECIES

1.d.1 Dominant species is saltcedar and/or camel thorn and often forms monocultures with >90% of the total tree and/or shrub cover. *Tamarix spp.* Temporarily Flooded Shrubland or *Alhagi maurorum* Semi-natural Shrubland (see picture below).
(MAP CLASS: **Little Colorado River Invasive Riparian Shrubland**)

1.d.1 Dominant species may be Russian thistle depending on its seasonal variation due to its annual lifeform. Mound saltbush is an indicator for this type and must be present in very low cover. *Atriplex obovata* Badland Sparse Vegetation (see picture below).
(MAP CLASS: **Mound Saltbush Badlands Sparse Vegetation**)

HERBACEOUS VEGETATION

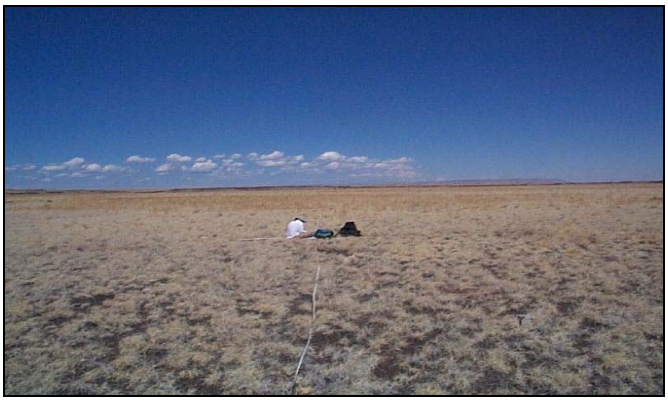
2.a.1 Sand bluestem is the dominant grass (>50% of total herbaceous cover) and often occurs in small patches (<0.5 ha). *Andropogon hallii* Colorado Plateau Herbaceous Vegetation (see picture below).
(MAP CLASS: **Sand Bluestem Grassland**)

2.a.1 Dominant grass not as above. (2.a.2)

2.a.2 Galleta is dominant (>50% of total herbaceous cover) or co-dominant (>25% of total herbaceous cover). (2.a.3)

2.a.2 Dominant grass not as above. (2.a.6)

2.a.3 Galleta >50% of total herbaceous cover. *Pleuraphis jamesii* Herbaceous Vegetation (see picture below).
(MAP CLASS: **Galleta Grassland**)



2.a.3 Presence >25% of the total herbaceous cover other herbaceous species. (2.a.4)

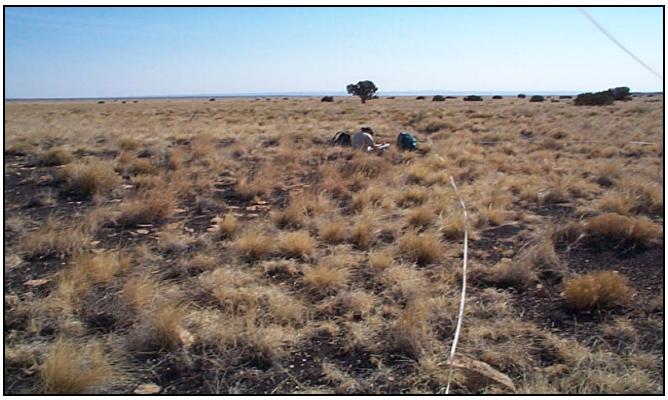
2.a.4 Alkali sacaton is the main other herbaceous species and may have greater cover than galleta. *Pleuraphis jamesii-Sporobolus airoides* Herbaceous Vegetation (see picture below).

(MAP CLASS: **Galleta Mixed Grasslands**)

2.a.4 Other main herbaceous species not as above. (2.a.5)

2.a.5 Black grama is the main other herbaceous species. *Bouteloua eriopoda-Pleuraphis jamesii* Herbaceous Vegetation (see picture below).
(MAP CLASS: **Galleta Mixed Grasslands**)

2.a.5 Needle-and-thread is the main other herbaceous species. *Hesperostipa comata-(Bouteloua eriopoda-Pleuraphis jamesii)* Herbaceous Vegetation (see picture below).
(MAP CLASS: **Needle-and-Thread Grassland**)



2.a.6 Alkali sacaton is the dominant grass (>50% of total herbaceous cover). This type occurs in washes and upland areas with frequent occurrence of sheetflow as evidenced by areas where water flows seasonally over gentle to low-slope areas to form an eroded open fan-like pattern of low gradient channels. *Sporobolus airoides* Herbaceous Vegetation (see picture below).
(MAP CLASS: **Wupatki Wash System**)

2.a.6 Dominant grass not as above. (2.a.7)

2.a.7 Black grama is the dominant grass (>50% of total herbaceous cover). *Bouteloua eriopoda* Coconino Plateau Shrub Herbaceous Vegetation (no picture available; this map class was defined only through the aerial photography interpretation).
(MAP CLASS: **Black Grama Grassland**)

2.a.7 Needle-and-thread is the dominant grass (>50% of total herbaceous cover). *Hesperostipa comata-(Bouteloua eriopoda-Pleuraphis jamesii)* Herbaceous Vegetation (see picture below).
(MAP CLASS: **Needle-and-Thread Grassland**)

SHRUB HERBACEOUS VEGETATION

2.b.1 Black grama is the dominant grass and shrub cover may include, but is not limited to shadscale, fourwing saltbush, rabbitbrush, Mormon tea or snakeweed. *Bouteloua eriopoda* Coconino Plateau Shrub Herbaceous Vegetation (see picture below).
(MAP CLASS: **Black Grama Coconino Plateau Mixed Shrubland**)

2.b.1 Dominant grass not as above. (2.b.2)

2.b.2 Alkali sacaton is the dominant grass and shrubs such as Mormon tea, salt bush, and snakeweed may be present. This type occurs in washes or sheetflow runoff areas (as evidenced by areas where water flows seasonally over gentle to low-slope areas to form an eroded open fan-like pattern of low gradient channels). *Sporobolus airoides* Herbaceous Vegetation (see picture below).
(MAP CLASS: **Wupatki Wash System**)

2.b.2 Galleta is the dominant grass or is co-dominated by alkali sacaton. (2.b.3)

2.b.3 Galleta is the dominant grass and rabbitbrush is the dominant shrub. Shadscale in smaller areas may also occasionally be the dominant shrub with galleta as the dominant grass. Needle-and-thread grass can be present, but with low cover. *Ericameria nauseosa / Pleuraphis jamesii – (Hesperostipa comata)* Shrub Herbaceous Vegetation (see picture below).
(MAP CLASS: **Rabbitbrush Shrubland**)

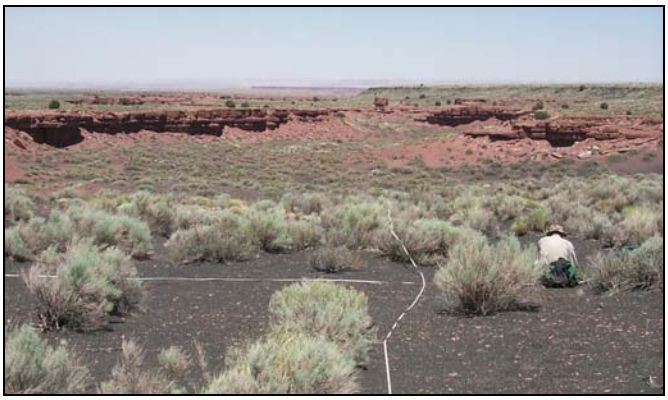
2.b.3 Rabbitbrush is not the dominant shrub. (2.b.4)

2.b.4 Galleta is the dominant grass and alkali sacaton may occur and be equally co-dominant. Snakeweed is the dominant shrub. *Gutierrezia sarothrae / Sporobolus airoides – (Pleuraphis jamesii)* Shrub Herbaceous Vegetation (see picture below).
(MAP CLASS: **Snakeweed / Galleta Grassland**)

2.b.4 Dominant shrubs not as above and may include species like Mormon tea, wolf berry, or fourwing saltbush. *Pleuraphis jamesii* Shrub Herbaceous Alliance (see picture below). (MAP CLASS: **Galleta Mixed Shrublands**)

SHRUBLANDS

3.1.Sand sagebrush is an indicator for this type and may also be dominant must always be present even in very low cover. Other shrubs may be more dominant including Torrey's joint-fir, Mormon tea, fourwing saltbush, or rabbitbrush, and at least one of these other shrubs must be present to be classified as this type. *Artemisia filifolia – Ephedra (torreyana, viridis)* Shrubland (see picture below).
(MAP CLASS: **Sand Sagebrush Shrubland** or MAP CLASS: **Wupatki Wash System** (if occurring in washes))



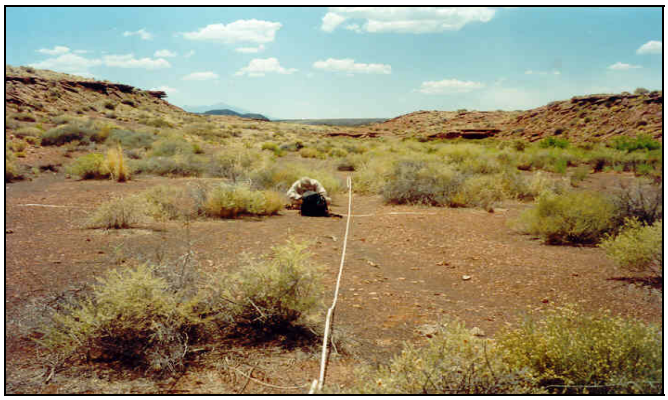
3.1. Dominant shrub not sand sagebrush or combination of above species. (3.2.)

3.2. Dominant shrub fourwing saltbush. Occurring in washes, floodplains, or upland drainageway areas as evidenced by areas with seasonal water flow that lacks a defined channel. (3.3.)

3.2.Dominant shrub not as above. (3.4)

3.3 Alkali sacaton is the characteristic grass. *Atriplex canescens / Sporobolus airoides* Shrubland (see picture below).
(MAP CLASS: **Wupatki Wash System**)

3.3. Dominant grass not alkali sacaton. *Atriplex canescens* Desert Wash Shrubland (Provisional) (see picture below).
(MAP CLASS: **Wupatki Wash System** (circle if occurring in washes) or **Fourwing Saltbush Upland Drainageways** (circle if occurring in upland drainageway areas))



3.4 Dominant shrub Apache plume and/or rabbitbrush, often occurring in deep cinder soils. *Fallugia paradoxa – (Atriplex canescens – Ephedra torreyana)* Cinder Shrubland (see picture below).
(MAP CLASS: **Apache Plume Cinder Shrubland**)

3.4. Dominant shrubs not as above. (3.5.)

3.5.Dominant shrubs skunkbush, desert olive, or brickelbush, and occurring on basalt outcrops. *Brickellia californica – Rhus trilobata* Shrubland (see picture below).
(MAP CLASS: **Basalt Outcrop Shrubland**)

3.5. Dominant shrubs not as above.

3.6. Occurring in washes or in the Little Colorado River Corridor. (3.7.)
3.6. Dominant shrubs not as above. (3.8.)

3.7. Sandbar willow dominant or co-dominant. *Salix exigua* / Barren Shrubland (see picture below).
(MAP CLASS: **Sandbar Willow Shrubland**)

3.7. Camelthorn dominant or co-dominant. *Alhagi maurorum* Semi-natural Shrubland (see picture below).
(MAP CLASS: **Little Colorado River Invasive Riparian Shrubland**)

3.8. Snakeweed dominant with twice as much cover as the herbaceous species. *Gutierrezia sarothrae* Dwarf-Shrub Alliance (see picture below).
(MAP CLASS: **Snakeweed / Galleta Grassland**)

Dominant shrubs not as above. Unclassified Mixed Shrubland (no picture available; this map class was defined only through the aerial photography interpretation).
(MAP CLASS: **Unclassified Mixed Shrubland**)

WOODLANDS

4.1. One-seed juniper dominates the woody layer with sparse to moderate cover. Grasses such as black grama and galleta may be present depending on the cinder depth. Locally grasses may have higher cover than oneseed juniper, but the vegetation is characterized by overall presence of oneseed juniper on cinder. *Juniperus monosperma* Cinder Wooded Herbaceous Vegetation (see picture below).
(MAP CLASS: **Oneseed Juniper Cinder Woodland**)

4.1. Sites occurring the in washes or in the Little Colorado River corridor. (4.2.)

4.2. Fremont's cottonwood is the dominant tree. Sandbar willow occurs in the understory and is an indicator to the association. The non-native exotic saltcedar may occur up to 15% of the total cover. *Populus fremontii / Salix exigua* Forest (see picture below).
(MAP CLASS: **Fremont Cottonwood Woodland**)

4.2. Saltcedar is dominant (>90% of the total tree cover) and forms a monoculture with no other tree or shrub species co-dominating. *Tamarix spp.* Temporarily Flooded Shrubland (see picture below).
(MAP CLASS: **Little Colorado River Invasive Riparian Shrubland**)

APPENDIX F

F. National Vegetation Classification (NVC) Local and Global Descriptions for Wupatki National Monument

(Kathryn Thomas and Monica Hansen of the USGS Colorado Plateau Research Station collected, analyzed, and initially classified field relevé data. Marion Reid and Keith Schulz of NatureServe reviewed and finalized local classification and compiled global classification.)

The following vegetation descriptions are derived from the 214 vegetation relevés sampled throughout the course of this project. Global information, information based on reports throughout the distribution of the associations/alliances, was also compiled by NatureServe to augment the local descriptions. All of the vegetation association descriptions will include information on both the global and local descriptions, unless the associations have only been described from Wupatki National Monument.

Each description is separated into twelve sections. Many of the sections are subdivided into a 'Wupatki National Monument' and a 'Globally' subsection. After the Wupatki National Monument subheading, information follows on the association/alliance as it appears in the park, the local information. After the Globally subheading information follows on the association/alliance as it appears throughout its range. Information about each of the sections is described in Table 1. References for all the vegetation descriptions are located at the end of Appendix F.

Table 1. Explanations on the vegetation descriptions sections.

Vegetation Description Sections	**Explanation**
Classification Confidence Level	The classification confidence level identified by NatureServe.
USFS Wetland System	The U.S. Dept. of Agriculture – Forest Service (USDA – FS) wetland classification system ranking crosswalked to NVC associations, provided by NatureServe.
Range	The range describes where this association was mapped in the project area, information on where particular relevés were sampled, and where the association occurs throughout its entire range.
Environmental Description	Environmental description describes the abiotic conditions measured related to the association/alliance. In the local descriptions, all slopes are described as a range of elevation (lowest to highest elevation) as well as an average elevation across all of the relevés measured in feet (ft) and meters (m).
Most Abundant Species	This section identifies the dominant and/or indicator species for Wupatki National Monument and globally throughout its range.
Associated Species	Associated species describes the most common species associated with all of the relevés locally and globally.
Vegetation Description	This section identifies the vegetation characteristics specific to the association/alliance. Locally, total vegetation cover is described as absolute percent cover and is given as a range (lowest to highest % cover) and average across all of the relevés.
Conservation Rank	The conservation rank is a ranking system used to identify and prioritize conservation areas applied to NVC associations by NatureServe. The global conservation rank is described in the Table 2. See NatureServe Explorer for further documentation of NaturServe's ranking system

	(http://www.natureserve.org/explorer/).
Database Code	Database codes are a unique code that NatureServe developed to organize and identify the vegetation associations.
Map Classes	Map classes describes how the association is crosswalked to the map class, a general description of where the map class occurs, and the total number of acres (ac)/hectares (ha) and polygons occurring inside and outside Wupatki National Monument.
Comments	Comments particular to the vegetation description locally at Wupatki National Monument and globally.
References	References that relate to the association. The entire citation is listed at the end of Appendix F.

Table 2. Conservation ranking system for associations.

Global Conservation Rank
GX – Eliminated
GH – Presumed eliminated (historic)
G1 – Critically imperiled
G2 – Imperiled
G3 – Vulnerable
G4 – Apparently secure
G5 – Secure
GU – Unrankable
G? – Unranked

List of vegetation community types (NVC Associations) organized by NVC structure.

NVC Association	Page
Atriplex obovata Badland Sparse Vegetation	F-5
Ephedra torreyana – (Atriplex canescens, confertifolia) Sparse Vegetation	F-7
Eriogonum corymbosum Cinder Sparse Vegetation	F-9
Atriplex canescens – (Ephedra viridis) / (Muhlenbergia porteri) Sandstone Sparse Vegetation [Provisional]	F-11
Andropogon hallii Colorado Plateau Herbaceous Vegetation	F-13
Bouteloua eriopoda – Pleuraphis jamesii Herbaceous Vegetation	F-15
Bouteloua eriopoda Coconino Plateau Shrub Herbaceous Vegetation	F-17
Hesperostipa comata – (Bouteloua eriopoda – Pleuraphis jamesii) Herbaceous Vegetation	F-19
Juniperus monosperma Cinder Wooded Herbaceous Vegetation	F-21
Gutierrezia sarothrae / Sporobolus airoides – (Pleuraphis jamesii) Shrub Herbaceous Vegetation	F-23
Ericameria nauseosa / *Pleuraphis jamesii – (Hesperostipa comata)* Shrub Herbaceous Vegetation	F-26
Pleuraphis jamesii Shrub Herbaceous Alliance	F-28
Pleuraphis jamesii – Sporobolus airoides Herbaceous Vegetation	F-31
Pleuraphis jamesii Herbaceous Vegetation	F-33
Sporobolus airoides Herbaceous Vegetation	F-36
Tiquilia latior / Sporobolus airoides Dwarf-shrubland [Provisional]	F-39
Alhagi maurorum Semi-natural Shrubland	F-41
Artemisia filifolia – Ephedra (torreyana, viridis) Shrubland	F-43
Atriplex canescens / Sporobolus airoides Herbaceous Vegetation	F-45
Atriplex canescens Desert Wash Shrubland [Provisional]	F-48
Brickellia californica – Rhus trilobata Shrubland	F-50
Ephedra torreyana – Achnatherum hymenoides Hummock Shrubland	F-52
Fallugia paradoxa – (Atriplex canescens – Ephedra torreyana) Cinder Shrubland	F-54
Gutierrezia sarothrae Dwarf-Shrubland Alliance	F-56
Poliomintha incana / (Pleuraphis jamesii) Shrubland	F-58
Salix exigua / Barren Shrubland	F-60
Tamarix spp. Temporarily Flooded Shrubland	F-63
Populus fremontii / Salix exigua Forest	F-66

Atriplex obovata Badland Sparse Vegetation

MAP CLASS	Mound Saltbush Badlands Sparse Vegetation
COMMON NAME	Mound Saltbush Badland Sparse Vegetation
PHYSIOGNOMIC CLASS	Sparse Vegetation (VII)
PHYSIOGNOMIC SUBCLASS	Unconsolidated material sparse vegetation (VII.C)
PHYSIOGNOMIC GROUP	Sparsely vegetated soil slopes (VII.C.3)
PHYSIOGNOMIC SUBGROUP	Natural/Semi-natural (VII.C.3.N.)
FORMATION	Dry slopes (VII.C.3.N.b)
ALLIANCE	Painted Desert Sparsely Vegetated Alliance

CLASSIFICATION CONFIDENCE LEVEL Weak

USFS WETLAND SYSTEM Upland

RANGE
Wupatki National Monument
Mound Saltbush Badland Sparse Vegetation is a uncommon association within Wupatki NM. Of the six relevés sampled, it was mainly located in the environs in sparse badland habitats on the Navajo Nation on the eastern section of the mapping area.

ENVIRONMENTAL DESCRIPTION
Wupatki National Monument
This association's elevation ranged from 4,265-4,495 ft (1,300-1,370 m) (average 4,331 ft/1,320 m). The topography consisted of flat areas with 0-10% slope (average 3%). The substrate in the badlands included clay, sandstone, and pebble plains.

MOST ABUNDANT SPECIES
Wupatki National Monument

Stratum	Species
Shrub	*Atriplex obovata*
Herbaceous	*Salsola tragus*

ASSOCIATED SPECIES
Wupatki National Monument
Atriplex canescens, Opuntia macrorhiza, Sphaeralcea hastulata, Sporobolus airoides

VEGETATION DESCRIPTION
Wupatki National Monument
Mound Saltbush Badland Sparse Vegetation total vegetation cover was 3-23% (average 11%) with 2-16% (average 6%) in the shrub layer and 1-9% (average 5%) in the herbaceous layer. The total species diversity was low and ranged from 4-7 species (average 6) within the 6 relevés sampled.

The vegetation was dominated by *Atriplex obovata* in the shrub layer with 0.5-17% absolute cover (average 5%) or *Salsola tragus* in the herbaceous layer with 0.5-7% absolute cover (average 5%). As this is a sparse type, total cover was generally less than 15%. The invasive non-native annual *Salsola tragus* can vary in percent cover, and may occur with higher cover than *Atriplex obovata*. Both *Atriplex obovata* and *Salsola tragus* must both be present, even in trace amounts, to be classified in this association.

CONSERVATION RANK G?

DATABASE CODE CEGL002928

MAP CLASSES
The association Mound Saltbush Badland Sparse Vegetation is represented by map class Mound Saltbush Badlands Sparse Vegetation (map code 4).

The Mound Saltbush Badlands Sparse Vegetation was mapped only in the project environs. The total area in the park environs is 3,304 ac (1,337 ha) within 29 map classes.

COMMENTS
Wupatki National Monument
Salsola tragus is a non-native annual species that is adventitious from Asia (Welsh et al. 1987). This species is widespread in North America and thrives in disturbed habitats (Welsh et al. 1987). The dominance of *Salsola tragus* in the association Mound Saltbush Badland Sparse Vegetation may result from the degree of human disturbance within this sparsely vegetated association.

Ephedra torreyana – (Atriplex canescens, confertifolia) Sparse Vegetation

MAP CLASS	Moenkopi Shale Sparse Vegetation
COMMON NAME	Torrey's Joint-fir – (Fourwing Saltbush, Shadscale) Sparse Vegetation
PHYSIOGNOMIC CLASS	Sparse Vegetation (VII)
PHYSIOGNOMIC SUBCLASS	Unconsolidated material sparse vegetation (VII.C)
PHYSIOGNOMIC GROUP	Sparsely vegetated soil slopes (VII.C.3)
PHYSIOGNOMIC SUBGROUP	Natural/Semi-natural (VII.C.3.N)
FORMATION	Dry slopes (VII.C.3.N.b)
ALLIANCE	*Ephedra torreyana* Sparsely Vegetated Alliance

CLASSIFICATION CONFIDENCE LEVEL Weak

USFS WETLAND SYSTEM Upland

RANGE
Wupatki National Monument
Torrey's Joint-fir – (Fourwing Saltbush, Shadscale) Sparse Vegetation is one of the most common associations on the sparse badlands. Our six relevés sampled were located in the eastern section of the project boundary in Wupatki NM, Babbitt Ranches, and Navajo Nation lands.

ENVIRONMENTAL DESCRIPTION
Wupatki National Monument
This association's elevation ranged from 4,298-4,524 ft (1,310-1,379 m) (average 4,380 ft/1,335 m). The topography ranged from level areas to hills with slopes ranging from 0-45% (average 9%). It is located within sparse badland habitats with substrate including clay soils, riverine cobbles, basaltic cobbles, and sandstone bluffs.

MOST ABUNDANT SPECIES
Wupatki National Monument

Stratum	Species
Shrub	*Ephedra torreyana, Atriplex canescens, Atriplex confertifolia*

ASSOCIATED SPECIES
Wupatki National Monument
Achnatherum hymenoides, Artemisia filifolia, Bouteloua eriopoda, Dasyochloa pulchella, Ephedra viridis, Eriogonum corymbosum, Ericameria nauseosa, Fallugia paradoxa, Gutierrezia sarothrae, Muhlenbergia porteri, Pleuraphis jamesii, Psorothamnus thompsoniae, Salsola tragus, Sphaeralcea sp., *Sporobolus airoides, Stanleya pinnata, Tiquilia latior, Yucca angustissima*

VEGETATION DESCRIPTION
Wupatki National Monument
Torrey's Joint-fir – (Fourwing Saltbush, Shadscale) Sparse Vegetation total vegetation cover was 6-17% (average 10%) with 4-12% (average 8%) in the shrub layer and 0.5-7% (average 3%) in the herbaceous layer. The total species diversity was low and ranged from 4-16 species (average 10) within the 6 relevés sampled.

Ephedra torreyana is an indicator for this association and must be present for the association definition. It was found with 0.5-7% absolute cover (average 4%). *Atriplex canescens* or *Atriplex confertifolia* may be dominant in this association, if *Ephedra torreyana* has low cover, but either do not have to be present. *Atriplex canescens* ranged from 0-5% absolute cover (average 1%) and *Atriplex confertifolia* ranged from 0-5% absolute cover (average 1%). The herbaceous layer was not dominated a single species.

CONSERVATION RANK G?

DATABASE CODE CEGL005801

MAP CLASSES

The association Torrey's Joint-fir – (Fourwing Saltbush, Shadscale) Sparse Vegetation is represented by map class Moenkopi Shale Sparse Vegetation (map code 6).

The total area mapped within Wupatki NM is 5,014 ac (2,029 ha) within 274 polygons and the total area in the park environs is 6,415 ac (2,596 ha) within 125 polygons.

The map class Moenkopi Shale Sparse Vegetation was used to map all sparsely vegetated Moenkopi shale badland associations. *Ephedra torreyana* was used an indicator for this map class, however it does not have to be dominant in the sparsely vegetated badland habitats to be mapped within this map class.

Eriogonum corymbosum Cinder Sparse Vegetation

MAP CLASS	Crispleaf Buckwheat Cinder Shrubland
COMMON NAME	Crispleaf Buckwheat Cinder Sparse Vegetation
PHYSIOGNOMIC CLASS	Sparse Vegetation (VII)
PHYSIOGNOMIC SUBCLASS	Unconsolidated material sparse vegetation (VII.C)
PHYSIOGNOMIC GROUP	Sparsely vegetated soil slopes (VII.C.3)
PHYSIOGNOMIC SUBGROUP	Natural/Semi-natural (VII.C.3.N)
FORMATION	Dry slopes
ALLIANCE	*Eriogonum corymbosum* Sparsely Vegetated Alliance

CLASSIFICATION CONFIDENCE LEVEL Weak

USFS WETLAND SYSTEM Upland

RANGE
Wupatki National Monument
Crispleaf Buckwheat Cinder Sparse Vegetation is an uncommon association within Wupatki NM that occurs in sparse cinder habitats. This association was only located in the southwestern corner of Wupatki NM and was not found in other areas within the project boundaries.

ENVIRONMENTAL DESCRIPTION
Wupatki National Monument
This association's elevation ranged from 4,856-5,020 ft (1,480-1,530 m) (average 4,970 ft/1,515 m). The topography ranged from minimal to steep slopes with 3-40% slope (average 24%). This association is specifically located within sparse community types on black cinder dominated substrate.

MOST ABUNDANT SPECIES
Wupatki National Monument

Stratum	Species
Shrub	*Eriogonum corymbosum*

ASSOCIATED SPECIES
Wupatki National Monument
Achnatherum hymenoides, Aristida purpurea, Artemisia filifolia, Brickellia californica, Ephedra torreyana, Ephedra viridis, Ericameria nauseosa, Fallugia paradoxa, Hesperostipa comata, Muhlenbergia porteri, Oenothera pallida, Stanleya pinnata

VEGETATION DESCRIPTION
Wupatki National Monument
Crispleaf Buckwheat Cinder Sparse Vegetation total vegetation cover was low with 11-25% (average 15%) with 6-25% (average 13%) in the shrub layer and 0-11% (average 3%) in the herbaceous layer. The total species diversity was low and ranged from 3-9 species (average 6) within the 8 relevés sampled.

The shrub layer consistently contains *Eriogonum corymbosum* with 2-15% absolute cover (average 8%). *Eriogonum corymbosum* must be present for assignment of this association type; however, other shrubs such as *Brickellia californica* and *Fallugia paradoxa* may be present in greater abundance. The herbaceous layer was sparse and not dominated by a single species.

CONSERVATION RANK G?

DATABASE CODE CEGL005803

MAP CLASSES

The association Crispleaf Buckwheat Cinder Sparse Vegetation is represented by map class Crispleaf Buckwheat Cinder Shrubland (map code 15).

The total area mapped within Wupatki NM is 203 ac (82 ha) within 14 polygons. The total for the project environs is 151 ac (61 ha) within 37 polygons.

Atriplex canescens – (Ephedra viridis) / (Muhlenbergia porteri) Sandstone Sparse Vegetation [Provisional]

MAP CLASS	Moenkopi Sandstone Sparse Vegetation
COMMON NAME	Fourwing Saltbush – (Mormon Tea) / (Bush Muhly) Sandstone Sparse Vegetation
PHYSIOGNOMIC CLASS	Sparse Vegetation (VII)
PHYSIOGNOMIC SUBCLASS	Boulder, gravel, cobble, or talus sparse vegetation (VII.B)
PHYSIOGNOMIC GROUP	Sparsely vegetated rock flats (VII.B.2)
PHYSIOGNOMIC SUBGROUP	Natural/Semi-natural (VII.B.2.N)
FORMATION	Boulder fields (VII.B.2.N.a)
ALLIANCE	Sandstone Sparsely Vegetated Alliance

CLASSIFICATION CONFIDENCE LEVEL Weak

USFS WETLAND SYSTEM Upland

RANGE
Wupatki National Monument
Fourwing Saltbush – (Mormon Tea) / (Bush Muhly) Sandstone Sparse Vegetation is the most common association in the sandstone sparse communities. This association was found in seven relevés sampled at Wupatki NM in the eastern half of the park. No relevés were sampled outside of Wupatki NM; however, this may be due to low numbers of relevés sampling outside of the national monument boundaries. Additional sampling outside the national monument boundaries may reveal more occurrences.

ENVIRONMENTAL DESCRIPTION
Wupatki National Monument
This association's elevation ranged from 4,396-4,856 ft (1,340-1,480 m) (average 4,741ft/1,445 m). The topography ranged from small to steep slopes with 0-25% slope (average 14%). This association is specific to sandstone soils including bluffs, boulders, and shards.

