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

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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
WACA	Walnut Canyon National Monument
VMP	Vegetation Mapping Program

SUMMARY

Walnut Canyon National Monument (WACA) 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

Thirteen vegetation map classes, three land cover map classes, and eight Anderson Level II land-use map classes were used for interpretation of approximately 20,700 ac (6,900 ha), encompassing the Monument (~3,600 ac/1,500 ha) and surrounding environs (~17,100 ac/8,400 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 1996 1:12,000 scale color infrared aerial photographs (0.5 hectare 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 69.2% using the acceptable error criteria with a Kappa Index of 66.7%. The overall 90% confidence interval is 64.1% to 71.8%.

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
- Federal Geographic Data Committee (FGDC)-compliant Metadata

WACA 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 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

Efforts to support the success of the WACA vegetation mapping project led to various work contracts with the following federal government agencies and private organizations:

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 collection and analysis, 3) provided data analysis and classification, 4) prepared the vegetation

[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.

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 WACA.

[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

WACA was first designated as a National Monument in 1915 as a presidential proclamation to protect significant cultural artifacts preserved as cliff dwellings. Since establishment, WACA's boundary has expanded four times to today's size of approximately 3,600 ac (1,500 ha) and is currently being sought out for further expansion by a local advocacy group, Friends of Walnut Canyon. WACA is located approximately 7.5 mi (12 km) east of Flagstaff, AZ (Figure 1). The Monument lies adjacent to the Coconino National Forest, the city limits of Flagstaff, AZ, and Arizona State lands (Figure 2). In the eastern section of the National Monument boundary, a private in holding of 290 ac (120 ha) occurs near the Santa Fe Dam. This project also encompasses a one-mile environ around the Monument, an additional ~17,100 ac (6,900 ha) of total mapped lands.

The National Monument is visited mostly for its extensive remains of cliff dwellings once inhabited by the Sinagua people from A.D. 1000-A.D.1250. Contemporary Native American tribes continue to have significant ties to the landscape. The National Monument also acts to preserve unique biotic communities of locally rare mesic plant communities, ecotonal communities ranging from semi-arid grasslands to mesic forests, and diverse animal communities.

Figure 1. Location of Walnut Canyon National Monument.

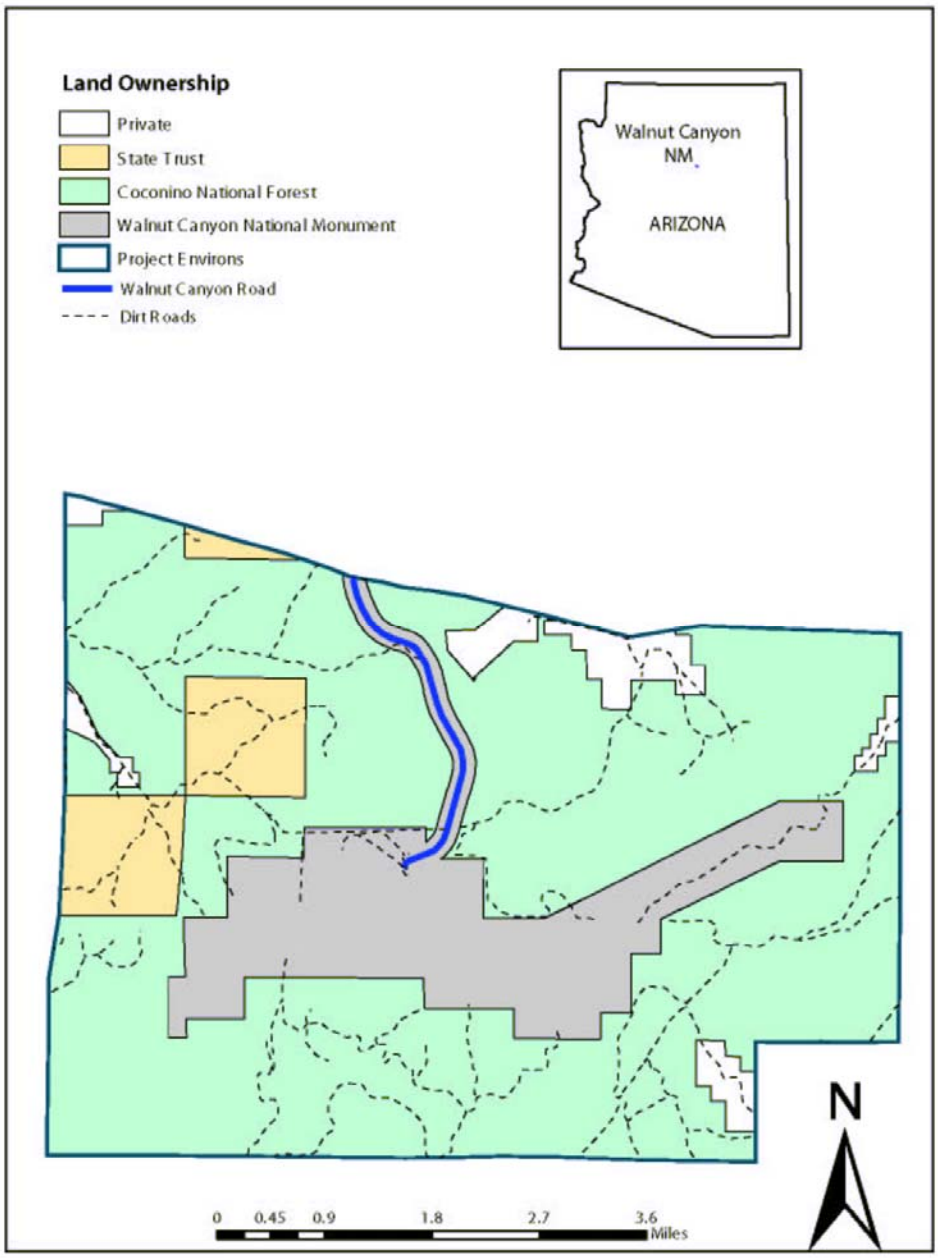

Figure 2. WACA vegetation map project boundaries and land ownership.

Location and regional setting

WACA is located on the Colorado Plateau in northern Arizona. Access to the park can be reached on a paved road, referred to as the park road in this report, to the northern rim of Walnut Canyon via Interstate-40. The main access route to the south rim of Walnut Canyon via Interstate-40 is Cosnino road, east of the park road. Cosnino road exits Interstate-40 northeast of the project boundary and winds around the southern boundary of WACA. Various other U. S.

Dept. of Agriculture - Forest Service (USDA-FS) dirt roads allow access to many other areas of WACA through the adjacent Coconino National Forest. A visitor center is maintained on the northern rim of the canyon at the end of the park road. Only two hiking trails are managed and maintained by WACA: the Island and Rim Trails. The National Monument limits public use of any area except these two designated trails and adjacent picnic areas. In the Coconino National Forest lands surrounding WACA, recreational hiking occurs throughout the project area on un-maintained trails as well as on the newly developed Arizona trail.

Climate

WACA has a semi-arid, continental climate typified by a moderately hot and moist summer, cool and dry spring and fall, and cold, periodically wet, winter. Monsoon-like precipitation events, often in the form of violent thunderstorms, occur principally from July through September. On average from 1971-2000, 5.9 in (15 cm) of rain fell from July-September out of the total 15.8 in (40 cm) of total precipitation (NOAA 2002). Average summer maximum temperatures range from 45 to 91 degrees F (7 to 33 degrees C), while average winter minimum temperatures range from 21 to 57 degrees F (-6 to 14 degrees C) (NOAA 2002). Winter snowfall average ranges from 2.5 to 4 in (6.4 to 10 cm) a month (NOAA 2002). Strong to moderate winds are commonplace within the region.

Geology, hydrology, and topography

The major geologic and topographic feature of WACA is the canyon itself (Walnut Canyon), an entrenched segment of Walnut Creek whose walls rise 300 ft (91 m) above the narrow canyon floor (Figure 3). The canyon cuts through the southeastern Coconino Plateau, a broad uplift that extends from the South Rim of the Grand Canyon to Flagstaff. Rising above the Coconino Plateau, south of Walnut Canyon in the southwestern section of the WACA project area, is an uplifted mesa referred to as Anderson Mesa. Cherry Canyon is the second largest canyon in the project area and is a major side canyon to the southeast of Walnut Canyon.

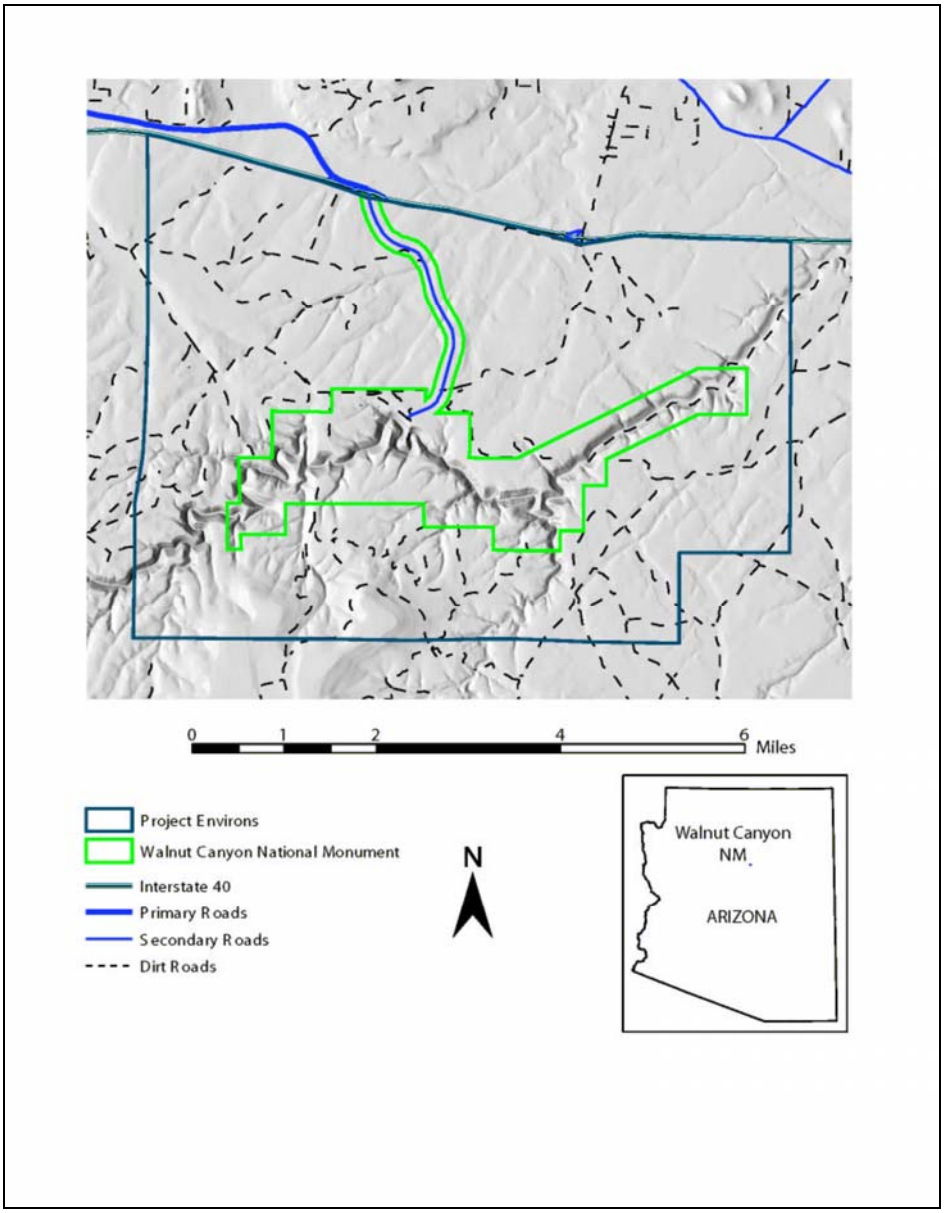

Figure 3. Shaded relief map of the WACA vegetation map project area.