MOST ABUNDANT SPECIES
Wupatki National Monument

Stratum	Species
Shrub	*Atriplex canescens, Ephedra viridis*
Herbaceous	*Muhlenbergia porteri*

ASSOCIATED SPECIES
Wupatki National Monument
Artemisia bigelovii, Artemisia dracunculus, Artemisia filifolia, Bouteloua curtipendula, Dasyochloa pulchella, Ephedra torreyana, Gutierrezia sarothrae, Isocoma drummondii, Pleuraphis jamesii, Rhus trilobata, Salsola tragus, Sporobolus airoides, Sporobolus flexuosus, Sphaeralcea hastulata, Stanleya pinnata

VEGETATION DESCRIPTION
Wupatki National Monument
Fourwing Saltbush – (Mormon Tea) / (Bush Muhly) Sandstone Sparse Vegetation total vegetation cover is 5-16% (average 11%) with 4-15% (average 9%) in the shrub layer and 1-6% (average 3%) in the herbaceous layer. The total species diversity ranged from 12-17 species (average 15) in the 7 relevés sampled.

The shrub layer was dominated by *Atriplex canescens* with 1-6% absolute cover (average 3%) and sometimes *Ephedra viridis* with 0-4% absolute cover (average 2%). The herbaceous layer could be dominated by *Muhlenbergia porteri* with absolute cover 0-4% (average 1%). *Atriplex canescens* must be present in this association, even with low percent cover. *Ephedra viridis* and *Muhlenbergia porteri* are often present; however, they do not necessarily need to be present within this sparse vegetation type.

CONSERVATION RANK G?

DATABASE CODE CEGL002927

MAP CLASSES
The association Fourwing Saltbush – (Mormon Tea) / (Bush Muhly) Sandstone Sparse Vegetation is represented by map class Moenkopi Sandstone Sparse Vegetation (map code 5).

The total area mapped within Wupatki NM is 1,811 ac (733 ha) within 543 polygons and the total area in the park environs is 717 ac (290 ha) within 146 polygons.

The map class Moenkopi Sandstone Sparse Shrubland was used to map all sparsely vegetated sandstone outcrops and soils. *Atriplex canescens*, used as an indicator for this association, does not necessarily have to be present for vegetation to be classified as this map class. Other vegetation types have been measured on the sandstone in the project boundaries, but have not been described as separate associations. For instance, the photointerpreters noticed that in some areas *Gutierrezia sarothrae* and *Rhus trilobata* were the dominant species within these sandstone sparse communities, without *Atriplex canescens* present. These areas were also included in the Moenkopi Sandstone Sparse Vegetation map class.

COMMENTS
Wupatki National Monument
Review of additional plot data on sandstone may reveal additional associations within the Sandstone Sparse Vegetation Alliance.

Andropogon hallii Colorado Plateau Herbaceous Vegetation

MAP CLASS	Sand Bluestem Grassland
COMMON NAME	Sand Bluestem Colorado Plateau Herbaceous Vegetation
PHYSIOGNOMIC CLASS	Herbaceous Vegetation (V.)
PHYSIOGNOMIC SUBCLASS	Perennial graminoid vegetation (V.A.)
PHYSIOGNOMIC GROUP	Temperate or subpolar grassland (V.A.5.)
PHYSIOGNOMIC SUBGROUP	Natural/Semi-natural (V.A.5.N.)
FORMATION	Tall sod temperate grassland (V.A.5.N.a.)
ALLIANCE	*Andropogon hallii* Herbaceous Alliance

CLASSIFICATION CONFIDENCE LEVEL Weak

USFS WETLAND SYSTEM Upland

RANGE
Wupatki National Monument
Sand Bluestem Colorado Plateau Herbaceous Vegetation is an uncommon association within Wupatki NM. This association was identified from only one relevé on top of Woodhouse Mesa adjacent to the Visitor Center at Wupatki NM. This association may occur as small patches in other areas within the park; however, these areas were not sampled or may be below the minimum mapping unit.

ENVIRONMENTAL DESCRIPTION
Wupatki National Monument
This association's elevation was recorded at 5,151 ft/1,570 m on a level basaltic outcrop.

MOST ABUNDANT SPECIES
Wupatki National Monument

Stratum	Species
Herbaceous	*Andropogon hallii*

ASSOCIATED SPECIES
Wupatki National Monument
*Ephedra torreyana, Fallugia paradoxa, Hesperostipa comata, Ericameria nauseosa, Pleuraphis jamesii (*all occur with >1% cover)

VEGETATION DESCRIPTION
Wupatki National Monument
Sand Bluestem Colorado Plateau Herbaceous Vegetation total vegetation cover was 40%, with 8% in the shrub layer and 36% in the herbaceous layer. Within the one relevé sampled the total species diversity was 12.

The shrub layer was not dominated by a single species. In the herbaceous layer *Andropogon hallii* dominated with 23% absolute cover.

CONSERVATION RANK G?

DATABASE CODE CEGL002785

MAP CLASSES
The association Sand Bluestem Colorado Plateau Herbaceous Vegetation was mapped when located in the field as a park special represented by Sand Bluestem Grassland (map code 7). However, due to this association occurring in low frequency and with a difficult photosignature to distinguish, this association type often mapped as an inclusion in the map class Galleta Mixed Grasslands.

The total area of the park special Sand Bluestem Grassland in Wupatki NM is 9 ac (4 ha) within 5 polygons. The total area of Sand Bluestem in the project environs is 3 ac (1 ha) within 4 polygons.

COMMENTS

Wupatki National Monument

This association may have a patchy distribution within Wupatki NM; a more extensive survey is needed in order to understand the distribution of this vegetation association.

Bouteloua eriopoda – Pleuraphis jamesii Herbaceous Vegetation

MAP CLASS	Galleta Mixed Grasslands
COMMON NAME	Black Grama – Galleta Herbaceous Vegetation
PHYSIOGNOMIC CLASS	Herbaceous Vegetation (V.)
PHYSIOGNOMIC SUBCLASS	Perennial graminoid vegetation (V.A.)
PHYSIOGNOMIC GROUP	Temperate or subpolar grassland (V.A.5.)
PHYSIOGNOMIC SUBGROUP	Natural/Semi-natural (V.A.5.N.)
FORMATION	Short sod temperate or subpolar grassland (V.A.5.N.e.)
ALLIANCE	*Bouteloua eriopoda* Herbaceous Alliance

CLASSIFICATION CONFIDENCE LEVEL Moderate

USFS WETLAND SYSTEM Upland

RANGE
Wupatki National Monument
Black Grama – Galleta Herbaceous Vegetation was only identified from the classification relevés in the project environs outside of Wupatki NM, north of Wupatki Ruins. It was found in the environs on the Babbitt Ranches land, north of the National Monument, near the Babbitt ranch houses, and west of Highway 89 between the water tank and the power line.

Globally
This Colorado Plateau association is known from the upper Rio Puerco watershed in northwestern New Mexico and Wupatki National Monument in north-central Arizona. It may extend south to the Chihuahuan Desert.

ENVIRONMENTAL DESCRIPTION
Wupatki National Monument
This association's elevation ranged from 4,774-5,643 ft (1,455-1,720 m) (average 5,249 ft/1,600 m). It was found on basaltic soils and intermixed sandstone with low slope ranging from 0-4% (average 1%).

Globally
This Colorado Plateau desert grassland has been documented from the upper Rio Puerco watershed in northwestern New Mexico and in north-central Arizona. Elevations range from 4,770-6,000 ft (1,455-1,830 m). Stands occur on flat to gently sloping plains, basin floors, and mesas. Substrates are variable and include weakly developed Entisols and Entisol-Mollisol complexes often with loam to clay-loam textured soils derived from basalt outcrop, clay and sandstone; and coarser-textured soils derived from black cinders and sandstone (Francis 1986).

MOST ABUNDANT SPECIES
Wupatki National Monument

Stratum	Species
Herbaceous	*Pleuraphis jamesii, Bouteloua eriopoda*

Globally

Stratum	Species
Dwarf-Shrub	*Gutierrezia sarothrae*
Herbaceous	*Pleuraphis jamesii, Bouteloua eriopoda*

ASSOCIATED SPECIES
Wupatki National Monument
Ephedra torreyana, Gutierrezia sarothrae, Hesperostipa comata, Muhlenbergia porteri, Sporobolus airoides

Globally
Atriplex canescens Ephedra torreyana, Ericameria nauseosa, Gutierrezia sarothrae, Aristida purpurea, *Bouteloua gracilis*, *Hesperostipa neomexicana, Muhlenbergia porteri*, *Sporobolus airoides* and *Sporobolus cryptandrus*

VEGETATION DESCRIPTION

Wupatki National Monument

Black Grama – Galleta Herbaceous Vegetation total vegetation cover ranges from 24-39% (average 36%) with 0.5-5% (average 2%) in the shrub layer and 21-40% (average 35%) in the herbaceous layer. The total species diversity ranged from 5-17 species (average 10) within the 3 relevés sampled.

The shrub layer was not dominated by a single species. The herbaceous layer was co-dominated by *Pleuraphis jamesii* with 12-24% absolute cover (average 19%) and *Bouteloua eriopoda* with 5-17% absolute cover (average 11%). *Bouteloua eriopoda* is an indicator in this association, with *Pleuraphis jamesii* having up to two times greater cover than *Bouteloua eriopoda.*

Globally

This association is characterized by *Bouteloua eriopoda* and *Pleuraphis jamesii (= Hilaria jamesii)* codominating an open to moderately dense perennial graminoid layer. Associates include low cover of *Aristida purpurea*, *Bouteloua gracilis*, *Hesperostipa neomexicana (= Stipa neomexicana), Muhlenbergia porteri*, *Sporobolus airoides* and *Sporobolus cryptandrus*. Forb cover and diversity is low. Scattered shrubs and dwarf-shrub may be present including *Atriplex canescens, Ephedra torreyana, Ericameria nauseosa* and *Gutierrezia sarothrae* (Francis 1986). The presence of *Bouteloua eriopoda* and *Muhlenbergia porteri* suggests that this grassland is transitional to Chihuahuan Desert grasslands that begin over 100 miles to the south.

CONSERVATION RANK G3

DATABASE CODE CEGL001751

MAP CLASSES

The association Black Grama – Galleta Herbaceous Vegetation is represented by map class Galleta Mixed Grasslands (map code 11).

The total area mapped of this combined map class within Wupatki NM is 7,270 ac (2,942 ha) within 374 polygons and the total area in the park environs is 22,025 ac (8,913 ha) within 427 polygons.

This association's photosignature is indistinguishable from other mixed galleta grassland types; therefore this association type was not mapped as a unique vegetation association and was combined into a Galleta Mixed Grassland map class. The map class Galleta Mixed Grasslands consists of *Pleuraphis jamesii- Sporobolus airoides* Herbaceous Vegetation and *Bouteloua eriopoda - Pleuraphis jamesii* Herbaceous Vegetation.

COMMENTS

Globally

Limited quantitative documentation exists for this type.

REFERENCES

Bourgeron and Engelking 1994, Driscoll et al. 1984, Francis 1986

Bouteloua eriopoda Coconino Plateau Shrub Herbaceous Vegetation

MAP CLASS	Black Grama Coconino Plateau Mixed Shrubland, Black Grama Grassland
COMMON NAME	Black Grama Coconino Plateau Shrub Herbaceous Vegetation
PHYSIOGNOMIC CLASS	Herbaceous Vegetation (V)
PHYSIOGNOMIC SUBCLASS	Perennial graminoid vegetation (V.A)
PHYSIOGNOMIC GROUP	Temperate or subpolar grassland with a sparse shrub layer (V.A.7)
PHYSIOGNOMIC SUBGROUP	Natural/Semi-natural (V.A.7.N)
FORMATION	Short temperate or subpolar grassland with sparse xeromorphic (evergreen and/or deciduous) shrub layer (V.A.7.N.m)
ALLIANCE	*Bouteloua eriopoda* Xeromorphic Shrub Herbaceous Alliance

CLASSIFICATION CONFIDENCE LEVEL Weak

USFS WETLAND SYSTEM Upland

RANGE
Wupatki National Monument
Black Grama Coconino Plateau Shrub Herbaceous Vegetation is a common association in Wupatki NM and its environs. This association was found in twenty-one of our relevés at the northern half of Wupatki NM, specifically north of Crack-in-rock Road in Antelope Wash and on White Mesa. It also was found to occur on Babbitt Ranches land on White Mesa as well as west of Highway 89.

ENVIRONMENTAL DESCRIPTION
Wupatki National Monument
This association's elevation ranged from 4,757-5,807 ft (1,450-1,770 m) (average 5,167 ft/1,575 m). The substrate consisted mainly of limestone cobbles, gravel, and bedrock with black cinders and clay loam soils. A few of the relevés also were characterized by sand and sandstone. The slope varied from gentle to steep, 0-20% (average 6%).

MOST ABUNDANT SPECIES
Wupatki National Monument

Stratum	Species
Shrub	Mixed shrubs including: *Atriplex confertifolia, Atriplex canescens, Ephedra viridis, Ericameria nauseosa, Gutierrezia sarothrae*
Herbaceous	*Bouteloua eriopoda*

ASSOCIATED SPECIES
Wupatki National Monument
Aristida purpurea var. longiseta, Brickellia oblongifolia, Ephedra cutleri, Ephedra torreyana, Fallugia paradoxa, Juniperus monosperma, Hesperostipa comata, Lycium andersonii, Muhlenbergia porteri, Opuntia whipplei, Pleuraphis jamesii, Sphaeralcea parvifolia, Sporobolus airoides, Sporobolus contractus

VEGETATION DESCRIPTION
Wupatki National Monument
Black Grama Coconino Plateau Shrub Herbaceous Vegetation total vegetation cover ranges from 21-46% (average 34%) with 1-24% (average 11%) in the shrub layer and 15-43% (average 24%) in the herbaceous layer. The total species diversity ranged from 4-16 species (average 10) in the 21 relevés sampled.

The shrub layer was not dominated by a single species; rather, several species of Colorado Plateau characteristic shrubs can dominate or co-dominate in the shrub canopy depending on abiotic factors and land use history. These shrubs include *Atriplex confertifolia* with 0-10% absolute cover (average 1%), *Atriplex canescens* with absolute cover 0-4% (average 1%), *Ephedra viridis* with absolute cover 0-6% (average 2%), *Ericameria nauseosa* with absolute cover 0-24% (average 4%), and *Gutierrezia sarothrae* with absolute cover 0-17% (average 3%). The herbaceous layer was dominated by *Bouteloua eriopoda* with 8-42% absolute cover (average 18%).

CONSERVATION RANK G?

DATABASE CODE CEGL002787

MAP CLASSES
The association Black Grama Coconino Plateau Shrub Herbaceous Vegetation is represented by map class Black Grama Coconino Plateau Mixed Shrubland (map code 16) and Black Grama Grassland (map code 8).

The association Black Grama Coconino Plateau Shrub Herbaceous Vegetation was separated into two different map classes. The map class Black Grama / Coconino Plateau Mixed Shrubland represents areas that have a high cover of *Ericameria nauseosa,* due to its consistent photosignature. However, other shrubs that had a less consistent photosignature were lumped within the Black Grama Grassland map class.

The total area mapped of these combined map classes within Wupatki NM is 3,096 ac (1,253 ha) within 224 polygons and the total area in the park environs is 3,944 ac (1,596 ha) within 189 polygons.

COMMENTS
Wupatki National Monument
Bouteloua eriopoda is the most characteristic species within this association, and must be present in order for the association definition. A steppe structure also must be present in order to be placed within this association; however, the shrub canopy can range from sparse to high densities and a variety of species can occur as well.

Note:
This association is found in two different map classes:
1) Black Grama Grassland
2) Black Grama Coconino Plateau Mixed Shrubland

Hesperostipa comata – (Bouteloua eriopoda – Pleuraphis jamesii) Herbaceous Vegetation

MAP CLASS	Needle-and-Thread Grassland
COMMON NAME	Needle-and-Thread – (Black Grama – Galleta) Herbaceous Vegetation
PHYSIOGNOMIC CLASS	Herbaceous Vegetation (V)
PHYSIOGNOMIC SUBCLASS	Perennial graminoid vegetation (V.A)
PHYSIOGNOMIC GROUP	Temperate or subpolar grassland (V.A.5)
PHYSIOGNOMIC SUBGROUP	Natural/Semi-natural Temperate (V.A.5.N)
FORMATION	Medium-tall bunch temperate or subpolar grassland (V.A.5.N.d)
ALLIANCE	*Hesperostipa comata* Bunch Herbaceous Alliance

CLASSIFICATION CONFIDENCE LEVEL Weak

USFS WETLAND SYSTEM Upland

RANGE
Wupatki National Monument
Needle-and-Thread – (Black Grama – Galleta) Herbaceous Vegetation is a common association in Wupatki NM and in the environs. This association was located from our relevé data mainly in the northwestern half of Wupatki NM. It specifically occurred in Woodhouse Mesa, Antelope Prairie, and White Mesa. It also occurred on the Babbitt Ranches land on North Mesa in Antelope Prairie, West Mesa, and near the western boundary of Wupatki NM.

ENVIRONMENTAL DESCRIPTION
Wupatki National Monument
This association's elevation ranged from 5,118-5,545 ft (1,560-1,690 m) (average 5,364 ft/1,635 m). The substrate always consisted of a black cinder component, with intermixed basaltic cobbles, lava flow, clay, and limestone soils. The slope was often flat; however, it ranged from 0-25% (average 5%).

MOST ABUNDANT SPECIES
Wupatki National Monument

Stratum	Species
Herbaceous	*Bouteloua eriopoda, Hesperostipa comata, Pleuraphis jamesii*

ASSOCIATED SPECIES
Wupatki National Monument
Achnatherum hymenoides, Aristida purpurea var. longiseta, Artemisia filifolia, Atriplex canescens, Bouteloua curtipendula, Bouteloua gracilis, Chaetopappa ericoides, Ephedra viridis, Ericameria nauseosa, Fallugia paradoxa, Gutierrezia sarothrae, Juniperus monosperma, Krascheninnikovia lanata, Muhlenbergia porteri, Psilostrophe sparsiflora, Sporobolus airoides, Sporobolus contractus

VEGETATION DESCRIPTION
Wupatki National Monument
Needle-and-Thread – (Black Grama – Galleta) Herbaceous Vegetation total vegetation cover ranges from 25-60% (average 44%) with 0-20% (average 6%) in the shrub layer and 22-52% (average 38%) in the herbaceous layer. The total species diversity ranged from 5-17 species (average 10) within the 21 relevés sampled.

The shrub layer was not dominated by a single species; however, *Ericameria nauseosa* was present in 18 of the 21 relevés with absolute cover ranging from 0-14% (average 3%). *Hesperostipa comata* was an indicator in the herbaceous class with absolute cover of 8-40% (average 18%). *Bouteloua eriopoda* and *Pleuraphis jamesii* both frequently occur within this association, but do not need to be present. *Bouteloua eriopoda* ranged from 0-27% absolute cover (average 8%) and *Pleuraphis jamesii* ranged from 0-23% absolute cover (average 11%).

CONSERVATION RANK G?

DATABASE CODE CEGL002997

MAP CLASSES
The association Needle-and-Thread – (Black Grama – Galleta) Herbaceous Vegetation is represented by map classes Needle-and-Thread Grassland (map code 9).

Needle-and-Thread – (Black Grama – Galleta) Herbaceous Vegetation was difficult to distinguish because of the potential for mixed grass species dominance. Therefore, this association was only mapped as a Needle-and-Thread Grassland with stands of relatively pure (≥ 50%) Needle-and-Thread Grass. Stands of mixed Needle-and-Thread and Galleta were mapped as Mixed Galleta Grassland and stands of mixed Needle-and-Thread and Black Grama were classified as Black Grama Grassland.

The total area mapped of Needle-and-Thread Grassland within Wupatki NM is 729 ac (295 ha) within 44 polygons and the total area in the park environs is 830 ac (336 ha) within 77 polygons.

COMMENTS
Wupatki National Monument
Hesperostipa comata is the diagnostic species in this association; however, it is not always the most dominant species in the association. In relevés where *Hesperostipa comata* is the dominant grass of the association, the photosignature of this type is often indistinguishable from pure stands of *Bouteloua eriopoda* or *Pleuraphis jamesii*.

Juniperus monosperma Cinder Wooded Herbaceous Vegetation

MAP CLASS	Oneseed Juniper Woodland
COMMON NAME	One-seed Juniper Cinder Wooded Herbaceous Vegetation
PHYSIOGNOMIC CLASS	Herbaceous Vegetation (V)
PHYSIOGNOMIC SUBCLASS	Perennial graminoid vegetation (V.A)
PHYSIOGNOMIC GROUP	Temperate or subpolar grassland with a sparse tree layer (V.A.6)
PHYSIOGNOMIC SUBGROUP	Natural/Semi-natural (V.A.6.N)
FORMATION	Medium-tall temperate or subpolar grassland with a sparse needle-leaved evergreen or mixed tree layer (V.A.6.N.f)
ALLIANCE	*Juniperus monosperma* Wooded Herbaceous Alliance

CLASSIFICATION CONFIDENCE LEVEL Weak

USFS WETLAND SYSTEM Upland

RANGE
Wupatki National Monument
One-seed Juniper Cinder Wooded Herbaceous Vegetation is the most common association on the USDA-FS lands in the project environs. This association from our relevé data was found to predominates the southwestern section of the project boundary including Antelope Prairie and adjacent lands surrounding Hulls Wash and Ball Court Wash. Within Wupatki NM it was found adjacent to the USDA-FS lands in Antelope Prairie.

ENVIRONMENTAL DESCRIPTION
Wupatki National Monument
This association's elevation ranged from 5,364-5,758 ft (1,635-1,755 m) (average 5,512 ft/1,680 m). The slope was minimal to flat ranging from 0-5% (average 0.5%). The substrate always consisted of black cinder, with sporadic occurrence of basaltic boulders and sandstone. The cinder depth was site specific and varied depending on the geologic history of the site. Some sites had a thin layer of surface cinders and others had more than 2 m (7 ft) cinder depth.

MOST ABUNDANT SPECIES
Wupatki National Monument

Stratum	Species
Shrub	*Juniperus monosperma*

ASSOCIATED SPECIES
Wupatki National Monument
Aristida purpurea var. *longiseta, Bouteloua curtipendula, Bouteloua eriopoda, Bouteloua gracilis, Chaetopappa ericoides, Ericameria nauseosa, Gutierrezia sarothrae, Hesperostipa comata, Sporobolus airoides*

VEGETATION DESCRIPTION
Wupatki National Monument
One-seed Juniper Cinder Wooded Herbaceous Vegetation total vegetation cover ranged from 7-48% absolute cover (average 22%) with 0-6% (average 0%) in the shrub layer and 1-27% (average 9%) in the herbaceous layer. Although the association is considered to be herbaceous, relevés were measured with low herbaceous cover. Varying depth of cinder caused broad scale patchiness of the grass species. The total species diversity ranged from 3-12 species (average 6) within the 27 relevés sampled.

The shrub layer is dominated by *Juniperus monosperma* with absolute cover ranging from 3-35% (average 13%). *Bouteloua eriopoda* and *Pleuraphis jamesii* occur frequently in the herbaceous layer; however, they do not need to be present. *Bouteloua eriopoda* ranged from 0-17% absolute cover (average 8%) and *Pleuraphis jamesii* ranged from 0-19% absolute cover (average 5%).

CONSERVATION RANK G?

DATABASE CODE CEGL005807

MAP CLASSES
The association One-seed Juniper Cinder Wooded Herbaceous Vegetation is represented by map class Oneseed Juniper Woodland (map code 27).

The total area mapped of this association within Wupatki NM is 4,240 ac (1,716 ha) within 290 polygons and the total area in the park environs is 18,666 ac (7,554 ha) within 266 polygons.

COMMENTS
Wupatki National Monument
These data are still under review with NatureServe to determine the range of variability in the percent cover of the understory community to still be maintained within the herbaceous alliance.

Gutierrezia sarothrae / Sporobolus airoides – Pleuraphis jamesii Shrub Herbaceous Vegetation

MAP CLASS	Snakeweed / Galleta Grassland
COMMON NAME	Snakeweed / Alkali Sacaton – Galleta Shrub Herbaceous Vegetation
PHYSIOGNOMIC CLASS	Herbaceous Vegetation (V.)
PHYSIOGNOMIC SUBCLASS	Perennial graminoid vegetation (V.A.)
PHYSIOGNOMIC GROUP	Temperate or subpolar grassland with a sparse shrub layer (V.A.7.)
PHYSIOGNOMIC SUBGROUP	Natural/Semi-natural (V.A.7.N.)
FORMATION	Medium-tall temperate or subpolar grassland with a sparse needle-leaved or microphyllous evergreen shrub layer (V.A.7.N.e.)
ALLIANCE	*Pleuraphis jamesii* Shrub Herbaceous Alliance

CLASSIFICATION CONFIDENCE LEVEL Weak

USFS WETLAND SYSTEM Upland

RANGE

Wupatki National Monument

Snakeweed / Alkali Sacaton – Galleta Shrub Herbaceous Vegetation occurs infrequently over a broad range within the project boundary. This association tends to occur in naturally or anthropogenically disturbed habitats within the project boundary including within Wupatki NM, the Navajo Reservation, and Babbitt Ranches. Specifically within Wupatki NM it was found adjacent to Kana a Wash and on White Mesa, on the Navajo Reservation adjacent to Black Falls crossing, and on the Babbitt Ranches in the northwestern section near the Babbitt Ranch house.

Globally

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

ENVIRONMENTAL DESCRIPTION

Wupatki National Monument

This association occurred over a wide range of elevations, 4,298-5,430 ft (1,310-1,655 m) (average 5,020ft/1,530 m). Slope was minimal in all sites ranging from 0-6% (average 3%). Substrate varied from a pure cinder soil to mixed cinder and clay or limestone soils as well as pure sand. Many of the relevés occurred in areas that have frequent sheet flow or in washes.

Globally

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 mesas and alluvial flats. Elevation ranges from 1310-1655m. Sites are level to gently sloping. Substrates are variable and include soils derived from relatively deep, fine-textured alluvium, shallow, coarse or fine loams, and pure cinder or mixed cinder and clay and limestone soils as well as pure sand (Francis 1986). Sites typically have been disturbed by improper grazing of livestock, frequent sheet flow, or wind.

MOST ABUNDANT SPECIES

Wupatki National Monument

Stratum	Species
Shrub	*Gutierrezia sarothrae*
Herbaceous	*Pleuraphis jamesii, Sporobolus airoides*

Globally

Stratum	Species
Shrub	*Gutierrezia sarothrae*
Herbaceous	*Pleuraphis jamesii, Sporobolus airoides*

ASSOCIATED SPECIES

Wupatki National Monument

Achnatherum hymenoides, Aristida purpurea var. *longiseta, Atriplex canescens, Bouteloua curtipendula, Bouteloua eriopoda, Bouteloua gracilis, Ephedra torreyana, Ephedra viridis, Eriogonum corymbosum, Ericameria nauseosa, Fallugia paradoxa, Hesperostipa comata, Isocoma drummondii Juniperus monosperma, Muhlenbergia porteri*

Globally

Artemisia tridentata, Atriplex canescens, Ephedra viridis, Eriogonum corymbosum, Ericameria nauseosa, Fallugia paradoxa, Isocoma drummondii, Opuntia spp., *Juniperus monosperma, Achnatherum hymenoides, Aristida purpurea, Bouteloua curtipendula, B. eriopoda, B. gracilis, Hesperostipa comata, Muhlenbergia porteri, Spheralcea coccinea, Sporobolus cryptandrus*

VEGETATION DESCRIPTION

Wupatki National Monument

Snakeweed / Alkali Sacaton – Galleta Herbaceous Vegetation total vegetation cover ranged from 25-35% absolute cover (average 31%) with 18-22% (average 20%) in the shrub layer and 7-22% (average 13%) in the herbaceous layer. The total species diversity ranged from 9-15 species (average 11) within the 5 relevés sampled.

The shrub layer is dominated by *Gutierrezia sarothrae* with absolute cover ranging from 5-20% (average 15%). *Pleuraphis jamesii* and *Sporobolus airoides* both occur consistently within this association at low cover with *Pleuraphis jamesii* ranging from 2-8% absolute cover (average 5%) and *Sporobolus airoides* ranging from 2-6% absolute cover (average 3%).

Globally

This association 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. The herbaceous layer has greater cover than the shrub layer that may include other scattered shrubs and dwarf-shrubs such as scattered *Artemisia tridentata, Atriplex canescens, Ephedra viridis, Eriogonum corymbosum, Ericameria nauseosa, Fallugia paradoxa, Isocoma drummondii, Opuntia* spp., or *Juniperus monosperma.* Associated herbaceous species such as *Achnatherum hymenoides, Aristida purpurea, Bouteloua curtipendula, B. eriopoda, B. gracilis, Hesperostipa comata, Muhlenbergia porteri, Sphaeralcea coccinea,* and *Sporobolus cryptandrus* may be present with low cover (Francis 1986).

CONSERVATION RANK GU

DATABASE CODE CEGL001776

MAP CLASSES

The association Snakeweed / Alkali Sacaton – Galleta Shrub Herbaceous Vegetation is represented by map class Snakeweed / Galleta Grassland (map code 13).

The total area mapped within Wupatki NM is 237 ac (96 ha) within 60 polygons and the total area in the park environs is 662 ac (268 ha) within 131 polygons.

COMMENTS

Wupatki National Monument

Although the global description suggests that *Sporobolus airoides* does not have to be present to be classified in this association, all relevés within our study suggest that *Sporobolus airoides* is consistent and a dominant component in this association. Currently, this association is classified as part of the *Pleuraphis jamesii* Shrub Herbaceous Alliance; however, our data suggests that *Sporobolus airoides* may be equally important in the community and could potentially be reassessed to occur within a *Sporobolus airoides* Shrub Herbaceous Alliance.

Globally

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

Grazing has significantly impacted much of the vegetation in this region, which has had a long history of settlement and heavy livestock use. With proper livestock management and time, palatable species such as *Krascheninnikovia lanata* and *Sporobolus airoides* may increase, and *Gutierrezia sarothrae* and *Opuntia* spp. may decline in abundance (Francis 1986).