In this report we refer to major landforms within the WACA project area. The main east-west canyon is Walnut Canyon. Side canyons feed into Walnut Canyon from the north and the south. The canyon consists of the canyon rims (upper lip of the canyon wall), canyon walls (slopes of the canyon), canyon terraces (level to gently sloping shelves bisecting the canyon wall), and the canyon bottom, where an intermittent drainage channel exists and water periodically scours the canyon bottom (Figure 4). The elevation in the project area ranges from 1,889m (6,197ft) to 2,207m (7,241ft). Although the vertical relief in the project area is less than 400m (~1,050ft), the vegetation responds significantly to this elevation change. We refer to elevation ranges throughout this report as low elevation (~2,000-2,100m; 6,550-6890ft), mid-elevation (the broad ecotonal area between the low and high elevation areas, ~2,100-2,200m; 6,890-7,220ft), and high elevation (~2200-2240m; 7,220 -7,350ft).

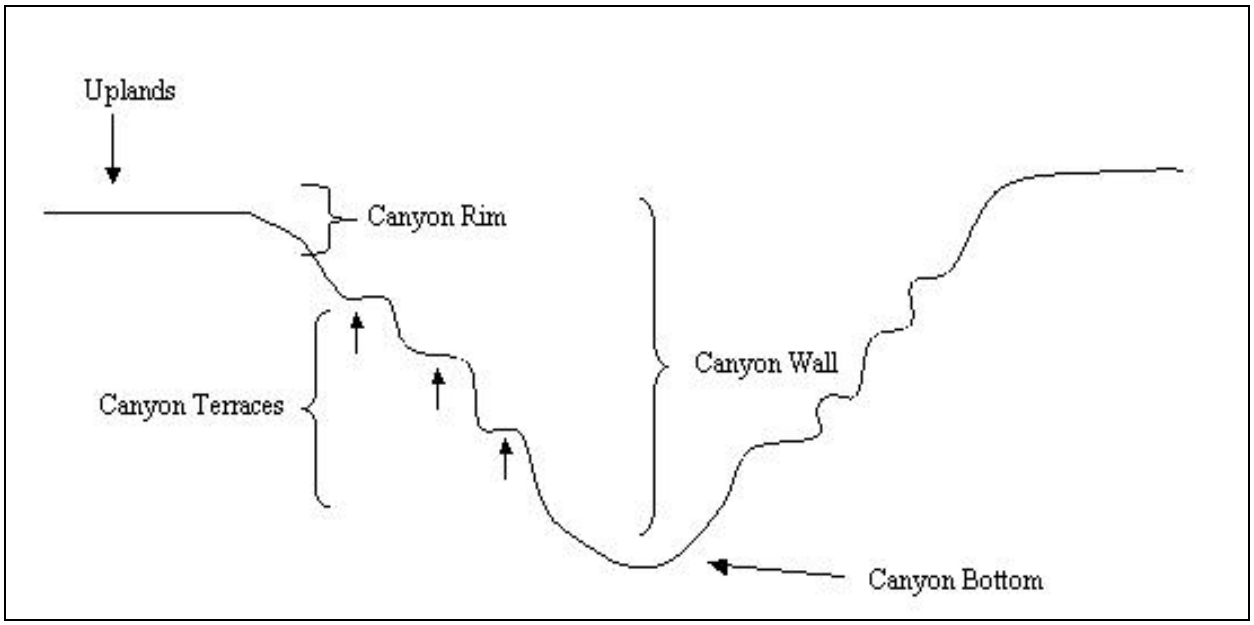

Figure 4. Landform descriptors used for the WACA vegetation map.

Well exposed within the Monument are two major rock units; the Kaibab Formation and the Coconino Sandstone (Figure 5). These units formed during the Paleozoic Era and record a time hundreds of millions of years ago when an ancient sea periodically covered much of the region (Chronic 1988).

The upper walls of Walnut Canyon are comprised of the Kaibab Formation, a resistant gray limestone that caps not only the canyon but also the rims of the Grand Canyon to the northwest. It forms characteristic ledges and slopes, and includes massive layers of limestone and dolomite as well as some thin siltstones and sandstones. Many of the layers are fossiliferous, bearing small clams, snails, and brachiopods (Chronic 1988). This unit also caps the higher, relatively flat mesas surrounding the narrow canyon within the Monument. More recent Mesozoic and Cenozoic rocks, such as the Chinle Formation seen in the Painted Desert and at Petrified Forest National Park, have been eroded away as this portion of the Colorado Plateau has risen slowly over time. Southward, the Colorado Plateau ends abruptly along the Mogollon Rim, a roughly 200 mi (320 km) long faulted escarpment that cuts across much of central Arizona.

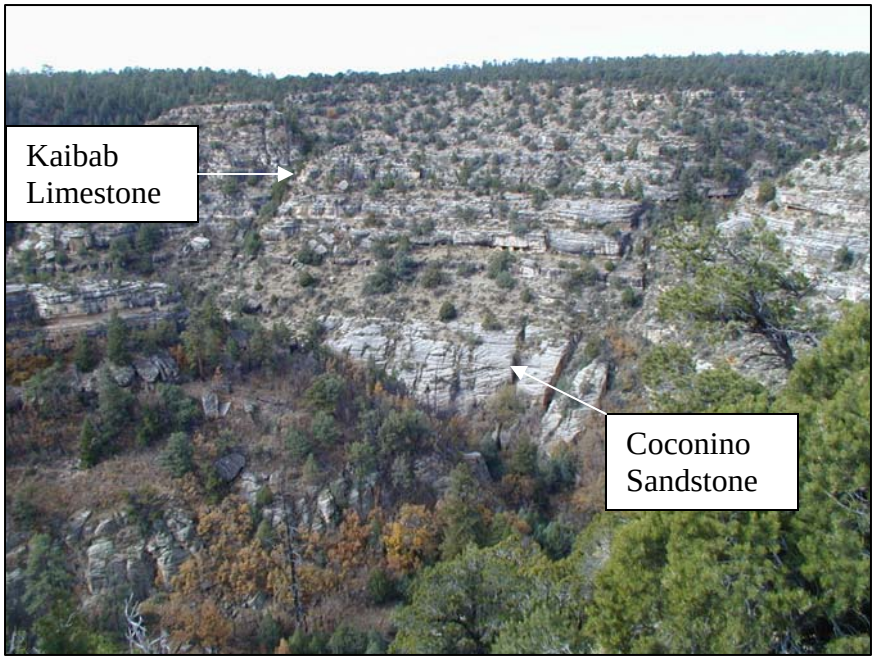

Figure 5. The two main geologic formations at WACA.

Lying stratigraphically beneath the Kaibab Formation are the light tan cliffs of the Coconino Sandstone. This distinctive unit is comprised of cross-bedded sandstones that developed as a regressive sea laid bare vast tracts of sand that were later reworked into large dune fields. Evidence of these dunes has been preserved as the striking bedding patterns seen in the rock. Much later in time faulting "broke up" these massive sedimentary units, forming small joints in the rocks that have commonly served as erosion channels. These small faults and joints likely influenced development of the canyon as these areas of fractured rock are much more easily eroded. Presumably beneath the Coconino Sandstone are additional Paleozoic rock units, such as those seen in the Grand Canyon, but the small watershed of the creek has not yet cut down into these older units.

In the southwestern section of the project area on Anderson Mesa younger basaltic soils lie on the surface of the Mesa as a result of geologically recent eruptions of Mormon Mountain.

Today Walnut Canyon is an intermittent drainage channel, but it likely flowed more often approximately 800 hundred years ago during habitation by the Sinagua, who built homes in recesses and alcoves in the canyon walls (Chronic 1988). Perennial pools may have developed, as the steep canyon walls and riparian vegetation offered shade and the scoured bedrock created small depressions that could trap water. Today Walnut Creek's upper watershed has been dammed to provide water for the city of Flagstaff. Upper and Lower Lake Mary (completed in 1903 and 1941 respectively), situated in a faulted graben south of Anderson Mesa, now capture a significant portion of the creek's water volume and this likely results in less flow through the canyon within the Monument. Prior to the dam, periodic flooding scoured the vegetation on the canyon bottom after snowmelts and summer monsoon storms.

Wildlife

Information used to prepare this wildlife summary for WACA includes Anonymous (1992), Hoffmeister (1986), Nowak et al. (2003), and Solomonson (1973), as well as additional data gathered during inventory projects for mammals and herpetofauna currently being conducted by researchers at the USGS CPRS.

Particularly in light of its proximity to suburban development, the variety of large mammals at WACA is remarkable. Mountain lions (*Puma concolor*), and occasional black bears (*Ursus americanus*) prowl the canyon and surrounding forest, and elk (*Cervus elaphus*) and mule deer (*Odocoileus hemionus*) are common. Collared peccaries (javelina; *Pecari tajacu*) are common, and are noteworthy because this is near the northern edge of their range. Among smaller mammals, Abert's or tassel-eared squirrels (*Sciurus abertii*) and gray-collared chipmunks (*Tamias cinereicollis*) are most likely to be seen because of their diurnal habits. Other mostly nocturnal small and medium-sized mammals include little brown myotis (a bat, *Myotis lucifugus*) and big brown bat (*Eptesicus fuscus*); deer mouse, brush mouse, and pinyon mouse (*Peromyscus maniculatus*, *P. boylii*, and *P. truei*); Stephens' woodrat (*Neotoma stephensi*), porcupine (*Erethizon dorsatum*), ringtail (*Bassariscus astutus*), hog-nosed skunk (*Conepatus mesoleucus*), gray fox (*Urocyon cinereoargenteus*), and bobcat (*Lynx rufus*). There are also some domestic large mammals in the eastern section of the Monument, since it is currently not fenced and open to cattle grazing, mostly in the bottom of Walnut Canyon. Cattle also graze on adjacent United States Department of Agriculture – Forest Service (USDA-FS) and State lands.