REFERENCES
Bourgeron and Engelking 1994, Driscoll et al. 1984, Francis 1986

Ericameria nauseosa / Pleuraphis jamesii – (Hesperostipa comata) Shrub Herbaceous Vegetation

MAP CLASS	Rabbitbrush Shrubland
COMMON NAME	Rabbitbrush / Galleta – (Needle-and-Thread) Shrub Herbaceous Vegetation
PHYSIOGNOMIC CLASS	Herbaceous Vegetation (V)
PHYSIOGNOMIC SUBCLASS	Perennial graminoid vegetation (V.A)
PHYSIOGNOMIC GROUP	Temperate or subpolar grassland with a sparse shrub layer (V.A.7)
PHYSIOGNOMIC SUBGROUP	Natural/Semi-natural
FORMATION	Medium-tall temperate or subpolar grassland with a sparse needle-leaved or microphyllous evergreen shrub layer (V.A.7.N.e)
ALLIANCE	*Pleuraphis jamesii* Shrub Herbaceous Alliance

CLASSIFICATION CONFIDENCE LEVEL Weak

USFS WETLAND SYSTEM Upland

RANGE
Wupatki National Monument
Rabbitbrush / Galleta – (Needle-and-Thread) Herbaceous Vegetation commonly occurs within Wupatki NM. This association was found in our relevés near Kana a-wash, around Crack-in-rock road, on Antelope Prairie adjacent to Citadel Ruin, and on North Mesa. This association was not sampled outside of the monument boundaries; however, it did occur adjacent to the Babbitt Ranches on North Mesa.

ENVIRONMENTAL DESCRIPTION
Wupatki National Monument
This association occurred over a wide range of elevations from 4,593-5,512 ft (1,400-1,680 m) (average 5,118 ft/1,560 m) and slopes from 0-45% (average 9%). All relevés contained cinder soils with some of the relevés also containing remnant basaltic lava flow or a limestone component.

MOST ABUNDANT SPECIES
Wupatki National Monument

Stratum	Species
Shrub	*Ericameria nauseosa*
Herbaceous	*Pleuraphis jamesii*, *Hesperostipa comata*

ASSOCIATED SPECIES
Wupatki National Monument
Achnatherum hymenoides, Artemisia filifolia, Bouteloua eriopoda, Bouteloua gracilis, Ephedra torreyana, Ephedra viridis, Eriogonum corymbosum, Ericameria nauseosa, Fallugia paradoxa, Gutierrezia sarothrae, Juniperus monosperma, Muhlenbergia porteri, Rhus trilobata, Tetraclea coulteri

VEGETATION DESCRIPTION
Wupatki National Monument
Rabbitbrush / Galleta – (Needle-and-Thread) Herbaceous Vegetation total vegetation cover ranged from 25-80% absolute cover (average 48%) with 7-19% (average 13%) in the shrub layer and 15-70% (average 38%) in the herbaceous layer. The total species diversity ranged from 6-16 species (average 9) within the 10 relevés sampled.

The shrub layer is dominated by *Ericameria nauseosa* with absolute cover ranging from 5-16% (average 9%). *Pleuraphis jamesii* is the dominant understory species with absolute cover ranging from 12-40% (average 22%). *Hesperostipa comata* is also a frequent but a less dominant understory component and ranged from 0-6% (average 2%).

CONSERVATION RANK G?

DATABASE CODE CEGL002996

MAP CLASSES
The association Rabbitbrush / Galleta – (Needle-and-Thread) Herbaceous Vegetation is represented by map class Rabbitbrush Shrubland (map code 17).

The total area mapped within Wupatki NM is 4,413 ac (1,786 ha) within 274 polygons and the total area in the park environs is 5,003 ac (2,025 ha) within 274 polygons.

Pleuraphis jamesii Shrub Herbaceous Alliance

MAP CLASS	Galleta Mixed Shrublands
COMMON NAME	Galleta Shrub Herbaceous Alliance
PHYSIOGNOMIC CLASS	Herbaceous Vegetation (V)
PHYSIOGNOMIC SUBCLASS	Perennial graminoid vegetation (V.A.)
PHYSIOGNOMIC GROUP	Temperate or subpolar grassland with a sparse shrub layer (V.A.7)
PHYSIOGNOMIC SUBGROUP	Natural/Semi-natural (V.A.7.N)
FORMATION	Medium-tall temperate or subpolar grassland with a sparse needle-leaved or microphyllous evergreen shrub layer (V.A.7.N.e)
ALLIANCE	*Pleuraphis jamesii* Shrub Herbaceous Alliance

CLASSIFICATION CONFIDENCE LEVEL Alliances are not ranked by NatureServe for classification confidence.

USFS WETLAND SYSTEM Upland

RANGE

Wupatki National Monument

Two associations were defined as part of the *Pleuraphis jamesii* Shrub Herbaceous Alliance. However, one field relevé did not have shrub species that correspond to a pre-existing association. This relevé was measured on the rim of White House Mesa.

Globally

This alliance is described from the upper Rio Puerco watershed in northwestern New Mexico and adjacent Arizona. It is likely that it occurs in other parts of the Colorado Plateau.

ENVIRONMENTAL DESCRIPTION

Wupatki National Monument

Based on one relevé, this association was located in cinder gravel and limestone cobbles.

Globally

This alliance has been described from the southern Colorado Plateau in northwestern New Mexico and adjacent Arizona. The elevation ranges from 4,921-6,102 ft (1,500-1,860 m), but stands likely occur over a wider elevational and geographical range. Climate is semi-arid with most of the highly variable precipitation falling in July and August. The driest month is April. Mean annual precipitation ranges from 9-13 in (22-32 cm) within the Rio Puerco watershed. Sites occur on a variety of landforms including mesas, plains, alluvial flats and fans, floodplains, and hillslopes. Soils are shallow, poorly developed and alkaline. Soil textures range from fine sandy loam to silty clay loam to clay. The ground surface has high cover of bare ground (to 90%) with little litter or rock cover (Francis 1986). Additional survey and description work are needed to fully describe the environment of this alliance.

MOST ABUNDANT SPECIES

Wupatki National Monument

Stratum	Species
Shrub	*Ephedra viridis, Atriplex confertifolia*
Herbaceous	*Pleuraphis jamesii*

Globally

Stratum	Species
Herbaceous	*Pleuraphis jamesii*

ASSOCIATED SPECIES

Wupatki National Monument

Atriplex canescens, Bouteloua eriopoda, Hesperostipa comata, Juniperus monosperma, Lycium andersonii Muhlenbergia porteri, Sporobolus airoides

Globally
Sporobolus airoides, *Sporobolus cryptandrus, Achnatherum hymenoides, Elymus elymoides, Muhlenbergia torreyi, Schedonnardus paniculatus*, *Bouteloua gracilis, Sphaeralcea coccinea, Astragalus* spp., *Atriplex obovata, Gutierrezia sarothrae*, *Artemisia bigelovii, Atriplex canescens, Atriplex confertifolia, Ericameria nauseosa, Ephedra* spp., *Krascheninnikovia lanata, Opuntia* spp., *Yucca* spp.

VEGETATION DESCRIPTION
Wupatki National Monument
Galleta Shrub Herbaceous Alliance total vegetation cover was 28%, with 12% absolute cover in the shrub layer and 14% absolute cover the herbaceous layer. Within the one relevé sampled the total species diversity was 14.

Ephedra viridis is the dominant species in the shrub lifeform (6% absolute cover); *Atriplex confertifolia* has the second highest cover (2.5% absolute cover). The herbaceous layer is dominated by *Pleuraphis jamesii* (11% absolute cover). *Bouteloua eriopoda* (2% absolute cover) and *Sporobolus airoides* (3% absolute cover) are also common species in the herbaceous layer.

Globally
This alliance is found on mesas in northwestern New Mexico and adjacent Arizona. The vegetation is dominated by a sparse to moderately dense herbaceous layer of perennial grasses that is characterized by *Pleuraphis jamesii (= Hilaria jamesii)* with a open short-shrub canopy (10-25% cover). *Pleuraphis jamesii* typically grows as a bunchgrass, but under favorable conditions may produce a sod. It dominates the herbaceous layer growing in nearly pure stands or is codominated by *Sporobolus airoides* or *Sporobolus cryptandrus*. Other common perennial grasses such as *Achnatherum hymenoides (= Oryzopsis hymenoides), Elymus elymoides, Muhlenbergia torreyi, Schedonnardus paniculatus*, or *Bouteloua gracilis* may occur in small amounts (less than half the cover of *Pleuraphis jamesii*). Forb cover is sparse and typically includes *Sphaeralcea coccinea* and *Astragalus* spp. The open short-shrub layer is often dominated by *Atriplex obovata* or *Gutierrezia sarothrae*, but may include may other shrubs and dwarf-shrubs such as *Artemisia bigelovii, Atriplex canescens, Atriplex confertifolia, Ericameria nauseosa, Ephedra* spp., *Krascheninnikovia lanata, Opuntia* spp., or *Yucca* spp., with less than 25% total cover. Total vegetation cover ranges from 10-75% with graminoids making up 8-60% cover. The sparse stands described by Francis (1986) may indicate a seral/degraded state and need further review.

CONSERVATION RANK G2G4

DATABASE CODE A.1532

MAP CLASSES
Galleta Shrub Herbaceous Alliance is represented by the map class Galleta Mixed Shrublands (map code 14).

The total area mapped within Wupatki NM is 1,315 ac (532 ha) within 255 polygons and the total area in the park environs is 1,213 ac (491 ha) within 107 polygons.

COMMENTS
Wupatki National Monument
Two associations were defined as part of the *Pleuraphis jamesii* Shrub Herbaceous Alliance (*Gutierrezia sarothrae / Sporobolus airoides – Pleuraphis jamesii* Shrub Herbaceous Vegetation and *Ericameria nauseosa / Pleuraphis jamesii* – (*Hesperostipa comata*) Shrub Herbaceous Vegetation). The one field relevé described in this vegetation description represented a community composition that did not correlate to a pre-existing association. With only one relevé described of this type, we were unable to define a provisional association and described this community to a coarser community classification using a pre-existing alliance. This community type, if described elsewhere on the Colorado Plateau, may be classified into an association with additional field sampling.

Globally
The main difference between stands in this alliance and the *Pleuraphis jamesii* Herbaceous Alliance (A.1287) is the presence of a significant woody layer composed of shrubs and dwarf-shrubs. However, stands described by Francis (1986) have less than 10% total vegetation cover and may be better classified in a sparsely vegetated alliance. Further confusing this type, Francis (1986) includes degraded stands of the *Sporobolus airoides - Pleuraphis jamesii*

alluvial flats plant community in this mesa top plant community. Francis (1986) also described many other plant communities in the Upper Rio Puerco watershed, some of which may also fit the concept of this alliance. This alliance description is based on two plant community descriptions by Francis (1986) and work done at Petrified Forest National Monument. Some stands included in this alliance may form a transitional stage between *Pleuraphis jamesii - Sporobolus airoides* grasslands and *Atriplex obovata* dwarf-shrublands. Further study is needed, especially on the effects of livestock grazing on vegetation structure.

DYNAMICS
Grazing has significantly impacted much of the vegetation in this region, which has had a long history of settlement and heavy livestock use. With proper livestock management and time, palatable species such as *Krascheninnikovia lanata* and *Sporobolus airoides* may increase, and *Gutierrezia sarothrae* and *Opuntia* spp. may decline in abundance (Francis 1986).

REFERENCES
Francis 1986, West et al. 1972

Pleuraphis jamesii – Sporobolus airoides Herbaceous Vegetation

MAP CLASS	Galleta Mixed Grasslands
COMMON NAME	Galleta – Alkali Sacaton Herbaceous Vegetation
PHYSIOGNOMIC CLASS	Herbaceous Vegetation (V.)
PHYSIOGNOMIC SUBCLASS	Perennial graminoid vegetation (V.A.)
PHYSIOGNOMIC GROUP	Temperate or subpolar grassland (V.A.5.)
PHYSIOGNOMIC SUBGROUP	Natural/Semi-natural (V.A.5.N.)
FORMATION	Short sod temperate or subpolar grassland (V.A.5.N.e.)
ALLIANCE	*Pleuraphis jamesii* Herbaceous Alliance

CLASSIFICATION CONFIDENCE LEVEL Moderate

USFS WETLAND SYSTEM Upland

RANGE
Wupatki National Monument
Galleta – Alkali Sacaton Herbaceous Vegetation is a common herbaceous physiognomic class that occurs on the Babbitt Ranches, Arizona State Lands, and Wupatki NM. This association was found to occur from our relevé data on the Babbitt Ranches on top of White Mesa, near the Bar Doney Tank and west of the Little Colorado River along the Crack-in-rock Road. On state lands this association is known from the southeastern ranch lands south of Kana a Wash. Within Wupatki NM this association was recorded from southeastern corner near Kana a Wash and Wukoki Ruins.

Globally
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, and in north-central Arizona. It has experienced significant declines throughout its range.

ENVIRONMENTAL DESCRIPTION
Wupatki National Monument
This association occurs over a wide range of elevations within the park and the environs 4,265-5,085 ft (1,300-1,550 m) (average 4,822 ft/1,470 m). Slope ranged from 0-15% (average 4%). Substrate varied from remnant lava flow, cinders, clay soils, to relic Pleistocene river cobbles.

Globally
This grassland is described in New Mexico from White Sands Missile Range and the upper Rio Puerco watershed, and in north-central Arizona. This association primarily occurs in swales within open valley bottoms and alluvial flats (<15% slope) at elevations between 4,260-6,800 ft (1,300-2,075 m). Substrates tend to be deep soils with surface textures ranging from fine loams to silty clay loams and clays, but include remnant lava flow, cinders, and relic Pleistocene river cobbles (Francis 1986, Muldavin et al. 2000a).

MOST ABUNDANT SPECIES
Wupatki National Monument

Stratum	Species
Herbaceous	*Pleuraphis jamesii, Sporobolus airoides*

Globally

Stratum	Species
Herbaceous	*Pleuraphis jamesii, Sporobolus airoides*

ASSOCIATED SPECIES
Wupatki National Monument
Atriplex confertifolia, Ephedra torreyana, Gutierrezia sarothrae, Muhlenbergia porteri, Opuntia macrorhiza

Globally
Atriplex canescens, A. confertifolia, A. obovata, Ephedra torreyana, Gutierrezia sarothrae, Krascheninnikovia lanata, Opuntia imbricata, O. macrorhiza, O. phaeacantha, Achnatherum hymenoides, Bouteloua gracilis, Muhlenbergia porteri, M. torreyi, Pascopyrum smithii, Scleropogon brevifolius, Sphaeralcea coccinea, Sporobolus cryptandrus

VEGETATION DESCRIPTION
Wupatki National Monument
Galleta – Alkali Sacaton Herbaceous Vegetation total vegetation cover ranged from 23-70% absolute cover (average 43%) with 0-8% (average 3%) in the shrub layer and 16-60% (average 40%) in the herbaceous layer. The total species diversity ranged from 4-14 species (average 7) within the 5 relevés sampled.

The shrub layer is not dominated by a single species. In the herbaceous layer *Pleuraphis jamesii* is the dominant understory species with absolute cover ranging from 9-50% (average 26%). *Sporobolus airoides* is always present in high cover, but at Wupatki NM it is never the dominant herbaceous species. Its absolute cover ranges from 6-18% (average 13%).

Globally
This association 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. 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, A. confertifolia, A. obovata, Ephedra torreyana, Gutierrezia sarothrae, Krascheninnikovia lanata, Opuntia imbricata, O. macrorhiza,* and *O. phaeacantha*. The key graminoid species dominate the herbaceous layer and account for more than 80% of the total percent plant cover. Associated herbaceous species such as *Achnatherum hymenoides, Bouteloua gracilis, Muhlenbergia porteri, M. torreyi, Pascopyrum smithii, Scleropogon brevifolius, Sphaeralcea coccinea,* and *Sporobolus cryptandrus* may be present with low cover (Francis 1986, Muldavin et al. 2000a).

CONSERVATION RANK G2G3

DATABASE CODE CEGL001778

MAP CLASSES
Galleta – Alkali Sacaton Herbaceous Vegetation is represented by map class Galleta Mixed Grasslands (map code 11).

The map class Galleta Mixed Grasslands includes the following combined associations: *Pleuraphis jamesii-Sporobolus airoides* Herbaceous Vegetation and *Bouteloua eriopoda - Pleuraphis jamesii* Herbaceous Vegetation.

The total area mapped within Wupatki NM is 7,270 ac (2,942 ha) within 374 polygons and the total area in the park environs is 22,025 ac (8,913 ha) within 427 polygons.

Global 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.

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. 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 Great Basin grassland is probably more widespread than is documented and hence the rank of G2G3.

REFERENCES
Bourgeron and Engelking 1994, Driscoll et al. 1984, Francis 1986, Muldavin et al. 1998, Muldavin et al. 2000a, West et al. 1972

Pleuraphis jamesii Herbaceous Vegetation

MAP CLASS	Galleta Grassland
COMMON NAME	Galleta Herbaceous Vegetation
PHYSIOGNOMIC CLASS	Herbaceous Vegetation (V.)
PHYSIOGNOMIC SUBCLASS	Perennial graminoid vegetation (V.A.)
PHYSIOGNOMIC GROUP	Temperate or subpolar grassland (V.A.5.)
PHYSIOGNOMIC SUBGROUP	Natural/Semi-natural (V.A.5.N.)
FORMATION	Short sod temperate or subpolar grassland (V.A.5.N.e.)
ALLIANCE	*Pleuraphis jamesii* Herbaceous Alliance

CLASSIFICATION CONFIDENCE LEVEL Moderate

USFS WETLAND SYSTEM Upland

RANGE
Wupatki National Monument
Galleta Herbaceous Vegetation is one of the most common associations within the project boundaries. This association was found from our relevé data at Wupatki NM in the southeastern section of the park west of the Little Colorado River, along Crack-in-rock Road, on Antelope Prairie, Woodhouse Mesa, Doney Mountain, White Mesa, and near Wupakti and Wukoki Ruins. This association was also found on Babbitt Ranch land on top of White Mesa, adjacent to the Babbitt Ranch houses and along the Lomatki Ruins service road.

Globally
This widespread grassland association is found on alluvial flats, plateau parks and plains in the Colorado Plateau and elsewhere in the southwestern U.S.

ENVIRONMENTAL DESCRIPTION
Wupatki National Monument
This association occurs over a wide range of elevations and slopes within the park and the environs ranging from 4,364-5,446 ft (1,330-1,660 m) elevation (average 5,069 ft/1,545 m) and 0-65% slope (average 16%). Its substrate included different geologic formations within the parks remnant lava flow and basaltic cobbles, black and red cinders, relic Pleistocene river cobbles, sandstone, sand, and clay soils.

Globally
This widespread grassland association is found on alluvial flats, plateau parks and plains in the Colorado Plateau and elsewhere in the southwestern U.S. Elevation ranges from 4,003-5,446 ft (1,220-1,660 m). Landforms vary from mesa tops, slopes, and basin floors. Stands may be small woodland parks or more extensive on the plains. Soils are variable. In bottomland stands soils tend to be fine-textured; however, stands also occur on sandy loams derived from sandstone, remnant lava flow, basaltic cobbles, black or red cinders, or alluvium derived from relic Pleistocene river cobbles, sandstone, sand, or clay soils.

MOST ABUNDANT SPECIES
Wupatki National Monument

Stratum	Species
Herbaceous	*Pleuraphis jamesii*

Globally

Stratum	Species
Herbaceous	*Pleuraphis jamesii*

ASSOCIATED SPECIES
Wupatki National Monument
Aristida havardii, Aristida purpurea, Artemisia dracunculus, Atriplex canescens, Bouteloua eriopoda, Brickellia oblongifolia, Dasyochloa pulchella, Elymus elymoides, Ephedra torreyana, Ephedra viridis, Ericameria nauseosus,

Fallugia paradoxa, Gutierrezia sarothrae, Hesperostipa comata, Muhlenbergia porteri, Sporobolus airoides, Zinnia grandiflora

Globally
Aristida spp., *Achnatherum hymenoides, Bouteloua eriopoda, Bouteloua gracilis, Hesperostipa comata, Muhlenbergia porteri, Sporobolus airoides*, *Sporobolus cryptandrus, Plantago* sp., *Gilia* sp., *Lappula* sp., *Zinnia* sp., *Opuntia* sp. *Artemisia filifolia, Atriplex canescens, Atriplex confertifolia, Brickellia oblongifolia, Ephedra torreyana, E. viridis, Ericameria nauseosa, Fallugia paradoxa, Gutierrezia* spp., *Tetradymia* spp., *Juniperus monosperma*

VEGETATION DESCRIPTION
Wupatki National Monument
Galleta Herbaceous Vegetation total vegetation cover ranged from 16-65% absolute cover (average 40%) with 1-10% (average 4%) in the shrub layer and 11-61% (average 36%) in the herbaceous layer. Diversity ranged from low (2) to high (17) species (average 10) within the 15 relevés sampled.

The shrub layer is not dominated by a single species; however, the most consistent shrubs species were *Ericameria nauseosa* with 0-3% absolute cover (average 1%) and *Atriplex canescens* with 0-10% absolute cover (average 1%). In the herbaceous layer *Pleuraphis jamesii* is the dominant understory species with absolute cover ranging from 10-55% (average 32%).

Globally
This association is characterized by a relatively sparse to moderately dense perennial herbaceous layer (10-60% cover) that is strongly dominated by the warm-season bunchgrass *Pleuraphis jamesii*. Low cover of other grasses such as *Aristida* spp., *Achnatherum hymenoides, Bouteloua eriopoda, Bouteloua gracilis, Hesperostipa comata, Muhlenbergia porteri, Sporobolus airoides*, or *Sporobolus cryptandrus* may be present. Forb cover is usually sparse and includes species of *Plantago, Gilia, Lappula, Zinnia,* and prickly pear cacti (*Opuntia* spp.). Many species of shrubs and dwarf-shrubs may be present, but they are not abundant enough to form a shrub layer. Woody species may include *Artemisia filifolia, Atriplex canescens, Atriplex confertifolia, Brickellia oblongifolia, Ephedra torreyana, E. viridis, Ericameria nauseosa, Fallugia paradoxa, Gutierrezia* spp., *Tetradymia* spp., and occasional *Juniperus monosperma* trees. The widespread introduced annual grass *Bromus tectorum* and several other exotic species like *Salsola kali, Bassia scoparia (= Kochia scoparia),* and *Sisymbrium altissimum* may be present to abundant, especially on disturbed sites. Some stands have high cover of cryptogams on the soil including *Collema tenax, Tortula ruralis, Bellia papillata*, and *Fulgensia bracteata*.

CONSERVATION RANK G2G4

DATABASE CODE CEGL001777

MAP CLASSES
Galleta Herbaceous Vegetation is represented by map class Galleta Grassland (map code 10).

The total area mapped within Wupatki NM is 62 ac (25 ha) within 24 polygons and the total area in the park environs is 583 ac (236 ha) within 94 polygons.

COMMENTS
Globally
This association is defined by the dominance of *Pleuraphis jamesii* in the graminoid layer without codominance of other grass species or the presence of a shrub layer.

DYNAMICS
Pleuraphis jamesii is both drought- and grazing-resistant (USFS 1937, Weaver and Albertson 1956, West et al. 1972). This grass is favored in mixedgrass stands because it is only moderately palatable to livestock; however, it decreases when heavily grazed during drought and in the more arid portions of its range where it is the dominant grass (West et al. 1972). This grass reproduces extensively from scaly rhizomes. These rhizomes make the plant

resistant to trampling by livestock and have good soil binding properties (USFS 1937, Weaver and Albertson 1956, West et al. 1972).

REFERENCES

Bourgeron and Engelking 1994, Cannon 1960, Collins 1984, Driscoll et al. 1984, Francis 1986, Francis and Aldon 1983, Helm 1981, Kleiner 1968, Kleiner 1983, Kleiner and Harper 1972, Kleiner and Harper 1977, Marr et al. 1973, Nichol 1937, Stewart et al. 1940, USFS 1937, Utah Environmental and Agricultural Consultants 1973, Von Loh et al. 2002, Weaver and Albertson 1956, West et al. 1972

Sporobolus airoides Herbaceous Vegetation

MAP CLASS	Wupatki Wash System
COMMON NAME	Alkali Sacaton Herbaceous Vegetation
PHYSIOGNOMIC CLASS	Herbaceous Vegetation (V.)
PHYSIOGNOMIC SUBCLASS	Perennial graminoid vegetation (V.A.)
PHYSIOGNOMIC GROUP	Temperate or subpolar grassland (V.A.5.)
PHYSIOGNOMIC SUBGROUP	Natural/Semi-natural (V.A.5.N.)
FORMATION	Medium-tall bunch temperate or subpolar grassland (V.A.5.N.e.)
ALLIANCE	*Sporobolus airoides* Herbaceous Alliance

CLASSIFICATION CONFIDENCE LEVEL Weak

USFS WETLAND SYSTEM Upland

RANGE

Wupatki National Monument

Alkali Sacaton Herbaceous Vegetation is a common association in the wash systems and in southeastern section of the project boundary. This association was found from our relevé data to occur on NPS lands, Babbitt lands, and Navajo Nation lands. In the park Alkali Sacaton Herbaceous Vegetation was located along the Little Colorado River corridor south of Black Falls Crossing and near Wukoki Ruins. It was located on the Navajo Nation along the Little Colorado River corridor north of Black Falls Crossing. On Babbitt lands it was located in side washes of the Little Colorado River.

Globally

This alkali sacaton mesic grassland community is found in the southwestern Great Plains and elsewhere in the southwestern United States and Mexico, ranging from Kansas and Colorado south to Texas, New Mexico and west to Arizona, Utah and possibly California.

ENVIRONMENTAL DESCRIPTION

Wupatki National Monument

This association's elevations ranged from 4,265-4,593 ft (1,300-1,400 m) (average 4,364 ft/1,330 m) and slope ranged from 0-30% (average 7%). The substrate varies depending on locations within the project boundary and includes lava flow, cinders, relic Pleistocene river cobbles, sandstone, sand, and clay soils. All of the relevés were located in washes and sheetflow runoff areas.

Globally

This grassland community occurs on alluvial toeslopes and flats, terraces, floodplain depressions, and sandy streambanks and washes in bottomlands throughout the southern Great Plains and Colorado Plateau. Elevations range from below 3,050 ft (1,000 m) to over 6,100 ft (2,000 m). Sites are typically flat to gently sloping but range to 30%. Soils are shallow to moderately deep, moderately well- to poorly drained, alkaline, and often saline with typically fine-textured silts or clays often derived from shale (Francis 1986, Johnston 1987, Kittel et al. 1999, Lauver et al. 1999, Von Loh et al. 2002). Other parent materials include lava flow, cinders, relic Pleistocene river cobbles, sandstone, and sand.

MOST ABUNDANT SPECIES

Wupatki National Monument

Stratum	Species
Herbaceous	*Sporobolus airoides*

ASSOCIATED SPECIES

Wupatki National Monument

Achnatherum hymenoides, Artemisia ludoviciana, Astragalus praelongus, Atriplex canescens, Atriplex confertifolia, Ephedra nevadensis, Ephedra torreyana, Ephedra viridis, Ericameria nauseosus, Gutierrezia sarothrae, Isocoma pluriflora, Muhlenbergia porteri, Pleuraphis jamesii, Salsola tragus, Sphaeralcea hastulata, Tiquilia latior

Globally
Achnatherum hymenoides, *Symphyotrichum subulatum, Buchloe dactyloides, Distichlis spicata, Hordeum jubatum, Bouteloua gracilis, Panicum obtusum, Pleuraphis jamesii, Sphaeralcea* spp*, Sporobolus cryptandrus*, and *Pascopyrum smithii, Atriplex canescens, A. confertifolia, Ephedra* spp.*, Ericameria nauseosus, Gutierrezia sarothrae, Sarcobatus vermiculatus*

VEGETATION DESCRIPTION
Wupatki National Monument
Alkali Sacaton Herbaceous Vegetation total vegetation cover ranged from 20-46% absolute cover (average 28%) with 4-20% (average 10%) in the shrub layer and 11-26% (average 19%) in the herbaceous layer. Diversity ranged from 8-15 species (average 11) within the 8 relevés sampled.

The herbaceous layer is dominated by *Sporobolus airoides* with absolute cover ranging from 8-26% (average 15%). Shrubs such as *Ephedra spp., Atriplex spp.* and *Gutierrezia sarothrae* are occasionally present. The shrub layer is never the dominant component to this association

Globally
This association is characterized by a sparse to moderately dense (20-60% cover), medium-tall graminoid layer dominated by *Sporobolus airoides*. Associated species include *Achnatherum hymenoides*, *Symphyotrichum subulatum (= Aster subulatus), Buchloe dactyloides, Distichlis spicata, Hordeum jubatum, Bouteloua gracilis, Panicum obtusum, Pleuraphis jamesii, Sphaeralcea* spp*, Sporobolus cryptandrus*, and *Pascopyrum smithii* (Francis 1986, Johnston 1987, Kittel et al. 1999, Lauver et al. 1999, Von Loh et al. 2002). Scattered shrubs may be present such as *Atriplex canescens, A. confertifolia, Ephedra* spp.*, Ericameria nauseosus, Gutierrezia sarothrae,* or *Sarcobatus vermiculatus*. Total shrub cover is low (<10%) and forb cover is minor.

CONSERVATION RANK G3Q

DATABASE CODE CEGL001685

MAP CLASSES
The association Alkali Sacaton Herbaceous Vegetation is represented by map class Wupatki Wash System (map code 24).

The Wupatki Wash System is a mosaic of associations that includes: *Sporobolus airoides* Herbaceous Vegetation, *Artemisia filifolia – Ephedra (torreyana, viridis)* Shrubland, *Atriplex canescens / Sporobolus airoides* Shrubland, *Atriplex canescens* Desert Wash Shrubland (Provisional), and *Fallugia paradoxa – (Atriplex canescens – Ephedra torreyana)* Cinder Shrubland.

The total area mapped within Wupatki NM is 1,384 ac (560 ha) within 182 polygons and the total area in the park environs is 939 ac (380 ha) within 123 polygons.

Global Comments
Compare this association with *Sporobolus airoides - Bouteloua gracilis* Herbaceous Vegetation (CEGL001686) and *Pleuraphis jamesii - Sporobolus airoides* Herbaceous Vegetation (CEGL001778). Stands in Montana are placed with *Sporobolus airoides* Northern Plains Herbaceous Vegetation (CEGL002274), which occurs in the northwestern Great Plains, and this type is restricted to the southwestern Great Plains and southwestern United States. In the southeastern Plains see *Distichlis spicata - (Hordeum jubatum, Poa arida, Sporobolus airoides)* Herbaceous Vegetation (CEGL002042).

DYNAMICS
This is an early-seral community that occurs on floodplains and depressions with moderately saline soils (Aldous and Shantz 1924 as cited in Johnston 1987). While the stand sampled may be flooded infrequently, other stands of *Sporobolus airoides* (alkali sacaton) are reported to occur on soils not flooded but with high water tables because of land position. The intermittent flood regime affects soil moisture and salinity which can alter species composition. Sudden increases in salinity will result in a decrease in cover of *Sporobolus airoides*. With no change in salinity, this plant association will form hummocks that accumulate sand. Gradually the sites will decrease in salinity, and

moisture and invasion by other grasses will follow (Ungar 1974a as cited in Johnston 1987). Soils are non-saline to moderately saline and usually alkaline. *Sporobolus airoides* will decrease in abundance with increased soil salinity.

REFERENCES

Aldous and Shantz 1924, Bourgeron and Engelking 1994, Driscoll et al. 1984, Francis 1986, Johnston 1987, Kittel and Lederer 1993, Kittel et al. 1999, Lauver et al. 1999, Lindauer 1970, Soil Conservation Service 1978, Steward 1982, Von Loh et al. 2002

Tiquilia latior / Sporobolus airoides Dwarf-shrubland [Provisional]

MAP CLASS	Crinklemat / Alkali Sacaton Dwarf Shrubland
COMMON NAME	Matted Crinklemat / Alkali Sacaton Dwarf-Shrubland
PHYSIOGNOMIC CLASS	Dwarf-shrubland (IV)
PHYSIOGNOMIC SUBCLASS	Evergreen dwarf-shrubland (IV.A)
PHYSIOGNOMIC GROUP	Extremely xeromorphic evergreen dwarf-shrubland (IV.A.2)
PHYSIOGNOMIC SUBGROUP	Natural/Semi-natural (IV.A.2.N)
FORMATION	Extremely xeromorphic evergreen subdesert dwarf-shrubland (IV.A.2.N.a)
ALLIANCE	*Tiquilia latior* Dwarf-Shrubland Alliance

CLASSIFICATION CONFIDENCE LEVEL Weak

USFS WETLAND SYSTEM Upland

RANGE
Wupatki National Monument
Matted Crinklemat / Alkali Sacaton Dwarf-Shrubland is only known from one location in the project boundary. This association was found at Wupatki NM adjacent to the Little Colorado River corridor near Black Falls Crossing.

ENVIRONMENTAL DESCRIPTION
Wupatki National Monument
This association was found at an elevation of 4,265 ft (1,300 m) with no slope. The substrate consisted of red sand, black cinders, and relict Pleistocene river cobbles.

MOST ABUNDANT SPECIES
Wupatki National Monument

Stratum	Species
Dwarf-Shrub	*Tiquilia latior*
Herbaceous	*Sporobolus airoides*

ASSOCIATED SPECIES
Wupatki National Monument
Atriplex canescens, Atriplex confertifolia

VEGETATION DESCRIPTION
Wupatki National Monument
Only one relevé was assigned to the association Matted Crinklemat / Alkali Sacaton Dwarf-Shrubland. Total vegetation was 22% absolute cover with 16% in the shrub layer and 5% in the ground layer. Species diversity consists of 8 species.

The dwarf-shrub layer is dominated by *Tiquilia latior* with 4% absolute cover. The herbaceous layer is dominated by *Sporobolus airoides* with 4% absolute cover.

CONSERVATION RANK G?

DATABASE CODE CEGL005809

MAP CLASSES
The association Matted Crinklemat / Alkali Sacaton Dwarf-Shrubland is represented by map class Crinklemat / Alkali Sacaton Dwarf Shrubland (map code 12).

The total area mapped within Wupatki NM is 217 ac (88 ha) within 8 polygons and the total area in the park environs is 30 ac (12 ha) within 3 polygons.

COMMENTS

Wupatki National Monument

This association is only known from one location within the park; however, with more extensive sampling along the Colorado River on basaltic substrate we believe that additional examples of this association may have been located.

Alhagi maurorum Semi-natural Shrubland

MAP CLASS	Little Colorado River Invasive Riparian Shrubland
COMMON NAME	Camelthorn Semi-natural Shrubland
PHYSIOGNOMIC CLASS	Shrubland (III)
PHYSIOGNOMIC SUBCLASS	Deciduous shrubland (III.B)
PHYSIOGNOMIC GROUP	Drought-deciduous shrubland (III.B.1)
PHYSIOGNOMIC SUBGROUP	Natural/Semi-natural (III.B.1.N)
FORMATION	Lowland drought-deciduous shrubland (III.B.1.N.a)
ALLIANCE	*Alhagi maurorum* Semi-natural Shrubland Alliance

CLASSIFICATION CONFIDENCE LEVEL Weak

USFS WETLAND SYSTEM Upland

RANGE
Wupatki National Monument
Camelthorn Semi-natural Shrubland is only known from one location in the project boundary. This association was found on the banks of the Little Colorado River near Black Falls Crossing within Wupatki NM.

ENVIRONMENTAL DESCRIPTION
Wupatki National Monument
This association was found at an elevation of 4,265 ft (1,300 m) with level slope. The substrate consisted of a sandy riverbank with some clay soils.

MOST ABUNDANT SPECIES
Wupatki National Monument

Stratum	Species
Shrub	*Alhagi maurorum*

ASSOCIATED SPECIES
Wupatki National Monument
Gutierrezia sarothrae, Salsola kali, Sporobolus airoides, Tamarix chinensis

VEGETATION DESCRIPTION
Wupatki National Monument
Only one relevé was identified as the association Camelthorn Semi-natural Shrubland. Total vegetation was 18% absolute cover with 13% in the shrub layer and 5% in the ground layer. Species diversity consists of 17 species; however, this high diversity is represented by a high percentage of exotic species with five of the 17 species being non-native exotic species.

The shrub layer is dominated by *Alhagi maurorum* with 10% absolute cover. The herbaceous layer is not dominated by a single species.

CONSERVATION RANK GW

DATABASE CODE CEGL002784

MAP CLASSES
The association Camelthorn Semi-natural Shrubland is represented by map class Little Colorado River Invasive Riparian Shrubland (map code 26).

The map class Little Colorado River Invasive Riparian Shrubland also includes the association *Tamarix spp.* Temporarily Flooded Shrubland.

The total area mapped within Wupatki NM is 77 ac (31 ha) within 8 polygons and the total area in the park environs is 1,774 ac (718 ha) within 74 polygons.

COMMENTS

Wupatki National Monument

Although only one relevé of this proposed association was described from the project, we have observed that this invasive association is not unique and occurs within other disturbed/riparian areas on the Colorado Plateau.

Artemisia filifolia – Ephedra (torreyana, viridis) Shrubland

MAP CLASS	Sand Sagebrush Shrubland, Wupatki Wash System
COMMON NAME	Sand Sagebrush – (Torrey's Joint-fir, Mormon-tea) Shrubland
PHYSIOGNOMIC CLASS	Shrubland (III)
PHYSIOGNOMIC SUBCLASS	Evergreen shrubland (III.A)
PHYSIOGNOMIC GROUP	Microphyllous evergreen shrubland (III.A.4)
PHYSIOGNOMIC SUBGROUP	Natural/Semi-natural (III.A.4.N)
FORMATION	Lowland microphyllous evergreen shrubland (III.A.4.N.a)
ALLIANCE	*Artemisia filifolia* Shrubland Alliance

CLASSIFICATION CONFIDENCE LEVEL Weak

USFS WETLAND SYSTEM Upland

RANGE
Wupatki National Monument
Sand Sagebrush – (Torrey's Joint-fir, Mormon-tea) Shrubland is one of the most common shrubland associations in the south central section of the project boundary. This association was identified from our relevé data only within Wupatki NM lands; however, more extensive sampling in the project environs may result in expanded distribution ranges. Within Wupatki NM it was identified east of Black Mesa near Kana a Wash, Dead Man's Wash, Wukoki Ruins, Wupatki Ruins, and a Navajo's home site.

ENVIRONMENTAL DESCRIPTION
Wupatki National Monument
This association's elevation ranged from 4,380-4,888 ft (1,335-1,490 m) (average 4,724 ft/1,440 m) and slope ranged from 0-12% (average 5%). The substrate is black cinder with a layer of sandstone cobbles. This association is sometimes found in washes or sheetflow areas.

MOST ABUNDANT SPECIES
Wupatki National Monument

Stratum	Species
Shrub	*Artemisia filifolia, Ephedra torreyana, Ephedra viridis*

ASSOCIATED SPECIES
Wupatki National Monument
Achnatherum hymenoides, Aristida purpurea, Artemisia bigelovii, Atriplex canescens, Artemisia dracunculus, Atriplex confertifolia, Bouteloua eriopoda, Ericameria nauseous, Eriogonum corymbosum, Fallugia paradoxa, Gutierrezia sarothrae, Lycium pallidum, Muhlenbergia porteri, Pleuraphis jamesii, Sphaeralcea parvifolia, Sporobolus airoides, Tetraclea coulteri, Yucca angustissima, Zinnia grandiflora

VEGETATION DESCRIPTION
Wupatki National Monument
Sand Sagebrush – (Torrey's Joint-fir, Mormon-tea) Shrubland total vegetation cover ranged from 15-30% absolute cover (average 24%) with 15-34% (average 20%) in the shrub layer and 1-15% (average 6%) in the herbaceous layer. Diversity ranged from 7-27 species (average 12) within the 14 relevés sampled.

The shrub layer was not dominated by a single species but rather by a group of species that co-dominate. *Artemisia filifolia* is the only consistent shrub to occur within the association and functions as an indicator species. Its absolute cover ranges from low to moderate, 1-18% (average 6%). Other shrubs can occur and can dominate or co-dominate within this association but they do not have to be present. These main shrubs consists of *Ephedra torreyana* with 0-9% absolute cover (average 4%), *Ephedra viridis* with 0-4% absolute cover (average 1%), *Ericameria nauseosa* with 0-12% absolute cover (average 2%), *Gutierrezia sarothrae* with 0-9% absolute cover (average 3%), and *Atriplex canescens* with absolute cover 0-7% (average 2%). The herbaceous layer is not dominated by a single species.

CONSERVATION RANK G?

DATABASE CODE CEGL002786

MAP CLASSES
The association Sand Sagebrush – (Torrey's Joint-fir, Mormon-tea) Shrubland is represented by map class Sand Sagebrush Shrubland (map code 19) and may also occur as a mosaic within the Wupatki Wash System (map code 24).

The Wupatki Wash System is a mosaic of associations that includes: *Sporobolus airoides* Herbaceous Vegetation, *Artemisia filifolia – Ephedra (torreyana, viridis)* Shrubland, *Atriplex canescens / Sporobolus airoides* Shrubland, *Atriplex canescens* Desert Wash Shrubland (Provisional), and *Fallugia paradoxa – (Atriplex canescens – Ephedra torreyana)* Cinder Shrubland.

The total areas mapped of Sand Sagebrush Mixed Shrubland within Wupatki NM is 1,888 ac (764 ha) within 80 polygons and the total area in the park environs is 42 ac (17 ha) within 8 polygons. The total area mapped of the complex Wupatki Wash System within Wupatki NM is 1,384 ac (560 ha) within 182 polygons and the total area in the park environs is 939 ac (380 ha) within 123 polygons.

COMMENTS
Wupatki National Monument
Artemisia filifolia is an indicator species within this association and can occur in low cover with other shrubs; these shrubs may not be listed in the NVC association name and may dominate cover in the shrub layer. *Artemisia filifolia*'s indicator status may need to be reassessed with additional relevé data.

Note:
This association is found in two different map classes:
1) Sand Sagebrush Shrubland
2) Wupatki Wash System

Atriplex canescens / Sporobolus airoides Shrubland

MAP CLASS	Wupatki Wash System
COMMON NAME	Fourwing Saltbush / Alkali Sacaton Shrubland
PHYSIOGNOMIC CLASS	Shrubland (III.)
PHYSIOGNOMIC SUBCLASS	Evergreen shrubland (III.A.)
PHYSIOGNOMIC GROUP	Extremely xeromorphic evergreen shrubland (III.A.5.)
PHYSIOGNOMIC SUBGROUP	Natural/Semi-natural (III.A.5.N.)
FORMATION	Facultatively deciduous extremely xeromorphic subdesert shrubland (III.A.5.N.b.)
ALLIANCE	*Atriplex canescens* Shrubland Alliance

CLASSIFICATION CONFIDENCE LEVEL Weak

USFS WETLAND SYSTEM Upland

RANGE

Wupatki National Monument

Fourwing Saltbush / Alkali Sacaton Shrubland occurs in small patches within washes or runoff areas in the project boundary. This association was only identified from our relevé data within Wupatki NM adjacent to Deadman's Wash; however, additional occurrences in the park environs may be found with additional sampling.

Globally

This shrubland occurs in the northern Chihuahua Desert extending into Trans-Pecos Texas, the southwestern Great Plains and Colorado Plateau in Colorado, New Mexico, Arizona, and Utah. It is reported from California and likely also occurs in Nevada and Mexico.

ENVIRONMENTAL DESCRIPTION

Wupatki National Monument

The two relevés of this association sampled had elevations of 1308 and 1309m and slope of 1 and 5%. The substrate consisted of clay soils and cinder sand.

Globally

This shrubland occurs in the northern Chihuahua Desert extending into the Trans-Pecos of Texas, southwestern Great Plains, and Colorado Plateau. Sites are in washes and on alluvial flats, extending up lower slopes of alluvial fans or bajadas. Elevation ranges from 3002-6,201 ft (915-1,890 m). Sites are level to gently sloping (1-2%), and substrates are typically moderately deep, alkaline, calcareous, fine-textured soils such as loamy clay or clay (Francis 1986, Muldavin et al. 2000a, Shaw et al. 1989). Cover of bare soil may be high (>50%) (Francis 1986). Evidence of overland flow and erosion, e.g., gullies, rills, plant pediceling is common (Soil Conservation Service n.d.).

MOST ABUNDANT SPECIES

Wupatki National Monument

Stratum	Species
Shrub	*Atriplex canescens*
Herbaceous	*Sporobolus airoides*

Globally

Stratum	Species
Shrub	*Atriplex canescens*
Herbaceous	*Sporobolus airoides*

ASSOCIATED SPECIES

Wupatki National Monument

Artemisia filifolia, Gutierrezia sarothrae, Isocoma pluriflora, Salsola kali

Globally
Artemisia filifolia, Atriplex confertifolia, A. obovata, Chrysothamnus viscidiflorus, Ericameria nauseosa, Gutierrezia sarothrae, Isocoma pluriflora, Krascheninnikovia lanata, Lycium berlandieri, L. pallidum, Opuntia imbricata, O. leptocaulis, O. phaeacantha, *Prosopis glandulosa*, *Sarcobatus vermiculatus, Elymus elymoides, Pascopyrum smithii, Pleuraphis jamesii, Sphaeralcea coccinea, Sporobolus cryptandrus, Sporobolus nealleyi, Suaeda* spp.

VEGETATION DESCRIPTION
Wupatki National Monument
Fourwing Saltbush / Alkali Sacaton Herbaceous Vegetation total vegetation cover ranged from 20 and 55% absolute cover with 10 and 26% in the shrub layer and 11 and 24% in the herbaceous layer. The total species diversity ranged from 7 and 12 species.

The shrub layer is dominated by *Atriplex canescens* with absolute cover of 9 and 18%. *Artemisia filifolia* can also occur with high cover (one relevé contained 8% absolute cover). The understory is dominated by *Sporobolus airoides* with 6-17% absolute cover.

Globally
The association is characterized by an open to moderately dense (10-50% cover) short-shrub layer dominated by *Atriplex canescens* with a perennial graminoid layer dominated by *Sporobolus airoides*. The shrub layer generally has greater cover than the herbaceous layer, and may include other scattered shrubs and dwarf-shrubs such as *Artemisia filifolia, Atriplex confertifolia, A. obovata, Chrysothamnus viscidiflorus, Ericameria nauseosa, Gutierrezia sarothrae, Isocoma pluriflora, Krascheninnikovia lanata, Lycium berlandieri, L. pallidum, Opuntia imbricata, O. leptocaulis, O. phaeacantha*, *Prosopis glandulosa*, and *Sarcobatus vermiculatus.* Associated herbaceous species such as *Elymus elymoides, Pascopyrum smithii, Pleuraphis jamesii, Sphaeralcea coccinea, Sporobolus cryptandrus, Sporobolus nealleyi,* and *Suaeda* spp. may be present. *Bouteloua gracilis* cover is minor and inconsistent (Francis 1986, Muldavin et al. 2000a, Shaw et al. 1989). Introduced species like *Salsola kali* or *Marrubium vulgare* may be common.

CONSERVATION RANK G5?

DATABASE CODE CEGL001291

MAP CLASSES
The association Fourwing Saltbush / Alkali Sacaton Herbaceous Vegetation was combined with other wash dependent associations into one map class, the Wupatki Wash System (map code 24).

Wupatki Wash System consists of these five association: *Artemisia filifolia – Ephedra (torreyana, viridis)* Shrubland, *Atriplex canescens / Sporobolus airoides* Shrubland, *Atriplex canescens* Desert Wash Shrubland (Provisional), *Fallugia paradoxa (Atriplex canescens – Ephedra torreyana)* Cinder Shrubland, and *Sporobolus airoides* Herbaceous Vegetation. Each of these associations may predominate the wash depending on different biotic and abiotic conditions.

The total area mapped of this map class within Wupatki NM is 1,384 ac (560 ha) within 182 polygons and the total area in the park environs is 939 ac (380 ha) within 123 polygons.

COMMENTS
Globally
Stands with relatively low cover of *Atriplex canescens* (10-25%) are included in this association because the shrub density is often variable within stands, but species composition and ecological processes do not change significantly. There are several similar associations that vary according to the abundance of different co-dominants, especially graminoids. Range-wide review of these types is needed to clarify their extent.

DYNAMICS
Both *Atriplex canescens* and *Sporobolus airoides* are widespread species in semi-arid and arid western North America. Both species are able to tolerate moderately high alkalinity or salinity and finer-textured soils with poor

drainage, but they are not restricted to these soils, and can be found growing on sand (USFS 1937). The shrub has an extensive root system and is very drought tolerant. It is very palatable and especially valuable winter forage, but can be severely damaged by over-utilization (USFS 1937). The bunchgrass produces abundant long-lived seeds that enable it to fully occupy and dominate favorable sites. It is deep-rooted and produces abundant coarse forage that is best utilized during the growing season (USFS 1937).

REFERENCES

Baker 1984, Bourgeron and Engelking 1994, Diamond 1993, Dick-Peddie 1986, Donart et al. 1978, Driscoll et al. 1984, Francis 1986, Muldavin et al 2000a, Shaw et al. 1989, U.S. Forest Service (USFS) 1937, Vest 1962

Atriplex canescens Desert Wash Shrubland [Provisional]

MAP CLASS	Wupatki Wash System, Fourwing Saltbush Upland Drainageways
COMMON NAME	Fourwing Saltbush Desert Wash Shrubland
PHYSIOGNOMIC CLASS	Shrubland (III)
PHYSIOGNOMIC SUBCLASS	Evergreen shrubland (III.A)
PHYSIOGNOMIC GROUP	Extremely xeromorphic evergreen shrubland (III.A.5)
PHYSIOGNOMIC SUBGROUP	Natural/Semi-natural (III.A.5.N)
FORMATION	Facultatively deciduous extremely xeromorphic subdesert shrubland (III.A.5.N.b)
ALLIANCE	*Atriplex canescens* Shrubland Alliance

CLASSIFICATION CONFIDENCE LEVEL Weak

USFS WETLAND SYSTEM Upland

RANGE
Wupatki National Monument
Fourwing Saltbush Desert Wash Shrubland is the most common association within the wash system at Wupatki NM. This association was only located from our relevé data within Wupatki NM; however, additional sampling may identify occurrences outside of the National Monument boundaries. Within Wupatki NM it was located in Citadel Wash, in the run off area south of Crack-in-rock Road, and in side washes near Wupatki Ruins.

ENVIRONMENTAL DESCRIPTION
Wupatki National Monument
Based on our four relevés, this association's elevation ranged from 4,429-4,856 ft (1,350-1,480 m) (average 4,636 ft/1,413 m) and occurred mainly on flat or gentle inclines from 3-10% (average 5.5%). This association occurs in washes with cinder and sandstone substrate.

MOST ABUNDANT SPECIES
Wupatki National Monument

Stratum	Species
Shrub	*Atriplex canescens*

ASSOCIATED SPECIES
Wupatki National Monument
Artemisia dracunculus, Artemisia filifolia, Ephedra torreyana, Ephedra viridis, Ericameria nauseosus, Gutierrezia sarothrae, Lycium andersoni, Muhlenbergia porteri, Sphaeralcea parvifolia, Sporobolus contractus, Stanleya pinnata

VEGETATION DESCRIPTION
Wupatki National Monument
Fourwing Saltbush Desert Wash Shrubland total vegetation cover ranges from 14-25% (average 20%) with 15-24% (average 19%) absolute cover in the shrub layer and 1-7% (average 3%) absolute cover in the herbaceous layer. The total species diversity ranged from 7-17 species (average 13) within the 4 relevés sampled.

The shrub layer was dominated or co-dominated by *Atriplex canescens* with 4-16% absolute cover (average 8%). *Artemisia dracunculus* is often present in this wash association, with low to high cover 0-13% (average 4%). The herbaceous layer was low to sparse and not dominated by a single species.

CONSERVATION RANK G?

DATABASE CODE CEGL003470

MAP CLASSES
The association Fourwing Saltbush Desert Wash Shrubland is represented by map class Wupatki Wash System (map code 24) and Fourwing Saltbush Upland Drainageways (map code 18).

Wupatki Wash System consists of five associations: *Artemisia filifolia – Ephedra (torreyana, viridis)* Shrubland, *Atriplex canescens / Sporobolus airoides* Shrubland, *Atriplex canescens* Desert Wash Shrubland (Provisional), *Fallugia paradoxa (Atriplex canescens – Ephedra torreyana)* Cinder Shrubland, and *Sporobolus airoides* Herbaceous Vegetation. Each of these associations may predominate the wash depending on the site biotic and abiotic conditions.

The total area of Wupatki Wash System mapped within Wupatki NM is 1,384 ac (560 ha) within 182 polygons and the total area in the park environs is 939 ac (380 ha) within 123 polygons. The total area of Fourwing Saltbush Upland Drainageways mapped within Wupatki NM is 42 ac (17 ha) within 8 polygons and the total area in the park environs is 77 ac (31 ha) within 9 polygons.

Note:
This association is found in two different map classes:
1) Fourwing Saltbrush Upland Drainageways
2) Wupatki Wash System

Brickellia californica – Rhus trilobata Shrubland

MAP CLASS	Basalt Outcrop Shrubland
COMMON NAME	California Brickelbush – Skunkbush Sumac Shrubland
PHYSIOGNOMIC CLASS	Shrubland (III)
PHYSIOGNOMIC SUBCLASS	Deciduous shrubland (III.B)
PHYSIOGNOMIC GROUP	Cold-deciduous shrubland (III.B.2)
PHYSIOGNOMIC SUBGROUP	Natural/Semi-natural (III.B.2.N.a)
FORMATION	Temperate cold-deciduous shrubland (III.B.2.N.a)
ALLIANCE	*Brickellia californica* Shrubland Alliance

CLASSIFICATION CONFIDENCE LEVEL Weak

USFS WETLAND SYSTEM Upland

RANGE
Wupatki National Monument
California Brickelbush – Skunkbush Sumac Shrubland is an uncommon association that occurs mainly on small rock outcrops. This association was only located from our relevé data within Wupatki NM on two locations, specifically adjacent to Kana a Wash and in outcrops on and below Woodhouse Mesa.

ENVIRONMENTAL DESCRIPTION
Wupatki National Monument
Based on our three relevés, this association's elevation ranged from 4,593-5,184 ft (1,400-1,580 m) (average 4,957 ft/1,511 m), and occurs on flat or steep slopes from 0-34% (average 19%). This association occurs on rock outcrops and is associated with sandstone and remnant basaltic lava flows.

MOST ABUNDANT SPECIES
Wupatki National Monument

Stratum	Species
Shrub	*Brickellia californica, Rhus trilobata*

ASSOCIATED SPECIES
Wupatki National Monument
Andropogon hallii, Ephedra torreyana, Ericameria nauseosa, Eriogonum corymbosum, Fallugia paradoxa, Gutierrezia sarothrae, Hesperostipa comata, Pleuraphis jamesii

VEGETATION DESCRIPTION
Wupatki National Monument
California Brickelbush – Skunkbush Sumac Shrubland total vegetation cover ranges from 25-27% (average 26%) with 18-24% (average 21%) absolute cover in the shrub layer and 1-7% (average 4%) absolute cover in the herbaceous layer. The total species diversity ranged from 11-16 species (average 13) within the 3 relevés sampled.

The shrub layer was dominated or co-dominated by *Brickellia californica* with 2-9% absolute cover (average 5%) and *Rhus trilobata* with 4-9% absolute cover (average 6%). *Ericameria nauseosa* may be present with high cover within this association with 1-7% absolute cover (average 4%). The herbaceous layer was low to sparse and not dominated by a single species.

CONSERVATION RANK G?

DATABASE CODE CEGL003493

MAP CLASSES
The association California Brickelbush – Skunkbush Sumac Shrubland is represented by map class Basalt Outcrop Shrubland (map code 2).

Basalt Outcrop Shrubland represents associations that are specific to basalt outcrops within Wupatki NM. Although this is the only association defined as occurring in this map class, other species and associations are likely to occur throughout this map class in the park and envrions.

The total area mapped within Wupatki NM is 59 ac (24 ha) within 78 polygons and the total area in the park environs is 237 ac (96 ha) within 249 polygons.

Ephedra torreyana – Achnatherum hymenoides Hummock Shrubland

MAP CLASS	Mormon Tea Cinder Dune Shrubland
COMMON NAME	Torrey's Joint-fir – Indian Ricegrass Hummock Shrubland
PHYSIOGNOMIC CLASS	Shrubland (III)
PHYSIOGNOMIC SUBCLASS	Evergreen shrubland (III.A)
PHYSIOGNOMIC GROUP	Extremely xeromorphic evergreen shrubland (III.A.5)
PHYSIOGNOMIC SUBGROUP	Natural/Semi-natural (III.A.5.N)
FORMATION	Broad-leaved and microphyllous evergreen extremely xeromorphic subdesert shrubland (III.A.5.N.a)
ALLIANCE	*Ephedra torreyana* Shrubland Alliance

CLASSIFICATION CONFIDENCE LEVEL Weak

USFS WETLAND SYSTEM Upland

RANGE
Wupatki National Monument
Torrey's Joint-fir – Indian Ricegrass Hummock Shrubland is an uncommon association that occurs specifically on cinder dunes in isolated areas within the park and the environs. Relevés were only located within Wupatki NM in the southeastern section of the park east of Peshlaki Springs.

ENVIRONMENTAL DESCRIPTION
Wupatki National Monument
Based on three relevés this association's elevation ranges from 4,839-4,872 ft (1,475-1,485 m) (average 4,856 ft/1,480 m) and it occurs on flat or low slopes from 0-5% (average 2%). This association occurs specifically on cinder dunes or hummocks with cinder substrate.

MOST ABUNDANT SPECIES
Wupatki National Monument

Stratum	Species
Shrub	*Ephedra torreyana*
Herbaceous	*Achnatherum hymenoides*

ASSOCIATED SPECIES
Wupatki National Monument
Aristida purpurea, Eriogonum corymbosum, Fallugia paradoxa, Pleuraphis jamesii

VEGETATION DESCRIPTION
Wupatki National Monument
Torrey's Joint-fir – Indian Ricegrass Hummock Shrubland total vegetation cover ranges from 21-25% (average 24%) with 13-24% (average 18%) absolute cover in the shrub layer and 1-11% (average 6%) absolute cover in the herbaceous layer. The total species diversity ranges from 6-9 species (average 7) within the 3 relevés sampled.

The shrub layer was dominated by *Ephedra torreyana* (10% absolute cover in all relevés). However, *Fallugia paradoxa* had higher cover (12.5% absolute cover) in one relevé and may co-dominate in these areas. The herbaceous layer was low to moderate with *Achnatherum hymenoides* occurring in all relevés and acting as an indicator species for this association with 1-5% absolute cover (average 3%).

CONSERVATION RANK G?

DATABASE CODE CEGL005802

MAP CLASSES
The association Torrey's Joint-fir – Indian Ricegrass Hummock Shrubland is represented by map class Mormon Tea Cinder Dune Shrubland (map code 20).

The total area mapped within Wupatki NM is 343 ac (139 ha) within 17 polygons and the total area in the park environs is 744 ac (301 ha) within 59 polygons.

COMMENTS
Wupatki National Monument
The three representative relevés of this association were sampled in a limited area. Additional quantitative data of this association throughout its range may refine the species cover data.

Fallugia paradoxa – (Atriplex canescens – Ephedra torreyana) Cinder Shrubland

MAP CLASS	Apache Plume Cinder Shrubland, Wupatki Wash System
COMMON NAME	Apache Plume – (Fourwing Saltbush - Torrey's Joint-fir) Cinder Shrubland
PHYSIOGNOMIC CLASS	Shrubland (III)
PHYSIOGNOMIC SUBCLASS	Evergreen shrubland (III.A)
PHYSIOGNOMIC GROUP	Extremely xeromorphic evergreen shrubland (III.A.5)
PHYSIOGNOMIC SUBGROUP	Natural/Semi-natural (III.A.5.N)
FORMATION	Broad-leaved and microphyllous evergreen extremely xeromorphic subdesert shrubland (III.A.5.N.a)
ALLIANCE	*Fallugia paradoxa* Shrubland Alliance

CLASSIFICATION CONFIDENCE LEVEL Weak

USFS WETLAND SYSTEM Upland

RANGE
Wupatki National Monument
Apache Plume – (Fourwing Saltbush - Torrey's Joint-fir) Cinder Shrubland is a common association throughout Wupatki NM and the environs, often occurring in small areas within cinder substrate. This association was located in Wupatki NM specifically near Kana a Wash, Crack-in-rock Road, and on Doney Mountain. In the Forest Service lands, it was located east of Highway 89 adjacent to the Tuba City Road Tank.