WACA supports a wide variety of birds of prey, including such rare or special interest species as Bald Eagle (*Haliaeetus leucocephalus*; in winter), Golden Eagle (*Aquila chrysaetos*), Northern Goshawk (*Accipiter gentilis*), Peregrine Falcon (*Falco peregrinus*), and Mexican Spotted Owl (*Strix occidentalis*). Other birds of prey at the Monument include Turkey Vulture (*Cathartes aura*), Sharp-shinned Hawk (*Accipiter striatus*), Cooper's Hawk (*A. cooperii*), Red-tailed Hawk (*Buteo jamaicensis*), American Kestrel (*Falco sparverius*) and Great Horned Owl (*Bubo virginianus*). Other medium-sized and large birds that inhabit the Monument are Wild Turkey (*Meleagris gallopavo*), Band-tailed Pigeon (*Columba fasciata*), and the ubiquitous Common Raven (*Corvus corax*). Smaller birds characteristic of the coniferous forest and canyon habitats of Walnut Canyon include Lewis' Woodpecker (*Melanerpes lewis*), Pinyon Jay (*Gymnorhinus cyanocephalus*), Steller's Jay (*Cyanocitta stelleri*), Pygmy Nuthatch (*Sitta pygmaea*), Black-throated Gray Warbler (*Dendroica nigrescens*), Grace's Warbler (*Dendroica graciae*), and Red-faced Warbler (*Cardellina rubrifrons*). Other common small birds are Mourning Dove (*Zenaida macroura*), Northern Flicker (*Colaptes auratus*), Hairy Woodpecker (*Picoides villosus*), Western Wood-pewee (*Contopus sordidulus*), Ash-throated Flycatcher (*Myiarchus cinerascens*), Violet-green Swallow (*Tachycineta thalassina*), Mountain Chickadee (*Poecile gambeli*), Rock Wren (*Salpinctes obsoletus*), and Canyon Wren (*Catherpes mexicanus*).

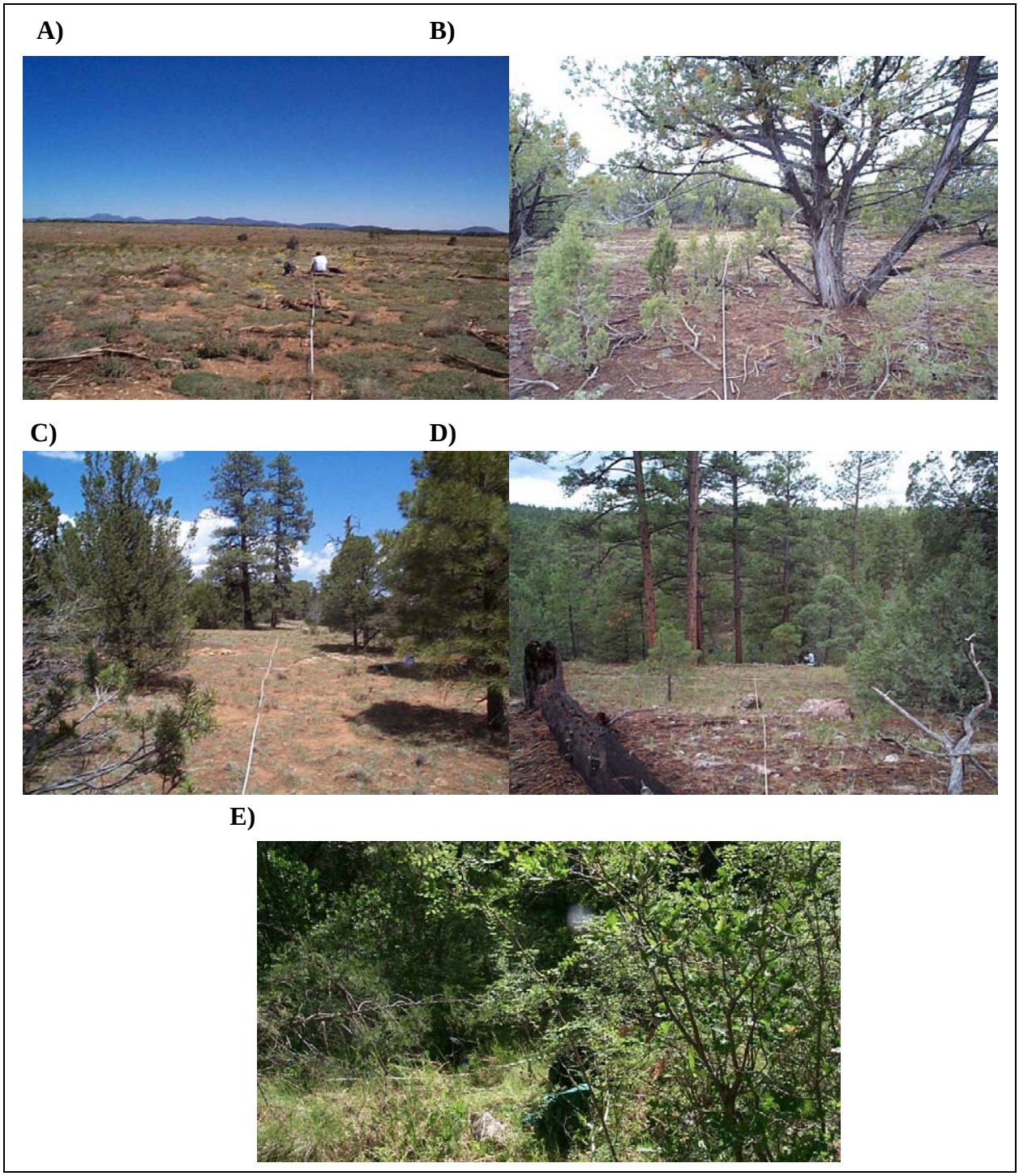

Figure 6. Vegetation typical of WACA include A) Previously chained areas with prairie dog towns, B) Utah juniper low elevation areas, C) Mixed ponderosa pine/ pinyon pine/ Utah juniper ecotonal areas, D) Ponderosa pine/ Douglas-fir mesic north-facing slopes, and E) Mesic dense riparian canyon bottom vegetation.