ENVIRONMENTAL DESCRIPTION
Wupatki National Monument
Based on seventeen relevés, this association's elevation ranged from 4,462-6,070 ft (1,360-1,850m) (average 5,003 ft/1,525 m). It occurs on flat land to steep hillslopes from 0-48% slope (average 18%). This association sometimes occurs within washes or sheetflow areas. The association is found on red and black cinder.

MOST ABUNDANT SPECIES
Wupatki National Monument

Stratum	Species
Shrub	*Atriplex canescens, Ephedra torreyana, Fallugia paradoxa*

ASSOCIATED SPECIES
Wupatki National Monument
Artemisia dracunculus, Bouteloua eriopoda, Bouteloua gracilis, Brickellia oblongifolia, Ephedra viridis, Ericameria nauseosa, Gutierrezia sarothrae, Hesperostipa comata, Muhlenbergia porteri, Phacelia welshii, Pleuraphis jamesii, Tetraclea coulteri

VEGETATION DESCRIPTION
Wupatki National Monument
Apache Plume – (Fourwing saltbush - Torrey's Joint-fir) Cinder Shrubland total vegetation cover ranges from 6-40% (average 20%) with 4-27% (average 16%) absolute cover in the shrub layer and 1-17% (average 5%) absolute cover in the herbaceous layer. The total species diversity ranged from 6-24 species (average 12) within the 17 relevés sampled.

The shrub layer is dominated by *Fallugia paradoxa* with 2-22% absolute cover (average 9%). *Atriplex canescens* and *Ephedra torreyana* are also often consistent species within this association; *Atriplex canescens* with 0-7% (average 2% absolute cover) and *Ephedra torreyana* with 0-9% (average 3% absolute cover). Other shrub species like *Ericameria nauseosa* may dominate this association as smaller patches within larger *Fallugia paradoxa* matrix. The herbaceous layer is low to moderate in cover with no consistent species.

CONSERVATION RANK G?

DATABASE CODE CEGL005806

MAP CLASSES
The association Apache Plume – (Fourwing Saltbush - Torrey's Joint-fir) Cinder Shrubland is represented by map class Apache Plume Cinder Shrubland (map code 21) and can also occur as a mosaic within the map class Wupatki Wash System (map code 24).

The Wupatki Wash System is a mosaic of associations that includes: *Sporobolus airoides* Herbaceous Vegetation, *Artemisia filifolia – Ephedra (torreyana, viridis)* Shrubland, *Atriplex canescens / Sporobolus airoides* Shrubland, *Atriplex canescens* Desert Wash Shrubland (Provisional), and *Fallugia paradoxa – (Atriplex canescens – Ephedra torreyana)* Cinder Shrubland.

The total area mapped within Wupatki NM is 2,471 ac (1,000 ha) within 576 polygons and the total area in the park environs is 2,414 ac (977 ha) within 374 polygons.

COMMENTS
Wupatki National Monument
Cinder substrate and the presence of *Fallugia paradoxa*, *Atriplex canescens*, or *Ephedra torreyana* are diagnostic for this association. Cover ranges from sparse to moderate. For sparse examples of this association, the diagnostic species may be widely spaced. *Fallugia paradoxa* is the most consistent species for this association.

Note:
This association is found in two different map classes:
1) Apache Plume Cinder Shrubland
2) Wupatki Wash System

Gutierrezia sarothrae Dwarf-Shrubland Alliance

MAP CLASS	Snakeweed/Galleta Grassland
COMMON NAME	Snakeweed Dwarf-Shrub Alliance
PHYSIOGNOMIC CLASS	Dwarf-shrubland (IV)
PHYSIOGNOMIC SUBCLASS	Deciduous dwarf-shrubland (IV.B)
PHYSIOGNOMIC GROUP	Cold-deciduous dwarf-shrubland (IV.B.2)
PHYSIOGNOMIC SUBGROUP	Natural/Semi-natural (IV.B.2.N.a)
FORMATION	Caespitose cold-deciduous dwarf-shrubland (IV.B.2.N.a)
ALLIANCE	*Gutierrezia sarothrae* Dwarf-shrubland Alliance

CLASSIFICATION CONFIDENCE LEVEL Alliances are not ranked for confidence by NatureServe.

USFS WETLAND SYSTEM Upland

RANGE

Wupatki National Monument

Snakeweed Dwarf-Shrub Alliance was only identified in one location on the Navajo Nation. This relevé was found in a heavily grazed area northeast of Black Falls Crossing, adjacent to the Little Colorado River. More extensive sampling on the Navajo Nation may identify additional occurrences of this alliance; however, with a limited sample size we were not able to further assign this relevé to an association.

Globally

This alliance is reported from Utah and Arizona, but is likely more widespread throughout the semi-arid western U.S.

ENVIRONMENTAL DESCRIPTION

Wupatki National Monument

Based on the one observed relevé, this alliance was located on a flat surface at 4,298 ft (1,310 m) on sandy soils with cinder gravel intermixed.

Globally

This alliance is described from Utah and Arizona. Elevations range from 4,429-6,562 ft (1,350-2,000 m). Sites include stream terraces, plains, gently sloping hillslopes, ridges, plateaus and bluffs. Stands occur on all aspects. Soils are variable, but tend to be fine-textured and may occur over gravel and cobbles. Disturbance may be important in maintaining this vegetation community in some areas as some stands may have been created by chaining of trees and improper grazing by livestock.

MOST ABUNDANT SPECIES

Wupatki National Monument

Stratum	Species
Shrub	*Gutierrezia sarothrae*

Globally

Stratum	Species
Shrub	*Gutierrezia sarothrae*

ASSOCIATED SPECIES

Wupatki National Monument

Aristida purpurea, Achnatherum hymenoides, Ericameria nauseosa, Isocoma drummondii, Sporobolus airoides

Globally

Opuntia spp, *Pinus edulis, Juniperus osteosperma, Achnatherum hymenoides, Aristida purpurea, Bouteloua gracilis, Elymus elymoides, Hesperostipa comata, Pascopyrum smithii, Pleuraphis jamesii*, *Sporobolus airoides*, *Chamaesyce* spp, *Sphaeralcea coccinea*, *Bromus tectorum, Salsola kali*

VEGETATION DESCRIPTION

Wupatki National Monument

Snakeweed Dwarf-Shrub Alliance's total vegetation cover was 27%, with 22% absolute cover in the shrub layer and 8% absolute cover in the herbaceous layer. Within the one relevé sampled the total species diversity was 10.

The shrub layer was dominated by *Gutierrezia sarothrae* with 15% absolute cover. The herbaceous layer was moderate with 4% absolute cover of both *Aristida purpurea* and *Sporobolus airoides*.

Globally

This broadly defined alliance is characterized by an open to moderately dense dwarf-shrub canopy (10-50% cover) dominated by *Gutierrezia sarothrae*, frequently with *Opuntia* spp. and a sparse to moderately dense herbaceous layer. Some stands have a diverse woody layer that includes low cover of *Artemisia nova, Atriplex canescens, Atriplex confertifolia, Atriplex obovata, Chrysothamnus viscidiflorus, Coleogyne ramosissima, Ephedra* spp., *Eriogonum* spp., *Grayia spinosa, Lycium pallidum, Parryella filifolia, Purshia tridentata, Yucca* spp., or occasional *Pinus edulis* or *Juniperus osteosperma* trees. The herbaceous layer is typically dominated by graminoids with several species present to abundant including *Pleuraphis jamesii, Achnatherum hymenoides, Aristida purpurea, Bouteloua gracilis, Elymus elymoides, Hesperostipa comata, Pascopyrum smithii*, or *Sporobolus airoides*. There is usually only sparse cover of native forbs like *Chamaesyce* spp. or *Sphaeralcea coccinea*; however, introduced species such as *Bromus tectorum, Erodium cicutarium, Sisymbrium altissimum*, or *Salsola kali* may dominate the herbaceous layer of some disturbed stands.

DATABASE CODE A.2528

MAP CLASSES

The alliance Snakeweed Dwarf-Shrub Alliance is represented by the map class Snakeweed/Galleta Grassland (map code 13).

The total area mapped within Wupatki NM is 237 ac (96 ha) within 60 polygons and the total area in the park environs is 662 ac (268 ha) within 131 polygons.

COMMENTS

Wupatki National Monument

Although only one relevé is assigned to this alliance, it is likely that with increased sampling, especially on the Navajo Nation, more relevés would be classified within this alliance. Increased sample size would allow for further refinement and classification of this alliance to the association level.

Although this relevé did occur on an anthropogenically disturbed site, other stands of *Gutierrezia sarothrae* are likely to occur in areas that have not been impacted by humans.

Globally

This broadly defined dwarf-shrubland alliance includes stands that could also be classified as a dwarf-shrub herbaceous vegetation.

REFERENCES

Stubbendieck et al. 1992, Cogan et al. 2004, USFS 1937, Von Loh 2000

Poliomintha incana / (Pleuraphis jamesii) Shrubland

MAP CLASS	Frosted Mint Shrubland
COMMON NAME	Hoary Rosemary-mint / (Galleta) Shrubland
PHYSIOGNOMIC CLASS	Shrubland (III)
PHYSIOGNOMIC SUBCLASS	Evergreen shrubland (III.A)
PHYSIOGNOMIC GROUP	Extremely xeromorphic evergreen shrubland (III.A.5)
PHYSIOGNOMIC SUBGROUP	Natural/Semi-natural (III.A.5.N)
FORMATION	Broad-leaved and microphyllous evergreen extremely xeromorphic subdesert shrubland (III.A.5.N.a)
ALLIANCE	*Poliomintha incana* Shrubland Alliance

CLASSIFICATION CONFIDENCE LEVEL Weak

USFS WETLAND SYSTEM Upland

RANGE
Wupatki National Monument
Hoary Rosemary-mint / (Galleta) Shrubland is a common association occurring in the eastern section of the project boundary in sand dunes at Wupatki NM and the environs. This association was located from the relevé data on Wupatki NM south of Tse Lichii Point, west of the Little Colorado River, and north of Deadman's wash. On the USDA-FS it was located east Highway 89 adjacent to the Tuba City Road Tank and near Kish Zhini wash.

ENVIRONMENTAL DESCRIPTION
Wupatki National Monument
Based on six relevés, this association was found from low to high elevations, 4,236-6,178 ft (1,291-1,883 m) (average 4,364 ft/1,330 m). It occurs on flat land to steep slopes ranging from 0-27% (average 14%). This association occurs on sand dunes with sandy soils that can be intermixed with clay, riverine cobbles, and cinders.

MOST ABUNDANT SPECIES
Wupatki National Monument

Stratum	Species
Shrub	*Poliomintha incana*
Herbaceous	*Pleuraphis jamesii*

ASSOCIATED SPECIES
Wupatki National Monument
Achnatherum hymenoides, Alhagi maurorum, Artemisia filifolia, Atriplex canescens, Bouteloua eriopoda, Dasyochloa pulchella, Ephedra torreyana, Ericameria nauseosa, Gutierrezia sarothrae, Isocoma drummondii, Isocoma pluriflora, Parryella filifolia, Psorothamnus thompsoniae var. *whitingii, Sporobolus airoides, Sporobolus flexuosus, Tiquilia latior, Yucca angustissima*

VEGETATION DESCRIPTION
Wupatki National Monument
Hoary Rosemary-mint / (Galleta) Shrubland total vegetation cover ranges from 10-45% (average 28%) with 9-22% (average 15%) absolute cover in the shrub layer and 2-30% (average 12%) absolute cover in the herbaceous layer. The total species diversity ranged from 11-21 species (average 15) within the 6 relevés sampled.

The indicator shrub for this association, *Poliomintha incana,* ranges from 2-6% absolute cover (average 3%). *Gutierrezia sarothrae* consistently occurred in our relevés and ranged in cover from 1-4% (average 2%). Dominant shrub species may include: *Artemisia filifolia, Ephedra torreyana, Isocoma pluriflora,* and *Psorothamnus thompsoniae* var. *whitingii.* The herbaceous layer's most consistent species is *Pleuraphis jamesii*; however, it was not present in all of our relevés and ranged in cover from 0-7% (average 2%).

CONSERVATION RANK G?

DATABASE CODE CEGL002930

MAP CLASSES
The association Hoary Rosemary-mint / (Galleta) Shrubland is represented by map class Frosted Mint Shrubland (map code 22).

The total area mapped within Wupatki NM is 220 ac (89 ha) within 8 polygons and the total area in the park environs is 10 ac (4 ha) within 1 polygon.

COMMENTS
Wupatki National Monument
Poliomintha incana is an indicator for Hoary Rosemary-mint / (Galleta) Shrubland at Wupatki NM; however, other shrubs may be dominant. The understory species, *Pleuraphis jamesii*, was selected as occurring most consistently within the relevés; however, other understory species may also dominate the association. The classification of this association may need to be reviewed with additional data.

Salix exigua / Barren Shrubland

MAP CLASS	Sandbar Willow Shrubland
COMMON NAME	Coyote Willow / Barren Shrubland
PHYSIOGNOMIC CLASS	Shrubland (III.)
PHYSIOGNOMIC SUBCLASS	Deciduous shrubland (III.B.)
PHYSIOGNOMIC GROUP	Cold-deciduous shrubland (III.B.2.)
PHYSIOGNOMIC SUBGROUP	Natural/Semi-natural (III.B.2.N.)
FORMATION	Temporarily flooded cold-deciduous shrubland (III.B.2.N.d.)
ALLIANCE	*Salix (exigua, interior)* Temporarily Flooded Shrubland Alliance

CLASSIFICATION CONFIDENCE LEVEL Strong

USFS WETLAND SYSTEM Palustrine

RANGE

Wupatki National Monument

Coyote Willow (sandbar willow) / Barren Shrubland has been only identified at Wupatki NM on the Little Colorado River. One relevé was identified on the east shore banks of the Little Colorado River, north of Black Falls Crossing. Only one small stand was sampled of this association, which may be due to *Tamarix* spp., a non-native invasive, possibly out-competing with the native *Salix exigua*. With more extensive sampling on the banks of the Little Colorado River more examples of this association may be revealed; however, it is likely that this association is diminishing within the project environs.

Globally

This riparian shrubland association is common at lower to middle elevations in the Great Basin, Colorado Plateau and Rocky Mountains extending out into the western Great Plains along major rivers.

ENVIRONMENTAL DESCRIPTION

Wupatki National Monument

This association was measured on the flat sandy riverbanks of the Little Colorado River at 4,268 ft (1,301 m).

Globally

This riparian shrubland is common in the Rocky Mountains, Colorado Plateau and Great Basin. Elevation ranges from 2,559-8,530 ft (780-2600 m). This association occurs within the annual flood zone of rivers on point bars, islands, sand or cobble bars, and on streambanks occurring along a wide variety of stream reaches, from moderately sinuous and moderate-gradient reaches. It can form large, wide stands on mid-channel islands in larger rivers or narrow stringer bands on small, rocky tributaries. Substrates are typically coarse alluvial deposits of sand, silt and cobbles that are highly stratified vertically from flooding scour and deposition, often consisting of alternating layers of finer textured soil with organic material over coarser alluvium. Occasionally, this association occurs on deep pockets of sand. The lack of soil development and high ground cover of coarse alluvial material are key indicators for this association.

MOST ABUNDANT SPECIES

Wupatki National Monument

Stratum	Species
Shrub	*Salix exigua*

Globally

Stratum	Species
Shrub	*Salix exigua*

ASSOCIATED SPECIES

Wupatki National Monument

Alhagi maurorum, Tamarix chinensis

Globally
Alnus incana, Salix monticola, Salix ligulifolia, Salix irrorata, Salix lucida, Acer negundo, Abies lasiocarpa, Populus angustifolia, Populus deltoides, *Populus fremontii, Mentha arvensis*, *Carex* spp., *Eleocharis* spp., *Juncus* spp., *Schoenoplectus* spp., *Equisetum* spp.

VEGETATION DESCRIPTION
Wupatki National Monument
Coyote Willow / Barren Shrubland total vegetation cover was 71%, with 71% absolute cover in the shrub layer and no species in the herbaceous layer. Within the one relevé sampled the total species diversity was 7.

The shrub layer is dense and consists solely of *Salix exigua*. The herbaceous layer is barren with no species occurring in this layer, as is indicated in the association nomenclature.

Globally
This riparian association is characterized by a sparse to dense tall-shrub (1.5-3 m) canopy composed of *Salix exigua* with ground cover of exposed gravel, cobbles or sand. Relatively low cover of several other shrubs and trees may be present including *Alnus incana, Salix monticola, Salix ligulifolia (= Salix eriocephala* var. *ligulifolia), Salix irrorata, Salix lucida, Acer negundo, Abies lasiocarpa, Populus angustifolia, Populus deltoides*, and *Populus fremontii*. A sparse herbaceous layer may be present among the bare soil, gravel, cobbles, or boulders consisting of a wide variety of forbs and graminoids. *Mentha arvensis*, and species of *Carex, Eleocharis, Juncus, Schoenoplectus*, and *Equisetum* are often present. Introduced species, such as *Elaeagnus angustifolia, Tamarix* spp., *Bromus tectorum, Bromus inermis, Elymus repens (= Elytrigia repens), Poa pratensis, Agrostis stolonifera* (and other exotic forage species), *Taraxacum officinale, Conyza canadensis*, and *Lepidium latifolium*, have been reported from some stands.

CONSERVATION RANK G5

DATABASE CODE CEGL001200

MAP CLASSES
The association Coyote Willow / Barren Shrubland is represented by the map class Sandbar Willow Shrubland (map code 25).

The total area mapped within Wupatki NM is 3 ac (1 ha) within 5 polygons and the total area in the park environs is 20 ac (8 ha) within 28 polygons.

COMMENTS
Wupatki National Monument
The Little Colorado River riverbanks can alter significantly depending on the flooding regime, therefore it is likely that the riverbed has changed from when the photography was taken to when the field sampling was conducted. This map class is likely to change throughout time and should be reassessed annually to determine change in the riverbeds and the vegetation communities.

Only one relevé was assigned to this association, which may be due to a not enough relevés sampled on the Little Colorado River as well as small populations sizes within the project boundaries.

Globally
In the western Great Plains this association includes stands composed of intermediates between *Salix interior (= Salix exigua* ssp. *interior)* and *Salix exigua (= Salix exigua* ssp. *exigua)* (Dorn 1997, G. Kittel pers. comm. 2001). Until recently these taxa were combined at the species level (Kartesz 1999). More information on the distribution of introgression between *Salix interior (= Salix exigua* ssp. *interior)* and *Salix exigua (= Salix exigua* ssp. *exigua)* is needed to fully understand the ranges of these two species.

This association is an early-seral type that colonizes newly created point bars and other recent alluvial deposits formed in rivers and streams (Kittel et al. 1999). Competition with *Tamarix* spp. in the southwestern U.S. likely limit the abundance of this association where these introduced species dominate.

REFERENCES

Bourgeron and Engelking 1994, Christy 1973, Cowardin et al. 1979, Dorn 1997, Driscoll et al. 1984, Hall and Hansen 1997, Hansen et al. 1995, Johnston 1987, Jones and Walford 1995, Kittel and Lederer 1993, Kittel et al. 1994, Kittel et al. 1995, Kittel et al. 1996, Kittel et al. 1999, Muldavin et al. 2000b, Padgett et al. 1988, Padgett et al. 1989, Tuhy and Jensen 1982, Von Loh et al. 2002

Tamarix spp. Temporarily Flooded Shrubland

MAP CLASS	Little Colorado River Invasive Riparian Shrubland
COMMON NAME	Saltcedar Temporarily Flooded Shrubland
PHYSIOGNOMIC CLASS	Shrubland (III.)
PHYSIOGNOMIC SUBCLASS	Microphyllous shrubland (III.A.4.N.c.)
PHYSIOGNOMIC GROUP	Temporarily flooded microphyllous shrubland (III.A.4.N.c.)
PHYSIOGNOMIC SUBGROUP	Natural/Semi-natural
FORMATION	Temporarily flooded microphyllous shrubland (III.A.4.N.c.)
ALLIANCE	*Tamarix* ssp. Semi-natural Temporarily Flooded Shrubland Alliance

CLASSIFICATION CONFIDENCE LEVEL Moderate

USFS WETLAND SYSTEM Palustrine

RANGE

Wupatki National Monument

Saltcedar Temporarily Flooded Shrubland is the most common riparian association at Wupatki NM and the environs. This association is found from our relevé data to occur in major drainages with intermittent stream flow including the Little Colorado River and Deadman's Wash within Wupatki NM and the Navajo Nation.

Globally

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

ENVIRONMENTAL DESCRIPTION

Wupatki National Monument

Based on six relevés, this association occurs on sandy riverbanks with low or no slopes (ranging 0-7%, average 1%) at elevations ranging from 3,960-4,364 ft (1,207-1,330 m) (average 4,199 ft/1,280 m).

Globally

These widespread shrublands are common along larger streams, rivers, and around playas in the western U.S. and Mexico. Elevation ranges from 246 ft (75 m) below sea level to 6,102 ft (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 like *Populus* spp. are declining. Substrates are commonly thin sandy loam soil over alluvial deposits of sand, gravel or cobbles.

MOST ABUNDANT SPECIES

Wupatki National Monument

Stratum	Species
Shrub	*Tamarix* spp.

Globally

Stratum	Species
Shrub	*Tamarix ramosissima, T. chinensis, T. gallica*, or *T. parviflora*

ASSOCIATED SPECIES

Wupatki National Monument

Alhagi maurorum, Gutierrezia sarothrae, Isocoma pluriflora, Pascopyrum smithii, Salix exigua

Globally

Salix exigua, Prosopis spp., *Rhus trilobata*, and *Sarcobatus vermiculatus*

VEGETATION DESCRIPTION

Wupatki National Monument

Saltcedar Temporarily Flooded Shrubland total vegetation cover ranges from 14-90% (average 55%) with 12-90% (average 54%) absolute cover in the shrub layer and 0-8% (average 2%) absolute cover in the herbaceous layer. The total species diversity ranged from pure monocultures *Tamarix* spp. to a more diverse riparian biota with 1-12 species (average 6) within the 6 relevés sampled.

The shrub layer was dominated almost exclusively by *Tamarix* spp. with 6-95% absolute cover (average 49%). The herbaceous layer was low to moderate with no consistent species.

Globally

This semi-natural shrubland 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 *T. ramosissima, T. chinensis, T. gallica*, and *T. parviflora*. Other shrubs may include species of *Salix* (especially *Salix exigua*) and *Prosopis, Rhus trilobata*, *Gutierrezia sarothrae, Isocoma pluriflora* and *Sarcobatus vermiculatus,* but with low cover (if shrub species are codominant then the 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 *Pascopyrum smithii*, *Distichlis spicata, Sporobolus airoides*, and introduced forage species such as *Agrostis gigantea, Agrostis stolonifera*, and *Poa pratensis*. Introduced herbaceous species such as *Polypogon monspeliensis, Conyza canadensis, Lepidium latifolium*, *Alhagi maurorum* and others have been reported from shrublands in this association.

CONSERVATION RANK GW

DATABASE CODE CEGL003114

MAP CLASSES

The association *Tamarix* spp. Temporarily Flooded Shrubland is represented by the map class Little Colorado River Invasive Riparian Shrubland (map code 26).

The map class Little Colorado River Invasive Riparian Shrubland also includes *Alhagi maurorum* Semi-natural Shrubland.

The total area mapped within Wupatki NM is 77 ac (31 ha) within 8 polygons and the total area in the park environs is 1,774 ac (718 ha) within 74 polygons.

COMMENTS

Wupatki National Monument

The Little Colorado River riverbanks can alter significantly depending on the flooding regime, therefore it is likely that the riverbed has changed from when the photography was taken to when the field sampling was conducted. This map class is likely to change throughout time and should be reassessed annually to determine change in the riverbeds and the vegetation communities.

It is characterized by dominance of the non-native invasive *Tamarix* spp. This shrub may be spreading and converting or degrading riparian associations characterized by native species. This vegetation association should be actively managed and monitored by park staff.

Globally

Tamarix spp. Temporarily Flooded Shrubland (CEGL003114) is a broadly defined plant association that is composed of many diverse *Tamarix* spp.-dominated vegetation communities from a wide variety of environments. Muldavin et al. (2000b) described 8 community types that will be reviewed as possible NVC associations.

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 with herbicide application on stumps to prevent resprouting (Smith 1989).

REFERENCES

Baalman 1965, Cowardin et al. 1979, Hansen et al. 1995, Hoagland 2000, Holland 1986, Muldavin et al. 2000b, Nachlinger and Reese 1996, Ortenberger and Bird 1933, Paysen et al. 1980, Sawyer and Keeler-Wolf 1995, Smith 1989, Stevens and Shannon 1917, Szaro 1989, Ungar 1968, Von Loh et al. 2002, Ware and Penfound 1949

Populus fremontii / Salix exigua Forest

MAP CLASS	Fremont Cottonwood Woodland
COMMON NAME	Fremont Cottonwood / Coyote Willow Forest
PHYSIOGNOMIC CLASS	Forest (I.)
PHYSIOGNOMIC SUBCLASS	Deciduous forest (I.B.)
PHYSIOGNOMIC GROUP	Cold-deciduous forest (I.B.2.)
PHYSIOGNOMIC SUBGROUP	Natural/Semi-natural (I.B.2.N.)
FORMATION	Temporarily flooded cold-deciduous forest (I.B.2.N.d.)
ALLIANCE	*Populus fremontii* Temporarily Flooded Forest Alliance

CLASSIFICATION CONFIDENCE LEVEL Weak

USFS WETLAND SYSTEM Palustrine

RANGE

Wupatki National Monument

Fremont Cottonwood / Coyote Willow Forest has been identified in our relevé data from Wupatki NM only on the Little Colorado River. One relevé was found on the north shore banks of the Little Colorado River adjacent to Inscription Point. This small isolated stand of *Populus fremontii* may be a remnant association that is declining due to invasion of non-native *Tamarix* spp. With more extensive sampling on the riverbank of the Little Colorado River larger patches of this association may be identified; however, it is likely that this association is diminishing within the project boundary.

Globally

This riparian forest is known from southwestern New Mexico along the Gila River, the East Fork of the Virgin River in southwestern Utah, and in canyons in north-central Arizona. It likely occurs elsewhere in Utah and Arizona.

ENVIRONMENTAL DESCRIPTION

Wupatki National Monument

Based on one relevé, this association was located on the sandy riverbanks of the Little Colorado River at 4,249 ft (1,295 m).

Globally

This riparian forest association is documented from large rivers in southwestern Utah, southwestern New Mexico, and Arizona. Elevation ranges from 4,003-5,577 ft (1,220-1,700 m). Stands are found on stable bars in floodplains and along streambanks in canyons. Substrates are typically relatively recently deposited alluvium. Stream gradient is typically gentle, and soils are sandy (Muldavin et al. 2000b, Szaro 1989).

MOST ABUNDANT SPECIES

Wupatki National Monument

Stratum	Species
Tree canopy	*Populus fremontii*
Shrub	*Salix exigua*

Globally

Stratum	Species
Tree canopy	*Populus fremontii*
Shrub	*Salix exigua*
Herbaceous	*Phragmites australis*, *Artemisia ludoviciana*

ASSOCIATED SPECIES

Wupatki National Monument

Alhagi maurorum, Tamarix chinensis

Globally
Acer negundo, Betula occidentalis, Ericameria nauseosa, Artemisia tridentata, Quercus gambelii, Distichlis spicata, Muhlenbergia asperifolia, Phragmites australis, Equisetum spp., *Juncus* spp., *Carex* spp.

VEGETATION DESCRIPTION
Wupatki National Monument
Fremont Cottonwood / Coyote Willow Forest total vegetation cover was 40%, with 20% absolute cover in the shrub layer and 20% absolute cover the herbaceous layer. Within the one relevé sampled the total species diversity was 7.

Salix exigua is an indicator species in the shrub layer (7% absolute cover). *Tamari*x spp. has higher percent shrub cover (13% absolute cover); however, it is ubiquitous and non-native and is not representative of this native riparian vegetation association. The herbaceous layer had little cover with no dominant species.

Globally
This association is characterized by an open to dense deciduous tree canopy that is dominated by *Populus fremontii*, with *Salix exigua* dominating the tall-shrub layer. *Acer negundo* may be present in the tree canopy, but *Salix gooddingii* is typically not. *Baccharis salicifolia* is also typically not abundant in the shrub layer, but a variety of other riparian and upland shrub species may be present, including *Betula occidentalis*, *Ericameria nauseosa*, *Artemisia tridentata*, or *Quercus gambelii*. The herbaceous layer is generally sparse, depending on the density of the shrub and tree layers. *Distichlis spicata*, *Muhlenbergia asperifolia, Phragmites australis*, and species of *Equisetum*, *Juncus*, and *Carex* are commonly present (Muldavin et al. 2000b, Szaro 1989). Introduced species such as *Elaeagnus angustifolia, Tamarix* spp., *Alhagi maurorum, Melilotus* spp., *Bromus* spp., and *Poa pratensis* are often present in disturbed stands.

CONSERVATION RANK G?

DATABASE CODE CEGL000666

MAP CLASSES
The association Fremont Cottonwood / Coyote Willow Forest is represented by the map class Fremont Cottonwood Woodland (map code 28).

The total area mapped within Wupatki NM is 3 ac (1 ha) within 2 polygons and the total area in the park environs is 12 ac (5 ha) within 12 polygons.

COMMENTS
Wupatki National Monument
The Little Colorado River riverbanks can alter significantly depending on the flooding regime, therefore it is likely that the riverbed has changed from when the photography was taken to when the field sampling was conducted. This map class may be likely to change throughout time and should be reassessed for annual variability in the riverbeds and the vegetation communities.

This association should be assigned special park status to recognize and monitor change in the population throughout time. No *Populus fremontii* juveniles or seedlings were found in the relevé. This may indicate that this association is not recruiting on the banks of the Little Colorado River.