Amphibians are rarely encountered at WACA because of the general scarcity of surface water. Canyon treefrogs (*Hyla arenicolor*) and New Mexico spadefoot toads (*Spea multiplicata*) have been recorded from the canyon bottom and around artificial water impoundments. Among reptiles, there are several common lizard species. Eastern fence lizards (*Sceloporus undulatus*) and tree lizards (*Urosaurus ornatus*) are abundant in rocky and cliff habitats throughout the area, and the greater short-horned lizard (*Phrynosoma hernandesi*) is fairly common. The little striped whiptail (*Cnemidophorus inornatus*), and the plateau striped whiptail (*C. velox*) are both fairly common in the canyon bottom area, but are not found on the rims. Of the snakes that are known to occur in the Monument, the brightly-colored Sonoran mountain kingsnake (*Lampropeltis pyromelana*) is easily the most distinctive. The gopher snake (*Pituophis catenifer*) and the western terrestrial garter snake (*Thamnophis elegans*) are also fairly common throughout the Monument. The western rattlesnake (*Crotalus viridis*) is the only venomous snake that occurs at WACA.

Vegetation

Vegetation of WACA and the environs is diverse and ecotonal in nature (Figure 6). It ranges from low elevation grasslands to high elevation woodland and forest communities. Species that are often specific to a vegetation community more frequently intermix in WACA than other areas on the Colorado Plateau, forming a broad transition zone. Species that often co-dominate in the same habitat are pinyon pine (*Pinus edulis*), Gambel oak (*Quercus gambelii*), Utah juniper (*Juniperus osteosperma*), and ponderosa pine (*Pinus ponderosa*). High elevation species, riparian obligates, and more mesic species occur in high abundance in WACA due to north facing slopes and mesic canyon walls and canyon bottoms. These mesic and cooler environments have species that are typically found at higher elevation such as dense patches of Rocky Mountain juniper (*Juniperus scopulorum*), Douglas-fir (*Pseudotsuga menziesii*), and New Mexican locust (*Robinia neomexicana*). The canyon floor has a rich vegetation community with the overstory composed mainly of deciduous trees and shrubs, primarily box elder (*Acer negundo*), dogwood (*Cornus stolonifera*), New Mexican olive (*Forestiera pubescens*), Arizona walnut *(Juglans major*), New Mexican locust (*Robinia neomexicana*), Arizona rose *(Rosa arizonica*), and snowberry (*Symphoricarpos rotundifolius*).

Approximately 90 ac (36 ha) (<1%) of the mapping area consists of sparsely vegetated steep canyon walls or intermittent stream channels. On the canyon walls the two main geologic formations (Kaibab Formation and Coconino Sandstone) often occur in large rock outcrops on the steep slopes of Walnut Canyon with sparse to no vegetation. Hanging garden species can occur on the steep vertical canyon walls, especially in areas of water seepage. Hanging garden communities were excluded in our sampling design, since they only occurred in small patches and were difficult to sample. On the canyon bottom of Walnut Canyon and in the side canyons, intermediate stream flow can limit vegetation growth by scouring the vegetation. Prior to damming, the vegetation was much sparser in Walnut Canyon due to higher stream flow (Brian 1992). The sparse vegetation that often persists in the intermittent stream channel can consist of disturbance thriving forbs (annuals and perennials) and grasses.

Disturbance-thriving species occur in unique communities of grassland, shrubland, and steppe types in the northeastern section of WACA. The vegetation in this area was chained to increase

the forage potential of the area. Gunnison's prairie dog (*Cynomys gunnisoni*) colonies also thrive in this area. The results of these activities are a recently disturbed, diverse community of native and non-native grass and shrub species including blue grama (*Bouteloua gracilis*), fernbush (*Chamaebatiaria millefolium*), snakeweed (*Gutierrezia sarothrae*), horehound (*Marrubium vulgare*), western wheatgrass (*Pascopyrum smithii*), little hogweed (*Portulaca oleracea*), and cliffrose (*Purshia stansburiana*).

Grasslands in WACA are often only a small patch amidst woodlands or shrublands. Most of the herbaceous species in the mapping area co-occur with shrubs, forming a steppe (grasses dominant with >10% shrub cover). Blue grama and mountain muhly (*Muhlenbergia montana*) typically dominate small meadows that are often adjacent to ponderosa pine, pinyon pine, and Utah juniper woodlands. In the moister areas in the uplands, muttongrass (*Poa fendleriana*), little bluestem (*Schizachyrium scoparium*), and squirreltail (*Elymus elymoides*) commonly occur. In the mesic canyon bottoms of Walnut Canyon fringed brome (*Bromus ciliatus*) is often the main grass species. In disturbed areas in the northeastern section of the park native grasses include blue grama, Fendler's threeawn (*Aristida purpurea*), and black grama (*Bouteloua eriopoda*). Non-native grasses in these areas include the invasive cheatgrass (*Bromus tectorum*) and western wheatgrass (*Pascopyrum smithii*), a grass often used in reseeding efforts.

Shrublands commonly occur in disturbed areas and along the canyon bottom. Shrubs that are typical of the previously disturbed areas include rabbitbrush (*Ericameria nauseosa*) and snakeweed. These species are both native to the area; however, they thrive in areas of disturbance. Shrublands often occur on the limestone terraces on the north rim with a warm southern exposure, with common species including fernbush, barberry (*Mahonia fremontii*), banana yucca (*Yucca baccata*), cliffrose, and mountain mahogany (*Cercocarpus montanus*). Shrub species also occur in small patches that are inter-fingered as mosaics on the canyon bottom. Historical photography of the canyon bottom suggests that much of the riparian vegetation has increased substantially over the last 50 years, due to dams eliminating the natural water flow through the canyon (Brian 1992). Common species on the canyon bottom include riparian obligates such as dogwood and willows (*Salix* spp.) as well as species that prefer mesic habitats such as gambel oak, New Mexico locust, New Mexico olive, chokecherry (*Prunus virginiana*) and roundleaf snowberry.