Globally
This association was not reported in the Handbook of Wetland Vegetation Communities of New Mexico (Muldavin et al. 2000b) and needs further review to distinguish from similar associations such as *Populus fremontii - Salix gooddingii / Salix exigua* Forest (CEGL002684). Part of the confusion is related to a taxonomic change in Rio Grande cottonwood from *Populus fremontii* var. *wislizeni* S. Wats. to *Populus deltoides* ssp. *wislizeni* (S. Wats.) Eckenwalder. This change resulted in part of this association (central NM along the Rio Grande) being moved into *Populus deltoides / Salix exigua* Woodland (CEGL002685). More work is needed to determine the range and possible areas of overlap between these two cottonwood species.

Few intact examples of this association remain in the Southwest U.S. It is documented from the Gila, middle Rio Grande and, possibly the lower Pecos rivers of southern New Mexico. It may also occur in southern Arizona. This association is found on stable bars at mid-elevations of the floodplain; it develops on recently deposited alluvium. Flood flows are required for the growth, maintenance and reproduction of this community type. The association continues to be in decline, primarily as a function of major hydrological alterations (dams and diversions), grazing, off-road vehicles and agricultural conversion. The remaining functional stands are restricted to wild rivers such as the Gila and San Francisco rivers, and possibly along the Mimbres River in New Mexico, or the San Pedro River in Arizona. It is a significant association with respect to biodiversity, particularly birds in the Southwest. Stands are rare that have not been invaded by exotic trees, shrubs and herbs. Even protected examples are threatened by continued declines in upland watershed conditions.

Periodic flooding is required for the growth, maintenance and reproduction of this forest.

REFERENCES

Bourgeron and Engelking 1994, Driscoll et al. 1984, Muldavin et al. 1993, Muldavin et al. 2000b, NMNHP n.d., Szaro 1989

REFERENCES

Aldous, A. E., and H. L. Shantz. 1924. Types of vegetation in the semiarid portion of the United States and their economic significance. Journal of Agricultural Research 28(2):99-128.

Baalman, R. J. 1965. Vegetation of the Salt Plains National Wildlife Refuge, Jet, Oklahoma. Unpublished Ph.D. dissertation, University of Oklahoma, Norman.

Baker, W. L. 1984. A preliminary classification of the natural vegetation of Colorado. Great Basin Naturalist 44(4):647-676.

Bourgeron, P. S., and L. D. Engelking, editors. 1994. A preliminary vegetation classification of the western United States. Unpublished report. The Nature Conservancy, Western Heritage Task Force, Boulder, CO. 175 pp. plus appendix.

Cannon, H. L. 1960. The development of botanical methods of prospecting for uranium on the Colorado Plateau. USDI Geological Survey Bulletin 1085-A. Washington, DC. 50 pp.

Christy, S. 1973. An analysis of the woody vegetation on the South Platte River flood plain in northeastern Colorado. Unpublished thesis, University of Northern Colorado, Greeley. 82 pp.

Cogan, D., M. Reid, K. Schulz, and M. Pucherelli. 2004. Zion National Park, Utah. 1999-2003 Vegetation Mapping Project, Rinal Report. March 31, 3004. Technical Memoradum 8260-03-01. Remote Sensing and GIS Group Technical Service Center. Bureau of Reclaimation, Denver, Colorado. 72pp. and Appendices.

Collins, E. I. 1984. Preliminary classification of Wyoming plant communities. Unpublished classification prepared for the Wyoming Natural Heritage Program, The Nature Conservancy, Laramie, WY.

Cowardin, L. M., V. Carter, F. C. Golet, and E. T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. U.S. Fish and Wildlife Service, Biological Service Program. FWS/OBS-79/31. Washington, DC. 103 pp.

Diamond, D. D. 1993. Classification of the plant communities of Texas (series level). Unpublished document. Texas Natural Heritage Program, Austin. 25 pp.

Dick-Peddie, W. A. 1986. Draft manuscript for book on vegetation of New Mexico to be published by University of New Mexico Press.

Donart, G. B., D. Sylvester, and W. Hickey. 1978. A vegetation classification system for New Mexico, USA. Pages 488-490 in: Rangeland Congress, Denver, CO, 14-18 August 1978. Society for Range Management, Denver.

Dorn, R. D. 1997. Rocky Mountain region willow identification field guide. Renewable Resources R2-RR-97-01. USDA Forest Service, Rocky Mountain Region, Denver, CO. 107 pp.

Driscoll, R. S., D. L. Merkel, D. L. Radloff, D. E. Snyder, and J. S. Hagihara. 1984. An ecological land classification framework for the United States. USDA Forest Service. Miscellaneous Publication No. 1439. Washington, DC. 56 pp.

Francis, R. E. 1986. Phyto-edaphic communities of the Upper Rio Puerco Watershed, New Mexico. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station. Research Paper RM-272. Fort Collins, CO. 73 pp.

Francis, R. E., and E. F. Aldon. 1983. Preliminary habitat types of a semiarid grassland. Pages 62-66 in: W. H. Moir and L. Hendzel, technical coordinators. Proceedings of the workshop on southwestern habitat types, 6-8 April 1983, Albuquerque, NM. USDA Forest Service, Southwestern Region, Albuquerque, NM.

Hall, J. B., and P. L. Hansen. 1997. A preliminary riparian habitat type classification system for the Bureau of Land Management districts in southern and eastern Idaho. Riparian and Wetland Research Program, School of Forestry, University of Montana. Idaho Bureau of Land Management, Technical Bulletin No. 97-11. 381 pp.

Hansen, P. L., R. D. Pfister, K. Boggs, B. J. Cook, J. Joy, and D. K. Hinckley. 1995. Classification and management of Montana's riparian and wetland sites. Montana Forest and Conservation Experiment Station, School of Forestry, University of Montana, Miscellaneous Publication No. 54. 646 pp. + posters.

Helm, D. J. 1981. Vegetation diversity indexes in several vegetation types of western Colorado. Unpublished dissertation, Colorado State University, Fort Collins. 113 pp.

Hoagland, B. 2000. The vegetation of Oklahoma: A classification for landscape mapping and conservation planning. The Southwestern Naturalist 45(4):385-420.

Holland, R. F. 1986. Preliminary descriptions of the terrestrial natural communities of California. Unpublished report prepared for the California Department of Fish and Game, Nongame-Heritage Program and Natural Diversity Database, Sacramento. 156 pp.

Johnston, B. C. 1987. Plant associations of Region Two: Potential plant communities of Wyoming, South Dakota, Nebraska, Colorado, and Kansas. R2-ECOL-87-2. USDA Forest Service, Rocky Mountain Region. Lakewood, CO. 429 pp.

Jones, G. P., and G. M. Walford. 1995. Major riparian vegetation types of eastern Wyoming. Submitted to Wyoming Department of Environmental Quality, Water Quality Division. Wyoming Natural Diversity Database, Laramie, WY. 245 pp.

Kartesz, J. T. 1999. A synonymized checklist and atlas with biological attributes for the vascular flora of the United States, Canada, and Greenland. First edition. In: J. T. Kartesz and C. A. Meacham. Synthesis of the North American Flora, Version 1.0. North Carolina Botanical Garden, Chapel Hill, NC.

Kittel, G. M., and N. D. Lederer. 1993. A preliminary classification of the riparian vegetation of the Yampa and San Miguel/Dolores river basins. Unpublished report prepared for Colorado Department of Health and the Environmental Protection Agency by The Nature Conservancy, Colorado Field Office, Boulder.

Kittel, G., R. Rondeau, N. Lederer, and D. Randolph. 1994. A classification of the riparian vegetation of the White and Colorado River basins, Colorado. Final report submitted to Colorado Department of Natural Resources and the Environmental Protection Agency. Colorado Natural Heritage Program, Boulder. 166 pp.

Kittel, G., R. Rondeau, and S. Kettler. 1995. A classification of the riparian vegetation of the Gunnison River Basin, Colorado. Submitted to Colorado Department of Natural Resources and the Environmental Protection Agency. Prepared by Colorado Natural Heritage Program, Fort Collins. 114 pp.

Kittel, G., R. Rondeau, and A. McMullen. 1996. A classification of the riparian vegetation of the Lower South Platte and parts of the Upper Arkansas River basins, Colorado. Submitted to Colorado Department of Natural Resources and the Environmental Protection Agency, Region VIII. Prepared by Colorado Natural Heritage Program, Fort Collins. 243 pp.

Kittel, G., E. Van Wie, M. Damm, R. Rondeau, S. Kettler, and J. Sanderson. 1999. A classification of the riparian plant associations of the Rio Grande and Closed Basin watersheds, Colorado. Unpublished report prepared by the Colorado Natural Heritage Program, Colorado State University, Fort Collins.

Kleiner, E. F. 1968. Comparative study of grasslands of Canyonlands National Park. Unpublished dissertation, University of Utah, Salt Lake City. 58 pp.

Kleiner, E. F. 1983. Successional trends in an ungrazed, arid grassland over a decade. Journal of Range Management 36(1):114-118.

Kleiner, E. F., and K. T. Harper. 1972. Environment and community organization in grasslands of Canyonlands National Park. Ecology 53(2):299-309.

Kleiner, E. F., and K. T. Harper. 1977. Occurrence of four major perennial grasses in relation to edaphic factors in a pristine community. Journal of Range Management 30(4):286-289.

Lauver, C. L., K. Kindscher, D. Faber-Langendoen, and R. Schneider. 1999. A classification of the natural vegetation of Kansas. The Southwestern Naturalist 44:421-443.

Lindauer, I. E. 1970. The vegetation of the flood plain of the Arkansas River in southeastern Colorado. Unpublished dissertation, Colorado State University, Fort Collins. 92 pp.

Marr, J. W., D. Buckner, and C. Mutel. 1973a. Ecological analyses of potential shale oil products pipeline corridors in Colorado and Utah. Unpublished report prepared for Colony Development Operation, Atlantic Richfield Company, Denver, by Thorne Ecological Institute and University of Colorado, Boulder. 96 pp. plus appendices.

Muldavin, E., B. Sims, and L. Johnson. 1993. Pecos Wild and Scenic River in stream flow report. Final Report prepared for the USDA National Forest Service, Santa Fe National Forest, Santa Fe, NM.

Muldavin, E., G. Harper, P. Neville, and Y. Chauvin. 1998. The vegetation of White Sands Missile Range, New Mexico. Volume II. Vegetation map. Final report for Cooperative Agreement No. 14-16-00-91-233 White Sands Missile Range, U.S. Fish & Wildlife Service. The Nature Conservancy and the University of New Mexico.

Muldavin, E., Y. Chauvin, and G. Harper. 2000a. Vegetation of White Sands Missile Range, New Mexico: Volume I Handbook of vegetation communities. Final Report to White Sands Missile Range by New Mexico Natural Heritage Program, University of New Mexico, New Mexico. 192 pp.

Muldavin, E., P. Durkin, M. Bradley, M. Stuever, and P. Mehlhop. 2000b. Handbook of wetland vegetation communities of New Mexico: Classification and community descriptions (volume 1). Final report to the New Mexico Environment Department and the Environmental Protection Agency prepared by the New Mexico Natural Heritage Program, University of New Mexico, Albuquerque, NM.

Nachlinger, J. L., and G. A. Reese. 1996. Plant community classification of the Spring Mountains National Recreation Area, Clark and Nye counties, Nevada. Unpublished report submitted to USDA Forest Service, Humboldt-Toiyabe National Forest, Spring Mountains National Recreation Area, Las Vegas, NV. The Nature Conservancy, Northern Nevada Office, Reno, NV. 85 pp. plus figures and appendices.

Nichol, A. A. 1937. The natural vegetation of Arizona. University of Arizona Agricultural Experiment Station Technical Bulletin 68:177-222.

NMNHP [New Mexico Natural Heritage Program]. No date. Unpublished data on file. Albuquerque, NM.

Ortenberger, A. I., and R. D. Bird. 1933. The ecology of the western Oklahoma salt plains. Publications of the University of Oklahoma Biological Survey 5:49-64.

Padgett, W. G., A. P. Youngblood, and A. H. Winward. 1988. Riparian community type classification of Utah. USDA Forest Service, Intermountain Region Publication R4-ECOL-88-01. Ogden, UT.

Padgett, W. G., A. P. Youngblood, and A. H. Winward. 1989. Riparian community type classification of Utah and southeastern Idaho. USDA Forest Service, Intermountain Region. Report R4-ECOL-89-01. Ogden, UT. 191 pp.

Paysen, T. E., J. A. Derby, H. Blake, Jr., V. C. Bleich, and J. W. Mincks. 1980. A vegetation classification system applied to southern California. USDA Forest Service General Technical Report PSW-45. USDA Forest Service, Pacific Southwest Research Station, Berkeley, CA.

Sawyer, J. O., and T. Keeler-Wolf. 1995. A manual of California vegetation. California Native Plant Society, Sacramento. 471 pp.

Shaw, R. B., S. L. Anderson, K. A. Schultz, and V. E. Diersing. 1989. Plant communities, ecological checklist, and species list for the U.S. Army Pinon Canyon Maneuver Site, Colorado. Colorado State University, Department of Range Science, Science Series No. 37, Fort Collins. 71 pp.

Smith, T. L. 1989. An overview of old-growth forests in Pennsylvania. Natural Areas Journal 9:40-44.

Soil Conservation Service. 1978. Range site descriptions for Colorado. Technical Guide, Section II-E. USDA Soil Conservation Service, Colorado State Office, Denver.

Soil Conservation Service. No date. Range site descriptions of vegetation in Colorado. Unpublished report series MLRA dating from 1975 to 1989. Soil Conservation Service, Colorado Field Office, Denver.

Stevens, R. L., and C. W. Shannon. 1917. Plant life in Oklahoma. In: C. W. Shannon, editor. Animal and plant life of Oklahoma. Oklahoma Geological Survey, Norman.

Steward, L. H. 1982. Desert grassland communities on Otero Mesa, Otero County, New Mexico. Unpublished thesis, New Mexico State University, Las Cruces.

Stewart, G., W. P. Cottam, and S. S. Hutchings. 1940. Influence of unrestricted grazing on northern salt desert plant associations in western Utah. Journal of Agricultural Research 60(5):289-317.

Stubbendieck, J., S. L. Hatch, and C. H. Butterfield. 1992. North American range plants, 4th ed. University of Nebraska Press, Lincoln. 493 pp.

Szaro, R. C. 1989. Riparian forest and scrubland community types of Arizona and New Mexico. Desert Plants Special Issue 9(3-4):70-139.

Tuhy, J. S., and S. Jensen. 1982. Riparian classification for the Upper Salmon and Middle Fork Salmon River drainages, Idaho. Unpublished report prepared for the USDA Forest Service, Intermountain Region by White Horse Associates, Smithfield, UT. 183 pp.

Ungar, I. A. 1968. Species-soil relationships on the Great Salt Plains of northern Oklahoma. The American Midland Naturalist 80(2):392-407.

USFS [U.S. Forest Service]. 1937. Range plant handbook. Dover Publications Inc., New York. 816 pp.

Utah Environmental and Agricultural Consultants. 1973. Pages 2-38 in: Environmental setting, impact, mitigation and recommendations for a proposed oil products pipeline between Lisbon Valley, Utah and Parachute Creek, Colorado. Unpublished report for Colony Development Operation, Atlantic Richfield Company, Denver, CO.

Vest, E. D. 1962. Biotic communities in the Great Salt Lake Desert. Institute of Environmental Biological Research, Ecology and Epizoology Series 73. Division of Biological Science, University of Utah. 122 pp.

Von Loh, J. 2000. Draft local descriptions of the vegetation associations of Ouray National Wildlife Refuge. USGS Bureau of Reclamation, Remote Sensing and GIS Group, Denver Federal Center, Denver.

Von Loh, J., D. Cogan, K. Schulz, D. Crawford, T. Meyer, J. Pennell, and M. Pucherelli. 2002. USGS-USFWS Vegetation Mapping Program, Ouray National Wildlife Refuge, Utah. USDI Bureau of Reclamation, Remote Sensing and GIS Group, Technical Memorandum 8260-02-03. Denver Federal Center, Denver, CO.

Ware, G. H., and W. T. Penfound. 1949. The vegetation of the lower levels of the floodplain of the south Canadian River in central Oklahoma. Ecology 30:478-484.

Weaver, J. E., and F. W. Albertson. 1956. Grasslands of the Great Plains: Their nature and use. Johnsen Publishing Co., Lincoln, NE. 395 pp.

Welsh, S. L., N. D. Atwood, S. Goodrich, and L. C. Higgins, editors. 1987. A Utah flora. Great Basin Naturalist Memoirs 9. Provo, UT. 894 pp.

West, N. E., R. T. Moore, K. A. Valentine, L. W. Law, P. R. Ogden, F. C. Pinkney, P. T. Tueller, and A. A. Beetle. 1972. Galleta: Taxonomy, ecology and management of ~Hilaria jamesii$ on western rangelands. Utah Agricultural Experiment Station. Bulletin 487. Logan, UT. 38 pp.

APPENDIX G

G. Wupatki National Monument Species List

(Species list was compiled from the relevé data collected in 1999 as part of the USGS-NPS National Mapping Program)

Family	Scientific Name	Common Name
Anacardiaceae	*Rhus trilobata* Nutt.	skunkbush sumac
Asclepiadaceae	*Asclepias subverticillata* (Gray) Vail	horsetail milkweed
	Asclepias sp. L.[1]	milkweed
Asteraceae	*Ageratina herbacea* (Gray) King & H.E. Robins.	fragrant snakeroot
	Ambrosia acanthicarpa Hooke.	flatspine burr ragweed
	Ambrosia psilostachya DC.	Cuman ragweed
	Artemisia campestris ssp. *pacifica* (Nutt.) Hall & Clements	field sagewort
	Artemisia carruthii Wood ex Carruth.	Carruth's sagewort
	Artemisia dracunculus ssp. *dracunculus* L.	tarragon
	Artemisia ludoviciana Nutt.	white sagebrush
	Artemisia sp. L.	sagebrush
	Bahia dissecta (Gray) Britt.	ragleaf bahia
	Brickellia californica (Torr. & Gray) Gray	California brickellbush
	Brickellia eupatorioides var. *eupatorioides* (L.) Shinners	false boneset
	Brickellia grandiflora (Hook.) Nutt.	tasselflower brickellbush
	Chaetopappa ericoides (Torr.) Nesom	rose heath
	Cirsium wheeleri (Gray.) Petrak	Wheeler's thistle
	Ericameria nauseosus ssp. *nauseosa* var. *nauseosa* (Pallas ex Pursh) Nesom & Baird	rubber rabbitbrush
	Erigeron divergens Torr. & Gray	spreading fleabane
	Erigeron flagellaris Gray	trailing fleabane
	Erigeron sp. L.	fleabane
	Gaillardia pinnatifida Torr.	red dome blanketflower
	Gutierrezia sarothrae (Pursh) Britt. & Rusby	broom snakeweed
	Helenium arizonicum Blake	Arizona sneezeweed
	Helianthus annuus L.	common sunflower
	Hymenopappus filifolius var. *lugens* (Greene) Jepson	Idaho hymenopappus
	Hymenoxys richardsonii (Hook.) Cockerell	pingue rubberweed
	Lactuca serriola L.	prickly lettuce
	Packera multilobata (Torr. & Gray ex Gray) W.A. Weber & A. Löve	lobeleaf groundsel
	Senecio sp. L.	ragwort
	Stephanomeria minor (Hook.) Nutt. var. *minor*	narrowleaf wirelettuce
	Stephanomeria sp. Nutt.	wirelettuce
	Tetradymia canescens DC.	spineless horsebrush
	Tragopogon dubius Scop.	yellow salsify
Berberidaceae	*Mahonia fremontii* (Torr.) Fedde	Fremont's mahonia
Boraginaceae	*Cryptantha cinerea* var. *jamesii* Cronq.	James' cryptantha
	Cryptantha sp. Lehm. ex G. Don	cryptantha
	Lappula occidentalis (S. Wats.) Greene	flatspine stickseed
	Lappula sp. Moench	stickseed
	Lithospermum multiflorum Torr. ex Gray	manyflowered stoneseed
Brassicaceae	*Arabis fendleri* (S. Wats.) Greene	Fendler's rockcress
	Arabis sp. L.	rockcress

[1] Genera that do not include specific epithets were unique unidentified species not included in the species list.

Family	Scientific Name	Common Name
	Descurainia incana ssp. *incana* (Bernh. ex Fisch. & C.A. Mey.) Dorn	mountain tansymustard
	Descurainia obtusa (Greene) O.E. Schulz	blunt tansymustard
	Descurainia sophia (L.) Webb ex Prantl	herb sophia
	Erysimum capitatum (Dougl. ex Hook.) Greene	sanddune wallflower
	Physaria newberryi Gray	Newberry's twinpod
	Sisymbrium altissimum L.	tall tumblemustard
Cactaceae	*Echinocereus* sp. Engelm.	hedgehog cactus
	Opuntia sp. P. Mill.	pricklypear
Capparidaceae	*Cleome serrulata* Pursh	Rocky Mountain beeplant
Chenopodiaceae	*Chenopodium album* L.	lambsquarters
	Chenopodium berlandieri Moq.	pitseed goosefoot
	Chenopodium graveolens Willd.	fetid goosefoot
	Chenopodium leptophyllum (Moq.) Nutt. ex S. Wats.	narrowleaf goosefoot
Commelinaceae	*Commelina dianthifolia* Delile	birdbill dayflower
Cupressaceae	*Juniperus deppeana* Steud.	alligator juniper
	Juniperus osteosperma (Torr.) Little	Utah juniper
	Juniperus sp. L.	juniper
Euphorbiaceae	*Chamaesyce fendleri* (Torr. & Gray) Small	Fendler's sandmat
	Euphorbia brachycera Engelm.	horned spurge
	Euphorbia sp. L.	spurge
	Tragia ramosa Torr.	branched noseburn
Fabaceae	*Alhagi maurorum* Medik.	camelthorn
	Astragalus sp. L.	milkvetch
	Lotus wrightii (Gray) Greene	Wright's deervetch
	Lupinus argenteus Pursh	silvery lupine
	Lupinus sp. L.	lupine
	Oxytropis lambertii Pursh	purple locoweed
	Phaseolus angustissimus Gray	slimleaf bean
Fagaceae	*Quercus gambelii* Nutt.	Gambel oak
Geraniaceae	*Geranium caespitosum* var. *eremophilum* (Woot. & Standl.) W.C. Martin & C.R. Hutchins	purple cluster geranium
Grossulariaceae	*Ribes cereum* var. *pedicellare* Brewer & S. Wats.	whisky currant
Hydrophyllaceae	*Phacelia crenulata* Torr. ex S. Wats.	cleftleaf wildheliotrope
	Phacelia egena (Greene ex Brand) Greene ex J.T. Howell	Kaweah River phacelia
	Phacelia serrata J. Voss	saw phacelia
	Phacelia sp. Juss.	phacelia
Lamiaceae	*Marrubium vulgare* L.	horehound
	Monardella odoratissima Benth.	mountain monardella
Liliaceae	*Yucca angustissima* Engelm. ex Trel.	narrowleaf yucca
	Yucca baccata Torr.	banana yucca
Linaceae	*Linum lewisii* Pursh	prairie flax
	Linum neomexicanum Greene.	New Mexico yellow flax
	Linum sp. L.	flax
Loasaceae	*Mentzelia pumila* Nutt ex Torr. & Gray	dwarf mentzelia
	Mentzelia sp. L.	blazingstar

Family	Scientific Name	Common Name
Malvaceae	*Sphaeralcea* sp. St.-Hil.	globemallow
Nyctaginaceae	*Mirabilis decipiens* (Standl.) Standl.	broadleaf four o'clock
	Mirabilis linearis (Pursh) Heimerl	narrowleaf four o'clock
	Mirabilis multiflora (Torr.) Gray	Colorado four o'clock
	Mirabilis sp. L.	four o'clock
Oleaceae	*Forestiera pubescens* var. *pubescens* Nutt.	stretchberry
Onagraceae	*Gaura coccinea* Nutt. ex Pursh	scarlet beeblossom
	Oenothera cespitosa Nutt.	tufted evening-primrose
	Oenothera sp. L.	evening-primrose
Pinaceae	*Pinus edulis* Engelm.	twoneedle pinyon
	Pinus flexilis James	limber pine
	Pinus ponderosa P. & C. Lawson	ponderosa pine
	Pseudotsuga menziesii (Mirbel) Franco	Douglas-fir
Plantaginaceae	*Plantago patagonica* Jacq.	woolly plantain
Poaceae	*Achnatherum hymenoides* (Roemer & J.A. Schultes) Barkworth	Indian ricegrass
	Agropyron desertorum (Fisch. Ex Link) J.A. Schultes	desert wheatgrass
	Andropogon hallii Hack.	sand bluestem
	Aristida divaricata Humb. & Bonpl. ex Willd.	poverty threeawn
	Aristida sp. L.	threeawn
	Bouteloua curtipendula (Michx.) Torr.	sideoats grama
	Bouteloua gracilis (Willd. ex Kunth) Lag. ex Griffiths	blue grama
	Bromus ciliatus L.	fringed brome
	Bromus rubens L.	red brome
	Bromus tectorum L.	cheatgrass
	Bromus sp. L.	brome
	Elymus elymoides ssp. *elymoides* (Raf.) Swezey	squirreltail
	Festuca arizonica Vasey	Arizona fescue
	Festuca sp. L.	fescue
	Hordeum jubatum L.	foxtail barley
	Muhlenbergia minutissima (Steud.) Swallen	annual muhly
	Muhlenbergia montana (Nutt.) A.S. Hitchc.	mountain muhly
	Muhlenbergia rigens (Benth.) A.S. Hitchc.	deergrass
	Pascopyrum smithii (Rydb.) A. Love	western wheatgrass
	Poa fendleriana (Steud.) Vasey	muttongrass
	Schizachyrium scoparium ssp. *scoparium* (Michx.) Nash	little bluestem
Polemoniaceae	*Ipomopsis aggregata* ssp. *aggregata* (Pursh) V. Grant	scarlet gilia
Polygonaceae	*Eriogonum corymbosum* var. *aureum* (M.E. Jones) Reveal	crispleaf buckwheat
	Eriogonum racemosum Nutt.	redroot buckwheat
	Eriogonum wrightii Torr . ex Benth.	bastardsage
	Eriogonum sp. Mitchx.	buckwheat
Polypodiaceae	*Pellaea atropurpurea* (L.) Link	purple cliffbrake
	Pellaea truncata Goodding	spiny cliffbrake
Ranunculaceae	*Thalictrum fendleri* Engelm. ex Gray	Fendler's meadow-rue
Rosaceae	*Cercocarpus montanus* Raf.	alderleaf mountain mahogany
	Chamaebatiaria millefolium (Torr.) Maxim	fernbush

Family	Scientific Name	Common Name
	Fallugia paradoxa (D. Don) Endl. ex Torr.	Apache plume
	Holodiscus dumosus (Nutt.ex Hook.) Heller	rockspirea
	Purshia stansburiana (Torr) Henrickson	Stansbury cliffrose
Rubiaceae	*Galium stellatum* Kellogg	bedstraw
	Galium wrightii Gray	Wright's bedstraw
Salicaceae	*Populus tremuloides* Michx.	quaking aspen
Scrophulariaceae	*Castilleja integra* Gray	wholeleaf Indian paintbrush
	Castilleja sp. Mutis ex L. f.	Indian paintbrush
	Linaria genistifolia (L.) P. Mill.	Dalmatian toadflax
	Penstemon barbatus (Cav.) Roth	beardlip penstemon
	Penstemon clutei A. Nels.	Sunset Crater beardtongue
	Penstemon jamesii Benth.	James' beardtongue
	Penstemon sp. Schmidel	penstemon
	Pericome caudata Gray	mountain tail-leaf
	Verbascum thapsus L.	common mullein
Solanaceae	*Physalis hederifolia* var. *fendleri* (Gray) Cronq.	Fendler's groundcherry

APPENDIX H

H. Visual Guide and Descriptions of the Wupatki National Monument Map Classes

Introduction

This document is a guide to the photointerpretation of vegetation map classes for Wupatki National Monument. It provides a ground photo image for each map class as well as at least one example of each map class as it appears on the aerial photographs.

This guide does not attempt to show all variations of each map class; only the most common or significant representations are included. The descriptions should be sufficient to give the user a feel for the imagery and an understanding of the relationships between the vegetation and the map classes. This guide does not describe non-vegetated map classes.

How this Guide is Organized

This guide describes and illustrates every vegetation map class used in the Wupatki vegetation mapping project. The format is one map class per page. The images are scanned aerial photographs with their Mylar overlays showing the photointerpreter's work and the map class code in yellow or black. Ground photos of each type are included where available. The photos are accompanied by a brief description of the distribution of the map class within the project area and a how it generally appeared on the aerial photos. Other information about the map class or the polygon may be included if it improved understanding or recognition of that particular map class.

We arranged the map classes in order of map code number. To find the information for a particular map class, use the index that follows this introduction to find the number for that map class.

Aerial Photographs

Horizons, Inc. of Rapid City South Dakota flew the color infrared (CIR) aerial photographs for WUPA on June 3, 1996. The photos were taken at a flight altitude of 6,000 ft (1,829 m) above sea level using Kodak Aerochrome Infrared 2443 film. The photo mission was designed to take photos with about 30% side lap (between each flight line) and 60% overlap (along each flight line). The scale of the 9 x 9-in photos is 1:12,000 (approximately 1 inch = 1000 ft.). Two sets of contact prints and positive transparencies were produced and used for stereoscopic interpretation. A total of 207 frames taken over 14 flightlines covered the project area.

Color Infrared Film (CIR)

CIR film is best for highlighting subtle changes in deciduous and wetland vegetation. Evergreen vegetation can also be distinguished using CIR film, although not as clearly as deciduous trees and shrubs. CIR film presents a "false color" picture that combines infrared reflectance with green and red visible bands. These differences in reflectance create differences in tone and color that can be easily distinguished and delineated as different plant communities. Reflectance is influenced by structure of the canopy, the orientation of the plants and their leaves, and the thickness and pigment content of leaves.

CIR photos are less effective in mapping sparsely vegetated areas and areas where the substrate is either white or black. Black (basalt) or white (alluvial and eolian sands) tend to reflect near-IR in such a way that the reflective signatures of vegetation may be masked. Large shrubs will still appear against a white or black background, but smaller plants such as grass clumps or small

shrubs do not even create a textural signature. Because of this, many of the map classes that occur partially or wholly on basalt or sand substrates we had to map in the field.

Texture is also important to the photointerpreter. For shrubs, texture is influenced by density of plants on the landscape, crown size and shape, and leaf size. Dense, medium-sized shrubs such as rabbitbrush give a grainy texture to the photographs. Small shrubs such as snakeweed and shadscale show little or no texture, since the plants are about the same size as a small bunchgrass. Grasslands tend to have a smooth texture, except where interrupted by prairie dog holes or anthills, which appear as pinhole-sized white dots. These are imprecise terms, but nonetheless provide important visual cues to the imagery.

CIR photography generally is not consistent enough to allow a species or type to be described precisely. Film batch, printing process, sun angle, light intensity, shadow, and exposure can all affect the appearance of CIR photography. For accurate mapping at Wupatki National Monument, ground verification by both the photointerpreter was very important for successful interpretation of map classes with confusing or similar signatures.

Alphabetical Index To the Vegetation Map Units

Map Unit Name **Unit #**

Active River Channel……...3
Apache Plume Cinder Shrubland…….. 21
Basalt Outcrop Shrubland……....2
Black Grama Grassland……..8
Black Grama Coconino Plateau Shrubland……...…… 16
Cinder Barren……...1
Crinklemat/Alkali Sacaton Dwarf Shrubland……12
Crispleaf Buckwheat Cinder Shrubland…… 15
Fourwing Saltbush Upland Drainageways…… 18
Fremont's Cottonwood Woodland……28
Frosted Mint Shrubland……22
Galleta Grassland…….. 10
Galleta Mixed Grasslands…… 11
Galleta Mixed Shrublands……14
Little Colorado River Invasive Riparian Shrubland……..26
Moenkopi Sandstone Sparse Vegetation…….....5
Moenkopi Shale Sparse Vegetation…….....6
Mormon Tea Cinder Dune Shrubland……... 20
Mound Saltbush Badlands Sparse Vegetation…….....4
Needle-and-Thread Grassland……...9
Oneseed Juniper Woodland……...27
Rabbitbrush Shrubland…….. 17
Sandbar Willow Shrubland……... 25
Sand Bluestem Grassland……...7
Sand Sagebrush Shrubland…… 19
Snakeweed/Galleta Grassland……... 13
Unclassified Mixed Shrubland…….. 23
Wupatki Wash System…….. 24

Alphabetical Index To the Geological and Anderson Land Use Map Units (Illustrations and descriptions not included in this guide)

Map Unit Name **Unit #**

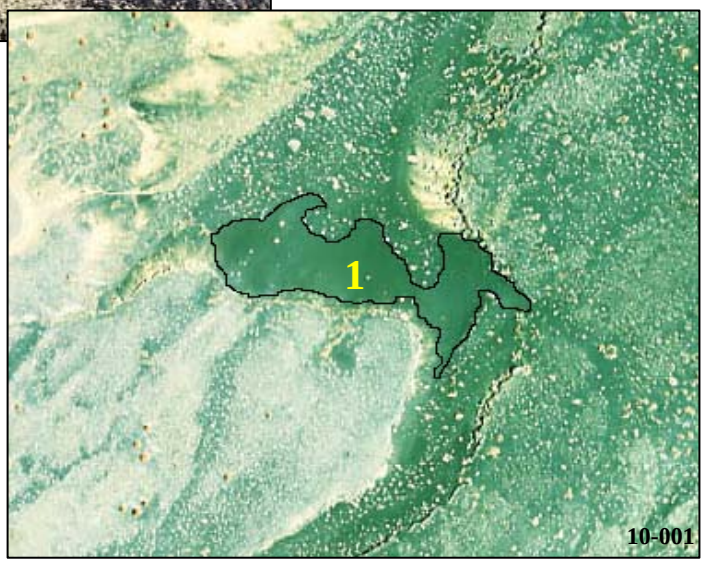
Commercial Development……31
Corrals……... 35
Facilities…… 30
Residential Land……32
Stock Tanks and Dams……..33
Strip Mines, Quarries and Gravel Pits……..34
Transportation Route……29

Numeric Index to the Vegetation Map Units

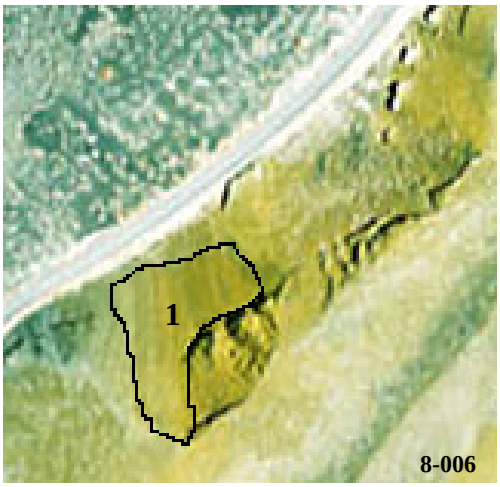
Unit #	Map Unit Name	Page
1	Cinder Barren	6
2	Basalt Outcrop Shrubland	7
3	Active River Channel	8
4	Mound Saltbush Badlands Sparse Vegetation	9
5	Moenkopi Sandstone Sparse Vegetation	10
6	Moenkopi Shale Sparse Vegetation	11
7	Sand Bluestem Grassland	12
8	Black Grama Grassland	13
9	Needle-and-Thread Grassland	14
10	Galleta Grassland	15
11	Galleta Mixed Grasslands	16
12	Crinklemat/Alkali Sacaton Dwarf Shrubland	17
13	Snakeweed/Galleta Grassland	18
14	Galleta Mixed Shrublands	19
15	Crispleaf Buckwheat Cinder Shrubland	20
16	Black Grama Coconino Plateau Shrubland	21
17	Rabbitbrush Shrubland	22
18	Fourwing Saltbush Upland Drainageways	23
19	Sand Sagebrush Shrubland	24
20	Mormon Tea Cinder Dune Shrubland	25
21	Apache Plume Cinder Shrubland	26
22	Frosted Mint Shrubland	27
23	Unclassified Mixed Shrubland	28
24	Wupatki Wash System	29
25	Sandbar Willow Shrubland	30
26	Little Colorado River Invasive Riparian Shrubland	30
27	Oneseed Juniper Woodland	31
28	Fremont's Cottonwood Woodland	30

Cinder Barren (1)

Location: A layer of black volcanic cinder of varying thickness covers much of the southern part of the Wupatki project area. In general it is unvegetated, but some occurrences will occasionally support communities of ephemeral annual plants, as shown in this photo. The deepest cinder beds lie on the slopes below the basalt plateau rims.

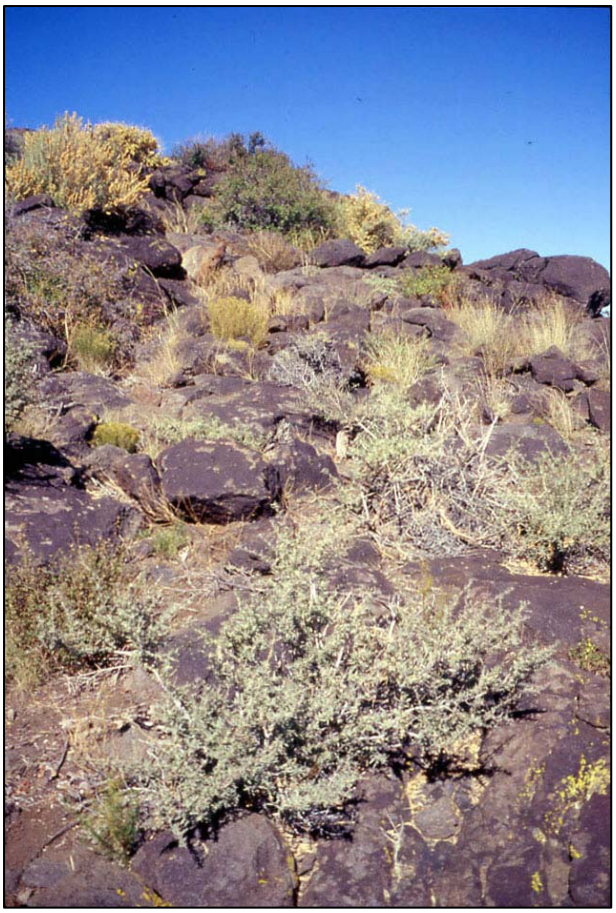


Photosignature: Because the aerial photos were flown so late in the year, ephemeral plant communities such as the one pictured above, do not obscure the smooth, evenly greenish-black signature of pure volcanic cinder.



Red cinder (restricted to Doney Mountain and associated cinder cones) appears smooth and orange-red. Its appearance on aerial photos is similar to Moenkopi sandstone and shale map classes.

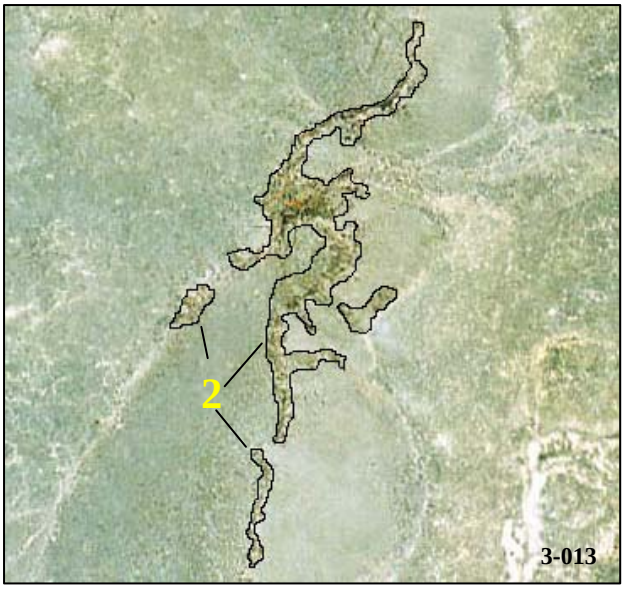
Basalt Outcrop Shrubland (2)

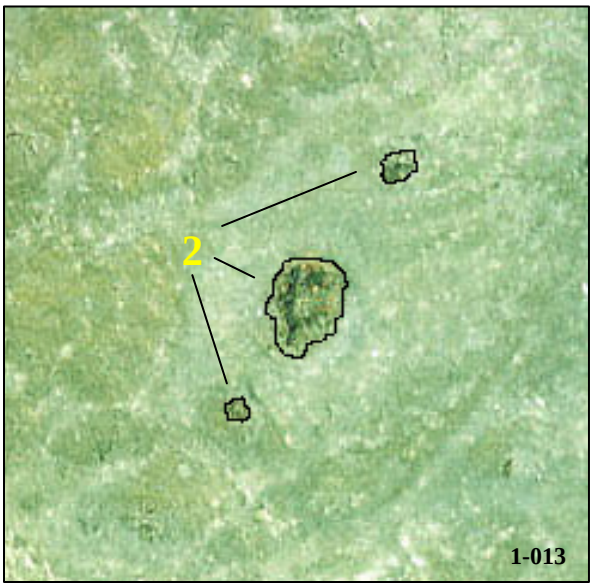


Location: Rims, slopes and isolated outcrops of basalt occur throughout the project area south and west of the Wupatki Basin. Although threeleaf sumac is the definitive species on the unit, it is generally less important than fourwing saltbush or green Mormon tea.

Photosignature: The rough, blocky texture of broken basalt is readily evident on the photos. Plateau rims and their associated slopes appear as narrow, curving lines (right photo below), while isolated piles of basalt occurring west of Highway 89 appear as small dark inclusions within the paler grassland matrix (left photo below).

On both types of basalt exposure, shrubs appear as orange-brown specks and blotches.

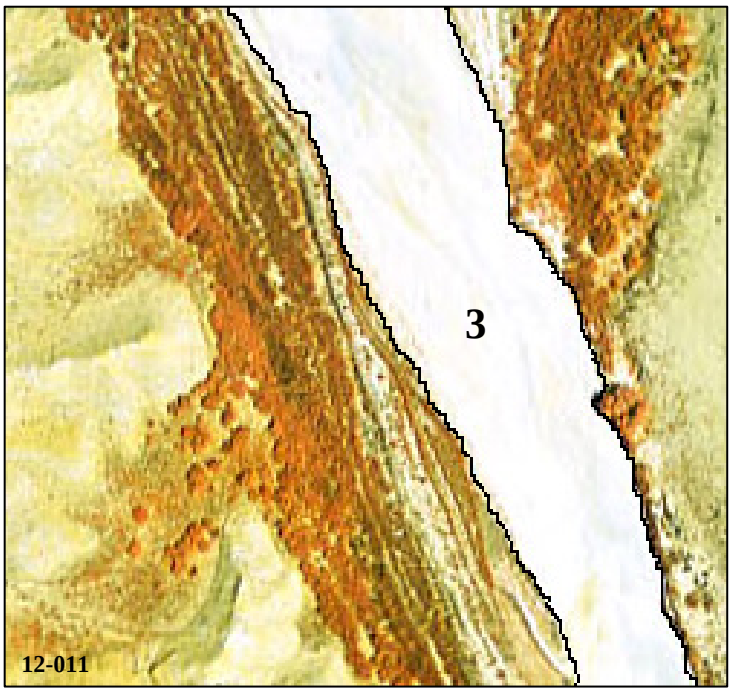




Active River Channel (3)

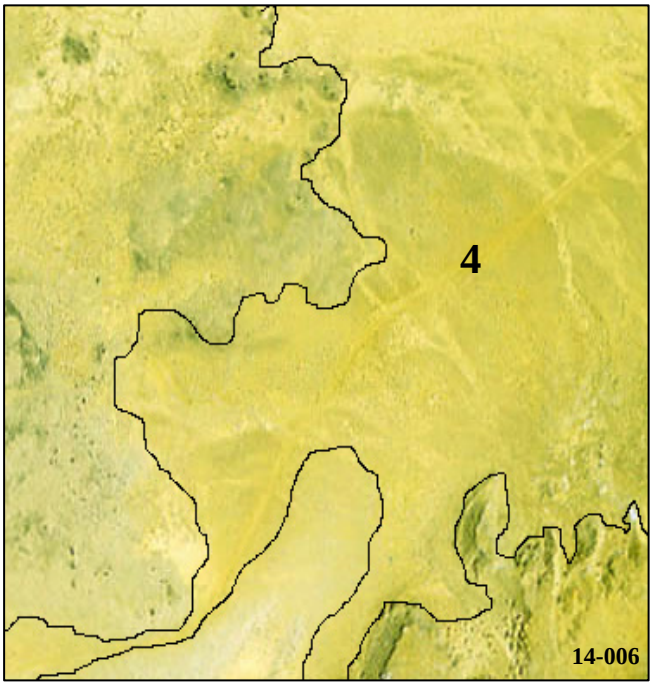
Location. This map class describes the parts of the Little Colorado River and its major tributaries, Antelope Wash and Deadman Wash, that flood at least annually. The channel bed may be either light-colored sand or black basalt, or a mix of the two. Both types occur in the photo of the Little Colorado River at left.

Photosignature. This type is easily recognized by its context – in the bed of a major stream - as well as its smooth texture because of the lack of perennial vegetation. The color may be either white with light-colored streaks indicating minor flood deposition, or greenish black, depending on the substrate (sand or basalt).



Mound Saltbush Badlands Sparse Vegetation (4)

Location. This type is restricted to Moenkopi lowlands on the Navajo Nation east of the Little Colorado River. The vegetation is sparse, and consists primarily of small mound saltbush shrubs and scattered clumps of alkali sacaton. Some areas show evidence of occasional surface flow.

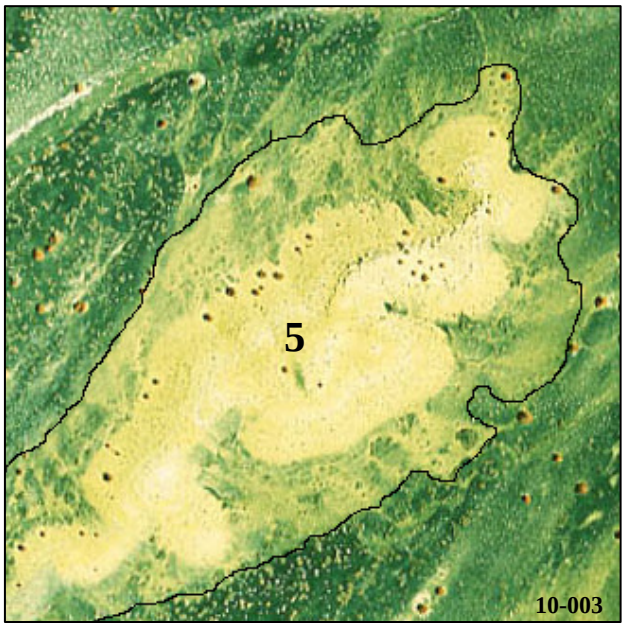


Photosignature. Because the vegetation in the map class is extremely sparse, the signature resembles poorly vegetated areas west of the Little Colorado River. The signature varies somewhat because of differences in dust and salt deposits at the surface, but is generally a smooth pale orange with large grayish splotches. Rare floods create characteristic streaking in the direction of flow (seen in the upper right-hand corner of the photograph).

Moenkopi Sandstone Sparse Vegetation (5)

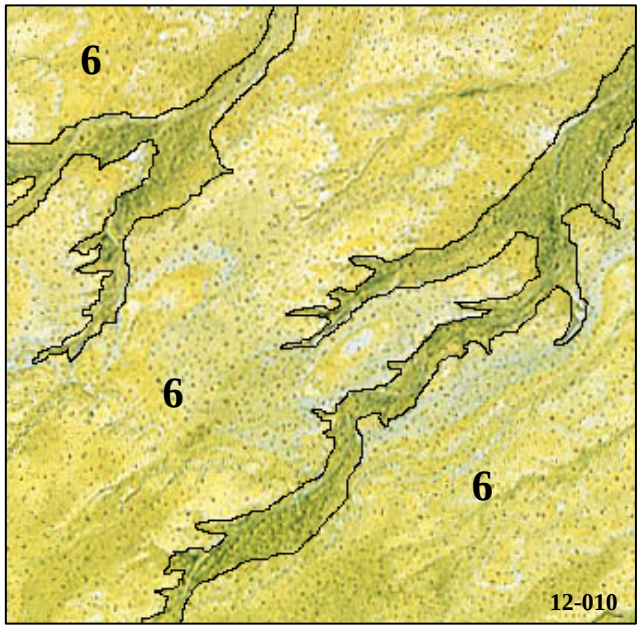
Location. Along with Moenkopi Shale Sparse Vegetation, this is a major map class within the Wupatki basin north and east of the Visitor's Center. The lower layers of the Moenkopi Formation consist of lenses of sandstone layered among sandy silt beds. The sandy red soils support a characteristic flora in which fourwing saltbush is nearly always present. Galleta and snakeweed are also common species.

Photosignature. The characteristic signature of this type is a pale orange with concentric rings of lighter, saline silts and rough edges or broken sandstone. The "skirts" of washed-down material surrounding outcrops of the sandstone frequently support similar vegetation and are also mapped as this type. Scattered juniper appear as dark-orange or brown dots, although shrubs are generally not visible.



Moenkopi Shale Sparse Vegetation (6)

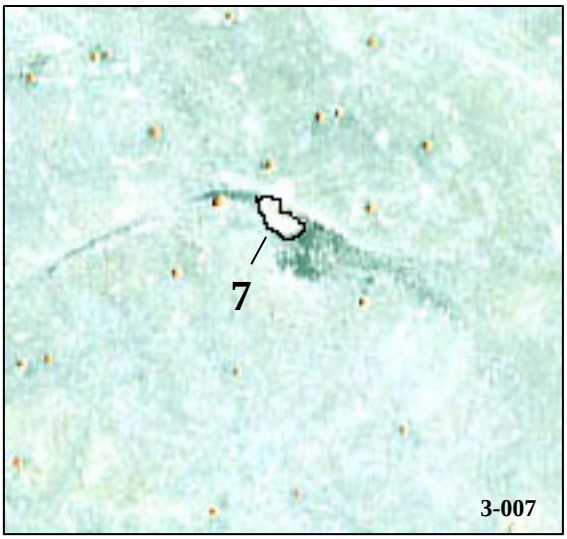
Location. The eastern and northern reaches of the Wupatki Basin are primarily this map class. The upper layers of the Moenkopi Formation break down into a saline, silty clay soil that supports only a sparse vegetation of shadscale, Torrey's joint-fir, and a few bunchgrasses.



Photosignature. The characteristic signature of this map class is a medium orange with white rings and layers visible. Shrubs appear as minute gray speckles distributed evenly over the surface. This type occurs primarily in large polygons. Darker patches, such as occur in the lower right-hand and lower center of this photo, may indicate the presence of stands of alkali sacaton.

Sand Bluestem Grassland (7)

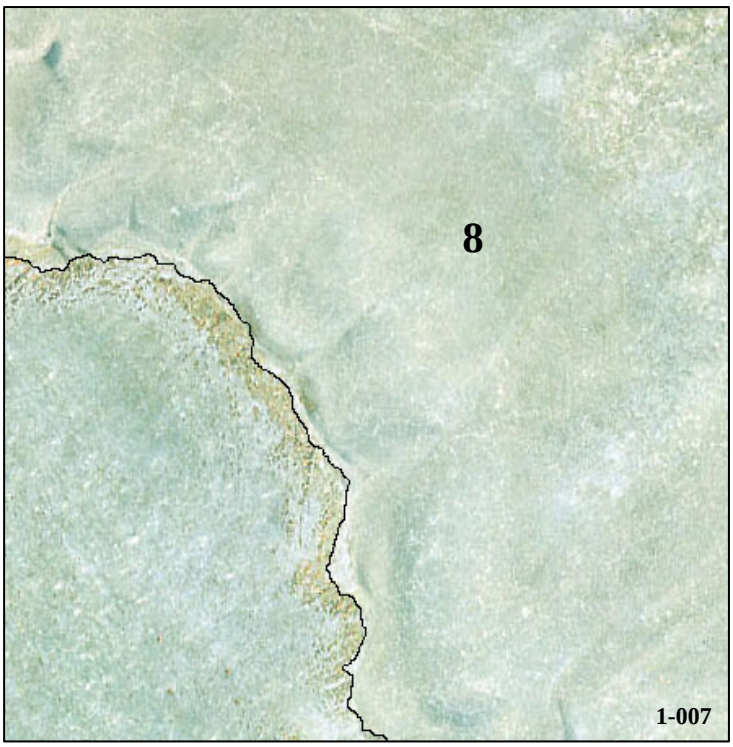
Location. This map class is rare, and is limited to very small areas along canyon rims and in deep cinder in the southern part of the project area.



Photosignature. This type was mapped where it was seen in the field, as most examples are much less than the minimum mapping unit in size and are virtually invisible on the aerial photos. The polygon pictured to the left is approximately 25m by 40m.

Black Grama Grassland (8)

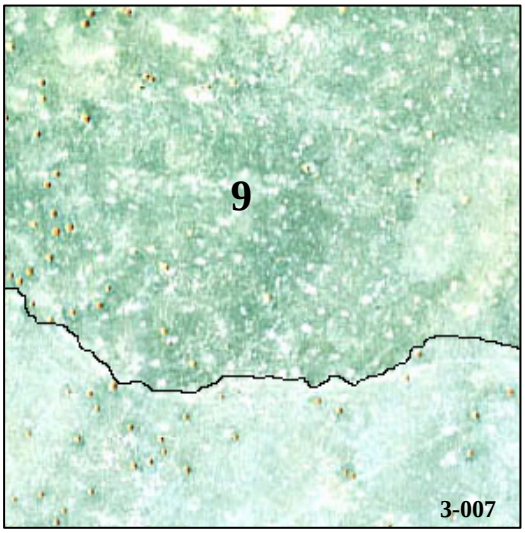
Location. Areas of nearly pure black grama are limited to level grasslands west of Highway 89 in the southwestern part of the project area. Polygons are large, but irregularly shaped.

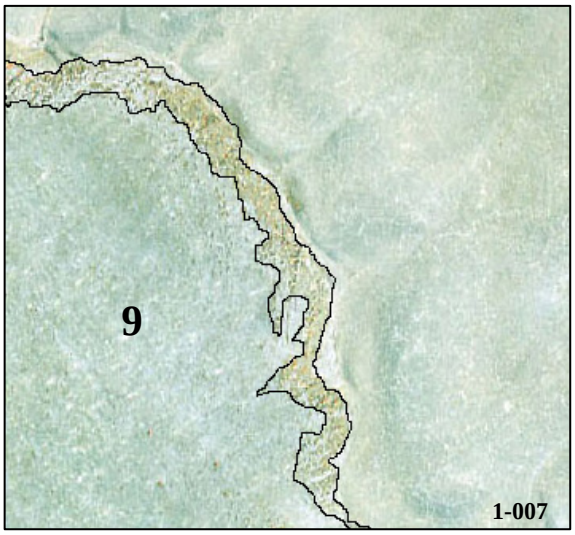


Photosignature. The lack of shrubs and the even spacing of uniformly sized grass clumps help to create the very smooth texture that is characteristic of this map class. Color varies from beige to light gray-green to light gray. Pure galleta grasslands (10) have a very similar signature, but are restricted to slopes below escarpments and only occur east of Highway 89.

Needle-and-Thread Grassland (9)

Location This map class occurs in isolated, large polygons within a mile (1.6 km) of Highway 89. In general, it is limited to the level summits of minor mesas, where pea-sized cinder mixes with limestone chips to form a coarse soil. Needle-and-thread grass is always dominant, although there may be significant cover of galleta or black grama.



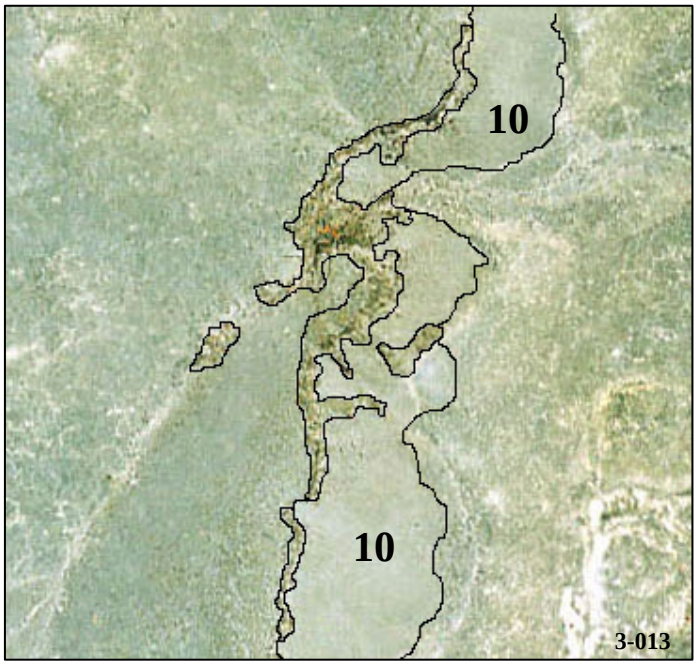


Photosignature. Polygons of this map class are easily distinguishable because of their distinctive gray-green color broken by white speckles. Surrounding grasslands are usually much smoother in texture and lighter gray in color. This map class may sometimes be confused with grasslands supporting prairie dog colonies or ant hills, which produce similarly sized white speckles.

Galleta Grassland (10)

Location. Stands of nearly pure galleta are restricted to the slopes below minor basalt escarpments, mostly between Highway 89 and Wupatki Basin.

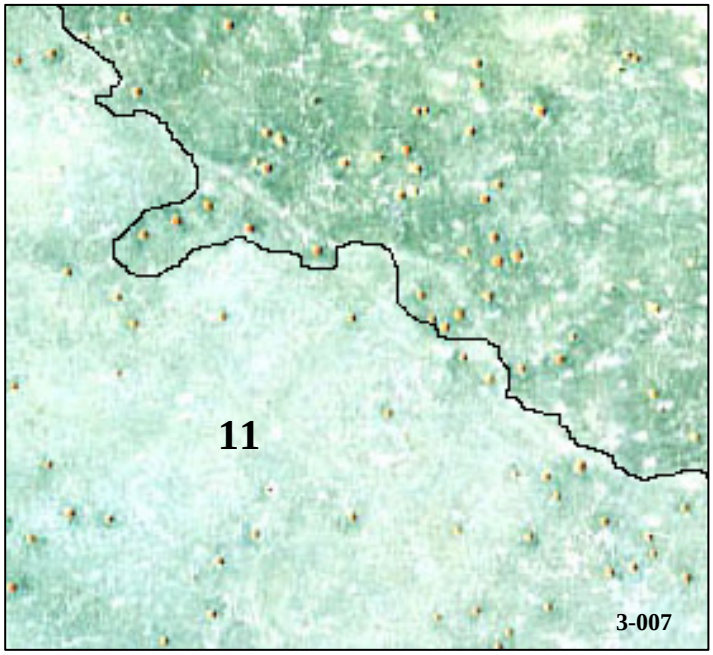
Photosignature. The smooth blue-gray of this map class's signature is always adjacent to a basalt rim (map code 2). It is usually surrounded by mixed galleta grasslands (11) with a rougher texture and usually darker color.