Woodlands are the most common vegetation type in WACA and range from dense stands of trees on north-facing canyon walls, canyon bottoms, and in fire-suppressed areas to open stands of sparse trees in meadow-like areas. The most common trees in the upland environments are ponderosa pine, ranging from mid to high elevation areas in the park and pinyon pine and Utah juniper occurring mainly in the mid to low elevation areas. In the early 1900's large ponderosa pines were logged and the natural fire regime was altered, allowing for ponderosa pine to regenerate quickly and change the vegetation community from open meadows with low densities of ponderosa pine to areas of high density of ponderosa pine with a sparse understory community (Covington and Moore 1994). Much of WACA has a dense ponderosa pine stand structure due to these activities; however, some of WACA has larger ponderosa pines that have withstood these management activities. In the more mesic areas, Douglas-fir (*Pseudotsuga menziesii*) and Rocky Mountain juniper are the most common species, occurring in vegetation types with higher densities than woodlands, and are considered a forest vegetation type. A wide range of tree

species occur in smaller patches in the linear corridors of the canyon bottom, including willow, box elder, narrow leaf cottonwood (*Populus angustifolia*) and Arizona walnut. Many of these species are restricted to mesic sites and require intermittent water flow. These community types typically have high cover and diversity of shrubs and understory species due to the additional water flow in these areas. Riparian obligate species include sedges (*Carex* sp.) and willows.

Four plant species of special concern also are suspected to occur in the park. These species include Arizona bugbane (*Cimicifuga arizonica*), Arizona leatherflower *(Clematis hirsutissima* var. *arizonica)*, Flagstaff pennyroyal *(Hedeoma diffusa)* and Chiricahua dock (*Rumex orthoneurus*).

Land use

WACA has had a long history of human land use. The earliest evidence of humans living in the canyon was 4000 B.C., with the highest density of prehistoric people residing in the area from 600 A.D. to 1250 A.D. (Short 1988) (Figure 7). The Spanish named these prehistoric people the "Sinagua". The Sinagua used the landscape for many different purposes, including cultivating crops for food and hunting and gathering of native plants and animals. Resources in WACA were used to provide heat and cooking fuels from the trees in the area, to provide shelter in the limestone cliffs, to make tools from the rocks, to make pottery from the clay, and to provide drinking water from the springs. The archaeological site density at WACA is greater than twice that of the surrounding ponderosa pine areas (see NPS Draft General Management Plan 2001), suggesting that the Sinagua probably significantly shaped the landscape surrounding Walnut Canyon.

The Sinagua mysteriously abandoned Walnut Canyon approximately around 1250 A.D. and until 1904, when the first ranger resided in the park, no other evidence exists of human occupation. Although no large settlements of humans inhabited Walnut Canyon after 1250 A.D., the surrounding landscape has been altered by historic and modern human activity. Historic and recent landscape altering activities include logging, hunting, fire suppression, housing development, and road and utility construction; these activities have altered the ecosystem processes. Cattle were known to be a constant problem for rangers in the areas where ruins were being maintained (Short 1988), until a fence was constructed in 1973 and livestock grazing was eliminated. Grazing continues adjacent the Monument as well as within the unfenced Monument boundary.

Figure 7. WACA Sinagua ruins restored and maintained by the NPS.

3. METHODS

In mapping and classifying the vegetation of WACA, we used the protocols and procedures established by the USGS/BRD (Appendix B) 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. Preliminary data collection and review of existing information
3. Aerial photography and base map acquisition
4. Sampling design development
5. Field data collection
6. Vegetation classification and characterization
7. Vegetation map preparation
8. Accuracy assessment

Project scoping and planning

WACA 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) 3-Flagstaff National Monuments headquarters staff and WACA NPS 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, the plant association local descriptions and key, and 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, MS Access database file of classification relevé and accuracy assessment observations, and jpeg image files of classification relevé photos
8. Develop FGDC compliant metadata files (Appendix A) for all vegetation classification 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 NVCS and present on a public website (www.natureserve.org/explorer/)

A scoping meeting was held in March 1999 at the NPS office in Flagstaff, Arizona. The purpose of this meeting was to inform Monument staff and interested neighbors about the USGS-NPS Vegetation Mapping Program, learn about the Monument management and scientific concerns, discuss and gather existing data, develop a preliminary work 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 the project boundaries.

Park management issues and concerns that a vegetation map could help with were identified during the scoping meeting and included: increase in small diameter ponderosa pine (*Pinus ponderosa*) trees, viability of floodplain plant communities prior to the Santa Fe Damn, understanding historical logging of ponderosa pine, rare plant species in the Monument, adequate sampling in the diverse vegetation communities, encroaching urbanization from Flagstaff, and the sensitivity of archeological resources in relation to the vegetation types.

The mapping area was set at 20,732 ac (8,390 ha), including 3,637 ac (1,472 ha) within the Monument boundary. The additional USDA-FS, state trust, and private acreage surrounding the Monument were included because of its management interest to the NPS.

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 material for the project boundary and other digital files. Site and

topographic maps were obtained from both the NPS and the Coconino National Forest. Digital elevation model files (DEMs), digital line graphics (DLGs), and digital raster graphics (DRGs) were obtained from the USGS. The USGS prepared digital orthophoto quarter-quadrangles (DOQQs) to be used as base maps for the digital transfer of data interpreted from the aerial photographs. 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 (Fort Collins, CO) provided the aerial photography used in this project. The photographs are color infra-red (CIR) and were acquired on October 8, 1996 by Merrick & Co. of Aurora, Colorado. They were taken at the 1:12,000 (1 in=1000 ft, 1 cm=102 m) scale. The photographs were produced as 9 in x 9 in diapositives. Overlap for these photos averaged 50-60% and sidelap between flight lines was approximately 30-40%. Flight lines of aerial photography were acquired for photointerpretation of vegetation types (Figure 7).