Galleta Mixed Grasslands (11)

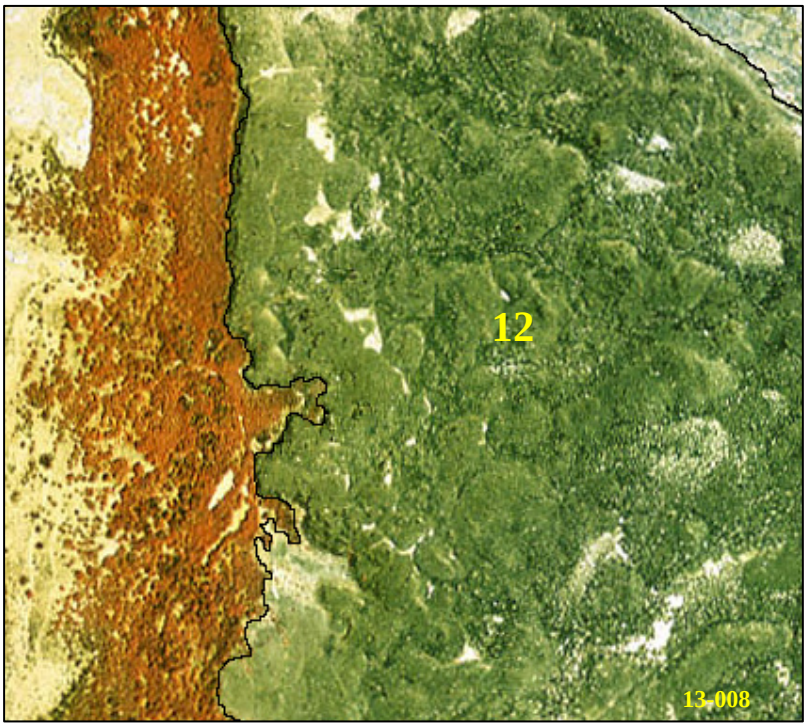
Location. Most of the grasslands at Wupatki and its surrounding area map to this type. Although galleta is generally dominant, black grama, alkali sacaton and needle-and-thread may contribute significant cover. This type may contain minor cover of shrubs such as yucca, snakeweed, shadscale, and rabbitbrush. An example of Galleta Grassland (10) is visible on the slope in the background.

Photosignature. This type generally appears as large, light gray or pale gray-green blotches, depending on the amount of volcanic cinder mixed in the soil and the depth of the grass litter layer. The texture is smooth because of the lack of shrubs. Scattered juniper appear as small brown dots. Most polygons are large.



Crinklemat/Alkali Sacaton Dwarf Shrubland (12)

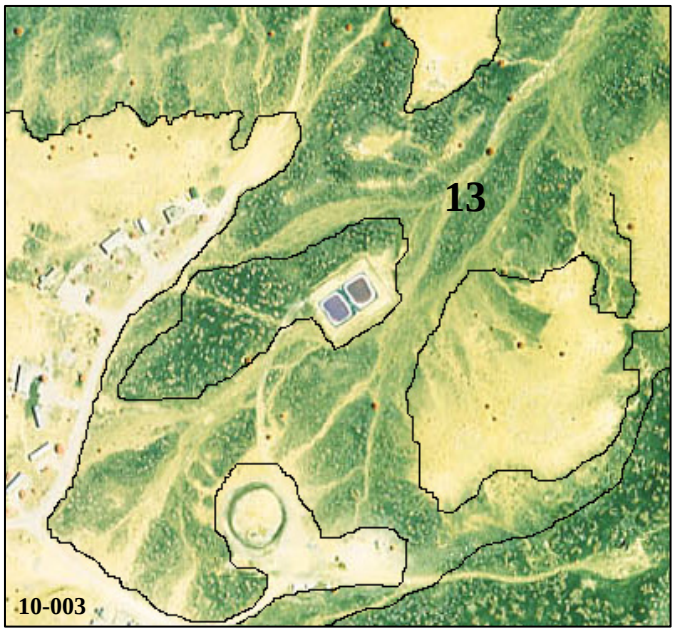
Location. This type is restricted to older basalt deposits that are exposed as a terrace adjacent to the Little Colorado River at Black Falls Crossing. The dominant species are shadscale and alkali sacaton, but the understory has a significant component of crinklemat (low gray mounds in photo above).



Photosignature. The lumpy, blackish-green signature of the old basalt flow is diagnostic. White areas are sands that have blown on top of the basalt. The shrubs and other vegetation are essentially invisible. This type was mapped primarily from field observations.

Snakeweed/Galleta Grassland (13)

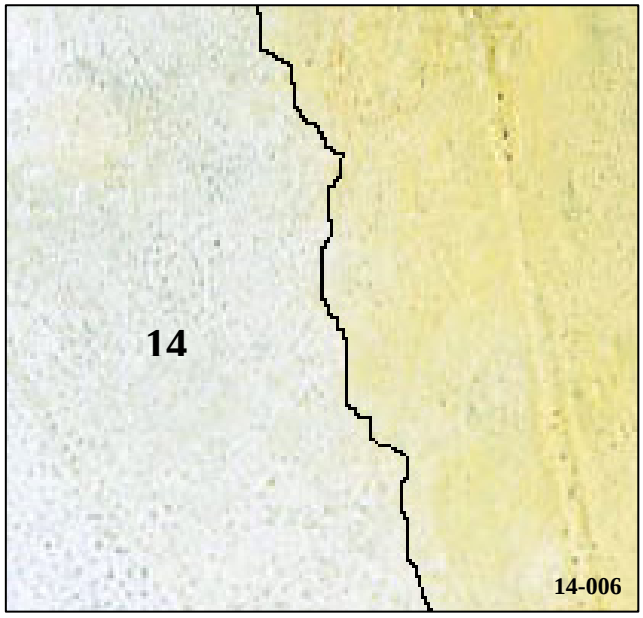
Location. This map class occurs primarily in the Wupatki Basin in the vicinity of the employee housing area, although a few polygons occur to the north on the Babbitt Ranches.



Photosignature. The streaky black-and-orange signature of this map class is very similar to some polygons of Moenkopi Sandstone Sparse Vegetation (5), because the substrate is a similar mix of silt, sandstone fragments and black cinder. For the most part, this map class was mapped in the field.

Galleta Mixed Shrublands (14)

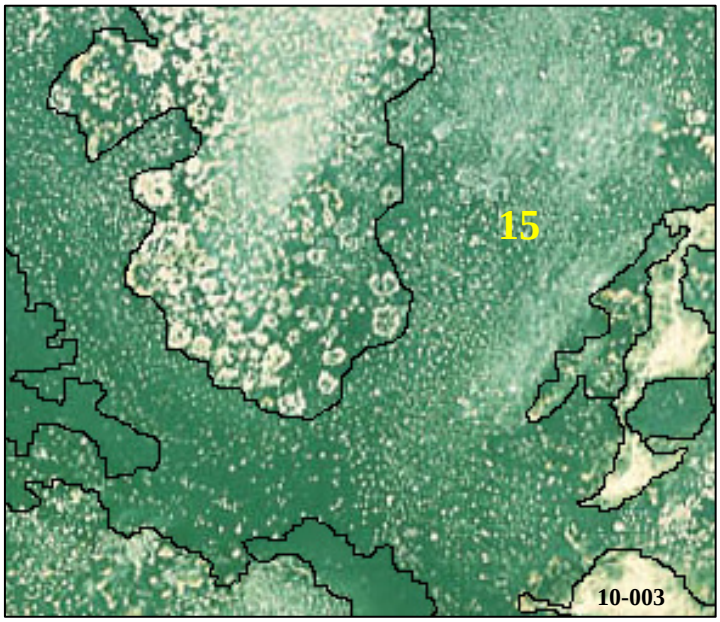
Location. Most polygons of this type occur in the Wupatki Basin, below major basalt escarpments (those NOT deeply covered in cinder), and in the Little Colorado River floodplain. The Little Colorado River is in the upper third of the photo, lined by tamarisk.



Photosignature. Because this map class includes a wide variety of shrubs mixed with galleta at different densities on different substrates, the signature is quite variable. The example to the left illustrates the ground photo above, where snakeweed and rabbitbrush grow with galleta on alluvial sands deposited by the river. The shrubs are visible as small dark speckles. Other examples may appear darker, depending on the substrate. This type was mapped primarily in the field.

Crispleaf Buckwheat Cinder Shrubland (15)

Location. This map class is limited in distribution to cinder-covered slopes and flats between the northern and eastern rims of Woodhouse Mesa and the Visitor's Center. It generally occurs in small polygons, although larger stands occur on cinder slopes above the Visitor's Center.



Photosignature. The best-developed examples appear as greenish black areas with evenly distributed, tiny white dots representing the shrubs. Larger white dots generally are rabbitbrush, orange speckles are generally Apache plume.

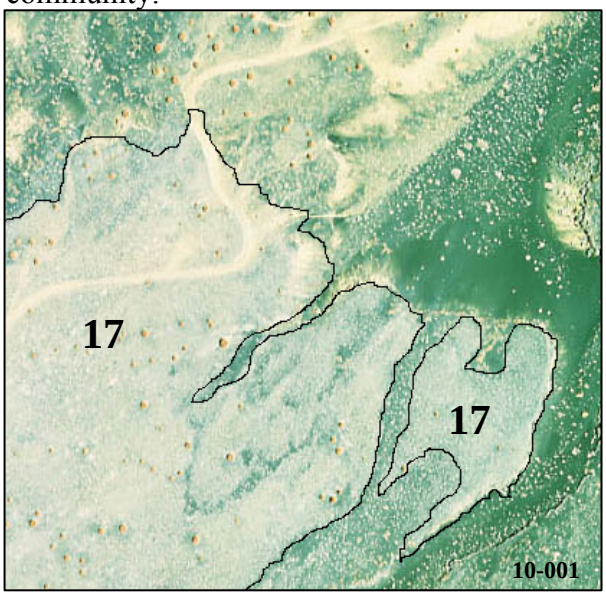
Black Grama Coconino Plateau Mixed Shrubland (16)

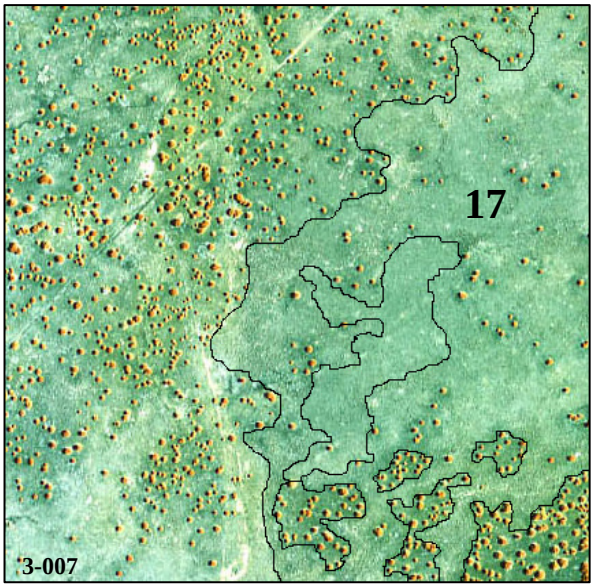
Location. This type is widespread across many habitats east of Highway 89. A Torrey's joint-fir/black grama community occupies Holocene gravel terraces, while a shadscale/black grama community occurs on barren limestone slopes.

Photosignature. This example shows the diversity of signatures exhibited by this map class. The upper left-hand corner of the photo is limestone slopes similar to the ground photo above. The area in the center of the photo is a low sandstone plateau covered with cinders, and on the right is lowland sandy silt soils liberally mixed with cinders and with an abundance of grass litter creating the whiter signature. Cobble areas such as shown in the ground photo above appear as dark gray irregular polygons on the aerial photos.

Rabbitbrush Shrubland (17)

Location. This map class covers large areas on level ground throughout the project area. On the limestone plateaus of the south and west parts of the area, it occurs interfingered with grasslands and with oneseed juniper woodland. On the basalt plateaus it is usually the primary type. North of the visitor center is a variation of this type, consisting of a galleta/shadscale shrub herbaceous community.





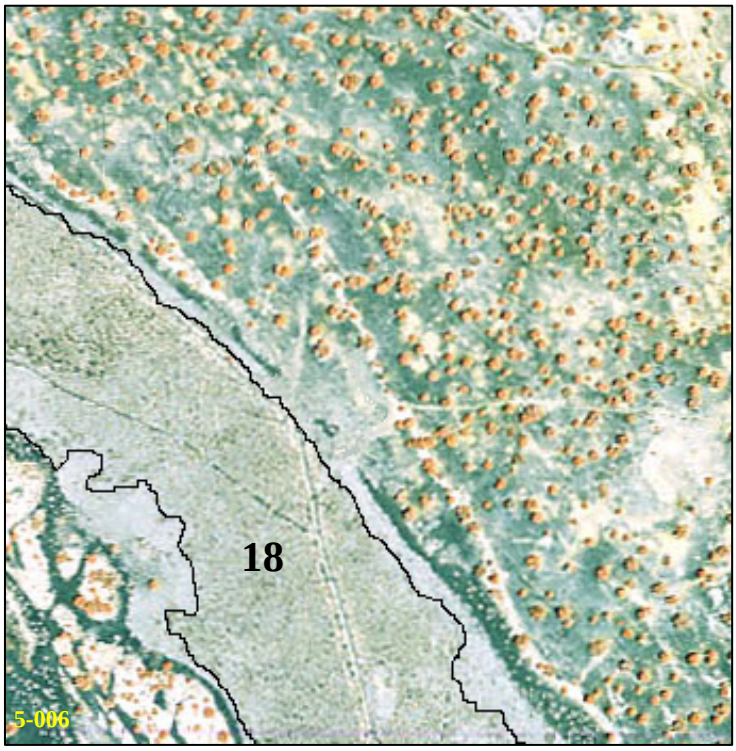
Photosignature. This is one of many map classes that appears light gray or blue-gray on the aerial photos. On limestone, a pebbly texture created by the rabbitbrush shrubs is visible (lower left photo); however, no texture is apparent with examples occurring on basalt or cinder substrates (lower right photo).

Fourwing Saltbush Upland Drainageways (18)

Location. This map class is a "park special" unit. It consists of upland floodways where soils are shallow over limestone. Although not contained within banks, water will flow then pond in these areas following storm events. These conditions favor the growth of fourwing saltbush, which dominates this community and is accompanied by lesser amounts of alkali sacaton, galleta, rabbitbrush and snakeweed.

No Ground Photograph Available

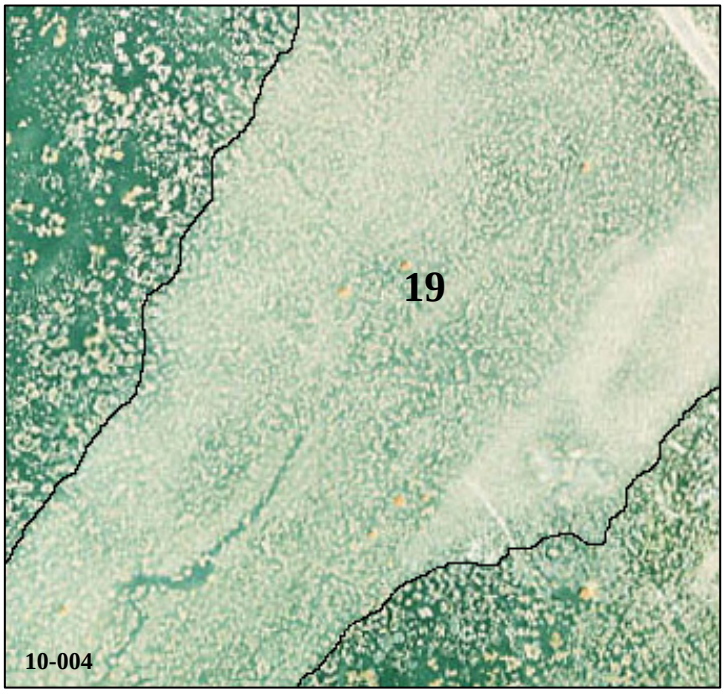
Photosignature. Polygons of this type are characterized by the dark green speckles that represent fourwing saltbush shrubs. The lighter gray background indicates the relatively high cover of grasses, principally alkali sacaton. Occasionally, streaks indicating the direction of flow are apparent.



Sand Sagebrush Shrubland (19)

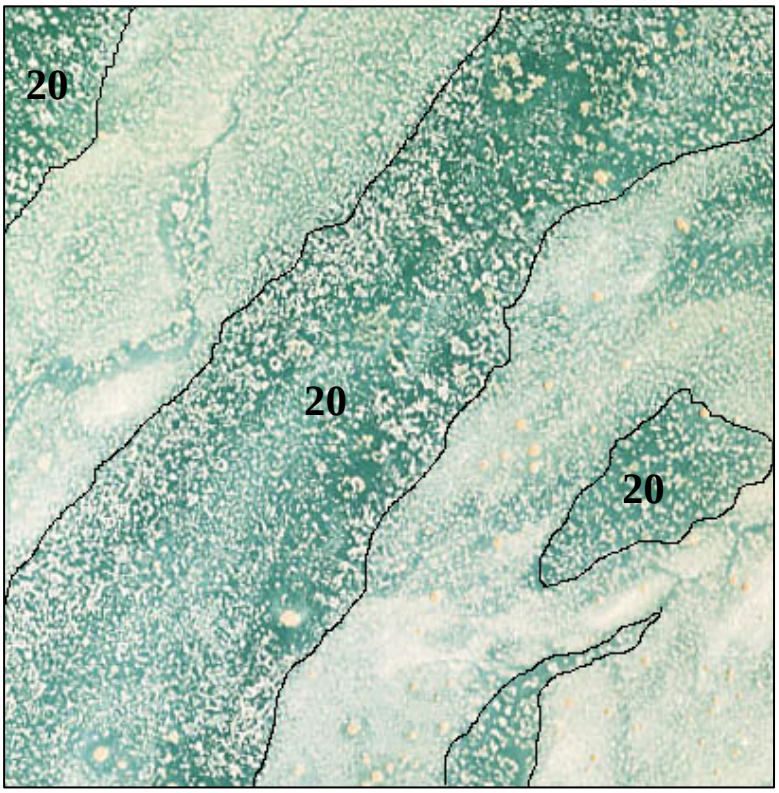
Location. This map class occurs in the upper Wupatki Basin, from the vicinity of the Visitor's Center east. It grows both on sandy soil derived from the Moenkopi Formation as well as coarse volcanic cinder substrates or a mix of the two. Sand sagebrush may be mixed with other shrubs and generally there is little grass cover.

Photosignature. Because of the variability in both substrate and shrub composition, the photosignature of this map class is variable. For the most part this unit was mapped from field observations. The example to the right is typical of occurrences on volcanic cinder; while the color is similar to the signature for rabbitbrush-galleta communities (17), individual shrubs of sand sagebrush and Apache plume are visible as white or brown specks.



Mormon Tea Cinder Dune Shrubland (20)

Location. This map class occurs primarily east and south of the employee housing area, on deep cinder deposits. The hummocky terrain results from wind erosion of cinders not held down by the roots of shrubs or perennial grasses.

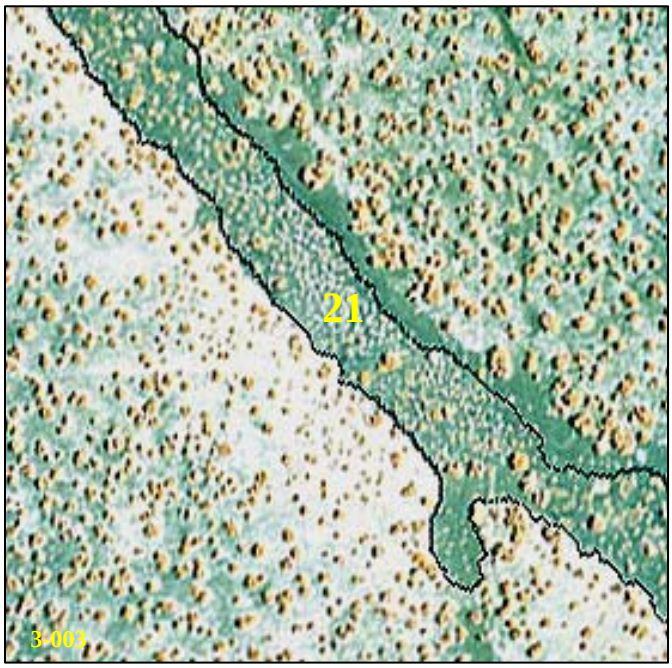


Photosignature. Polygons of this map class are often long, narrow and oriented southwest-northeast (the direction of the prevailing winds). The clumps of Apache plume, Torrey's joint-fir, crispleaf buckwheat and Mormon tea appear as large, irregularly shaped white or orange-brown speckles against a greenish black background.

Apache Plume Cinder Shrubland (21)

Location. This is the most common map class on cinder substrates east of the Doney Fault. Small polygons also occur west of the fault within the juniper woodland, anywhere there is a deep bed of black volcanic cinder. Apache plume is generally dominant, but may be mixed with green Mormon tea, fourwing saltbush, and rabbitbrush. Grasses may be sparse or abundant.

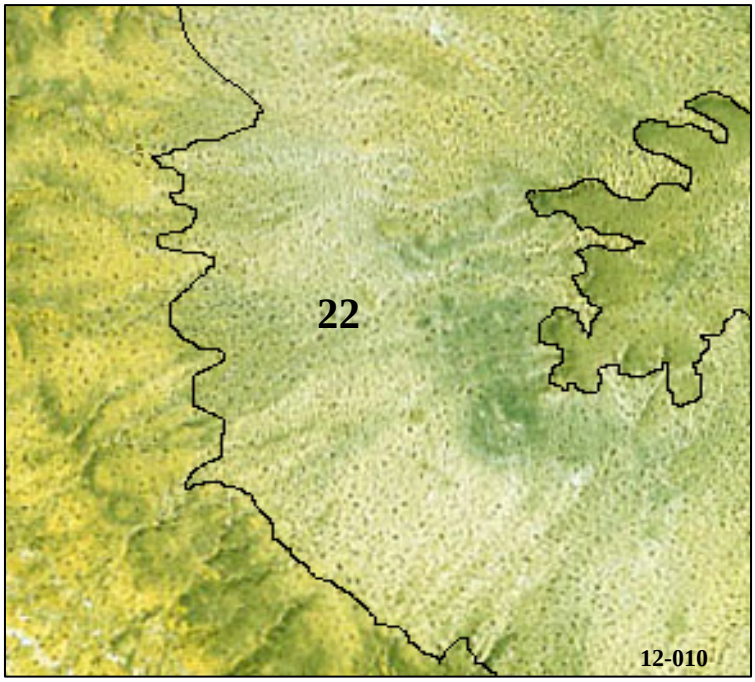
Photosignature. The dominant color is the greenish-black of cinder. Shrubs appear as white or brown speckles, and juniper as larger brown dots.



Frosted Mint Shrubland (22)

Location. Isolated Holocene deposits of alluvial sand occur scattered throughout the lower third of the Wupatki Basin. These sands support a sparse mixed shrubland which includes frosted mint.

Photosignature. The alluvial sands that support frosted mint are usually sandwiched between Moenkopi shales below and Holocene river cobble deposits above. This juxtaposition is illustrated in this aerial photo. The sands are mostly white to light gray in color, and the shrubs appear as minute darker specks.



Unclassified Mixed Shrubland (23)

No Ground Photograph Available

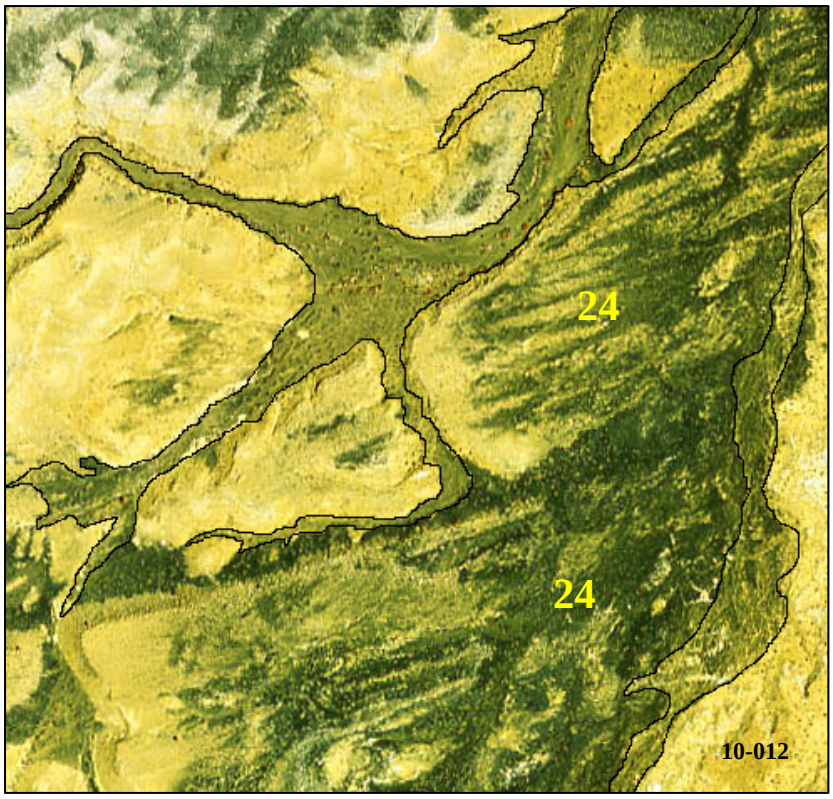
Location. A single polygon was classified to this map class. It is really a mix of many different map classes, each occurring in polygons too small to map individually. The map classes occurring within this polygon include: Snakeweed/Galleta Grassland (13), Wupatki Wash System (24), Apache Plume Cinder Shrubland (21), Moenkopi Shale Sparse Shrubland (6), Moenkopi Sandstone Sparse Shrubland (5), and Galleta Mixed Shrublands (14).

Photosignature. This type was mapped from field observations, but its appearance on the aerial photo gives an indication of the diversity of vegetation it contains.

Wupatki Wash System (24)

Location. This type includes several plant associations, all occurring in defined drainages throughout the project area. Dominant species include Apache plume, sand sagebrush, fourwing saltbush and alkali sacaton. The latter two types are illustrated below:

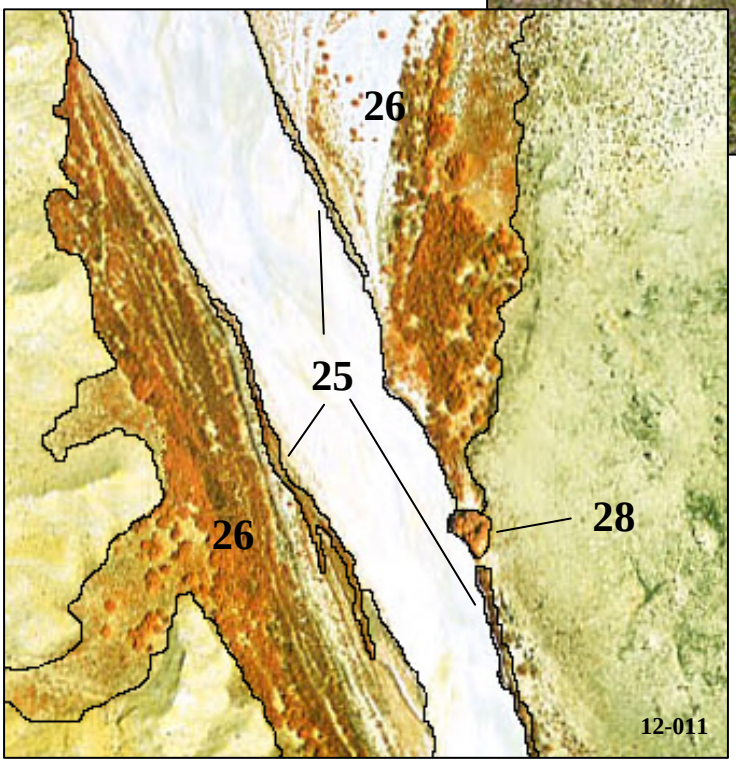
Photosignature. The dendritic shape of the drainages is diagnostic. Drainage floors may appear black, orange-black, orange, greenish black, or light gray, depending on the bedrock within the drainage. Apache plume and strechberry (*Forestiera pubescens* var. *pubescens*) shrubs appear as irregular red specks; other shrubs appear as gray specks. Streaking due to flow of water within the drainages may be apparent.



Little Colorado River Invasive Riparian Shrubland (26)
Fremont Cottonwood Woodland (28) – No Ground Photograph Available

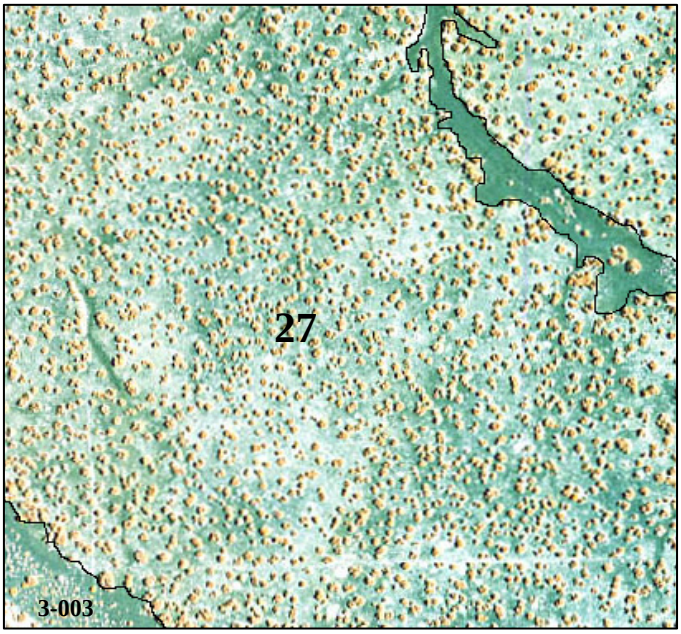
Location. These types are limited to the floodplains of the Little Colorado River and its major tributaries. Small patches of invasive riparian shrubland also occur away from the river in seeps.

Sandbar Willow Shrubland (25)



Photosignature. Mature tamarisk stands appear dark red with a rough texture. Young tamarisk have a bright red signature with a rough texture, as do the mature cottonwood trees. Camelthorn stands appear as a bright red haze with no texture. Sandbar willow was mapped entirely from field observations, as it occurs in belts too narrow to discern on these photos.

Oneseed Juniper Woodland (27)

Location. Open to closed juniper woodlands occur on the higher plateaus of the southern part of the project area. All woodlands are included in this map class, whether they have a sparse understory on cinder, or a relatively dense understory of grass and shrubs, as pictured above. The trees thin out toward the north, until they disappear entirely north of the park-Babbitt Ranches boundary.

Photosignature. The brown dots that represent juniper crowns are diagnostic. They may occur in a matrix of smooth white (usually grassland), rough light gray (rabbitbrush-grass understory), or greenish black (sparsely vegetated cinder understory).