We acquired base maps, standard USGS DOQQs, for geo-referencing the vegetation map from the NPS. These maps are black-and-white, with a one-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: Flagstaff East (NE and SE quarter quads) and Winona (NE, NW, SE and SW quarter quads).

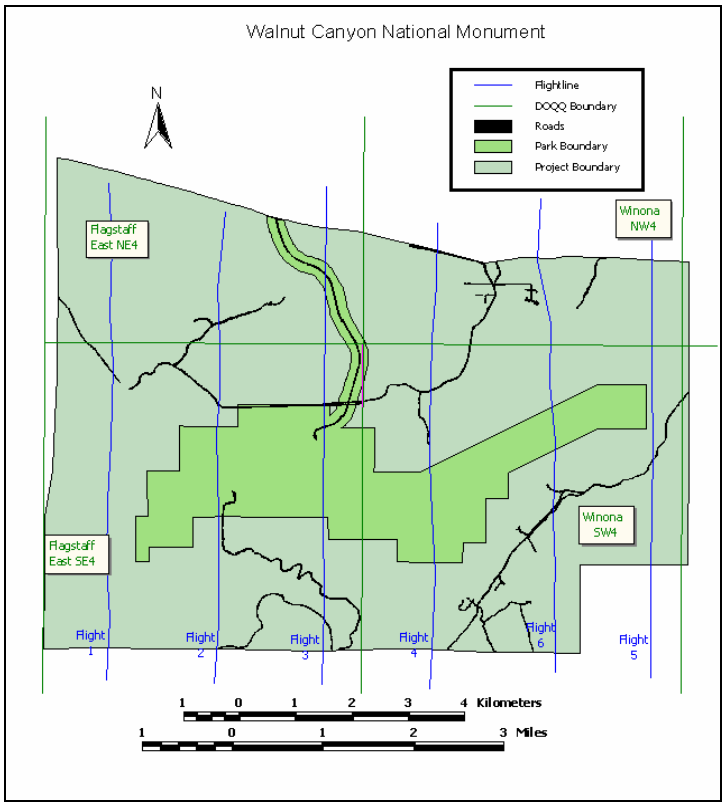

Figure 8. Aerial photo flightlines and DOQQ boundaries used for the WACA vegetation map.

Sampling design development

A gradsect sampling design was used to divide the WACA study boundary into 'environmental types' to stratify for field sampling. This division into environmental types was based on the assumptions that site characteristics determine vegetation community types, site characteristics repeat across the landscape, and that selective sampling within these sites provides accurate representation of plant community types (Austin & Heyligers 1989).

The gradsect was developed combining abiotic data of terrain types and elevation classes. Terrain types were identified from the USDA – FS Terrestrial Ecosystem Survey (TES) mapping data for the Coconino National Forest (Miller et al. 1991). We identified elevation classes from a scoping session with USGS, BOR, and NPS scientists and managers. Six elevation classes were developed from a Digital Elevational Model (DEM) and were combined with the TES data to produce unique environmental types for field sampling.

Forty-eight new environmental types were determined in the uplands. Fifty relevé locations were allocated within these areas to guide sampling. Within our selected environmental types we initially determined placement of relevés based on road accessibility and land ownership access. Some of the environmental types were not sampled due to inaccessible areas, occurrences of less than the minimum mapping unit of ½ hectare, and placement of types on private land.

We determined that environmental types along the canyon walls were often too difficult and dangerous to access. We implemented new tools to sample along the canyon walls and within the canyon bottom. Laser binoculars were lent to the program from Karl Brown of the Center of Biological Informatics (CBI). The binoculars provide locality information in UTM using the distance and azimuth offset of targeted locations in conjunction with the GPS Precision Lightweight GPS Receiver (PLGR) system. These observations provided information on dominant tree species; however, they did not provide additional data on the understory species. Thus, the complexity of strata of the canyon wall vegetation was not sampled as extensively as the upland relevés. These canyon wall relevés were used as reference relevés, but were not included into the statistical analysis.

Sampling on the canyon bottom was also based on accessibility. Relevés were completed using laser binoculars and when possible field sampling. Due to the density and heterogeneity of the vegetation on the canyon bottom, we clustered relevés in five locations. Strict allocation of observations by environmental types on the canyon bottom was not practical in sampling these habitats.

Field data collection

RSGIG ecologists conducted reconnaissance field surveys during which photointerpretive observation sites were sampled (in June 1999, May 2000, and June 2001). RSGIG ecologists photographed representative photosignatures 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. Photointerpretive observations also guided the development of a draft list of map classes. The data collected described the habitat and vegetation structure and composition. Specific information recorded at each observation point

included Universal Transverse Mercator (UTM) X-Y coordinates (NAD83 datum), dominant species cover estimates, and a brief description of the environmental characteristics (Appendix C).

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.

In August-September 1999 and July-September 2000 classification relevé sampling was conducted throughout the entire WACA project boundary. We used standardized methods (Muller-Dombois 1974, USGS-NPS 2000) to sample 109 classification relevés. 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 with specific interest to the park.

Typically we measured 1,000 m^2 circular plots, also known as vegetation relevés, in sparsely vegetated areas. We selected 1000 m^2 relevé as our standard as the vegetation of the area is relatively sparse and this size better represents the 0.5ha MMU than a 400 m^2 relevé (20% vs. 8%). Other vegetation studies of arid lands have also used this relevé size (Thomas et al 2003) and State Heritage ecologists recommended this size for arid and semi-arid vegetation (T. Keeler-Wolf pers. comm.). In areas of dense vegetation, such as riparian corridors, we would lower our relevé size to 400 m^2. Additionally, if rectangular or square areas better represented the vegetation patch shape we used this relevé layout instead, as found in dense riparian corridors within Walnut Canyon and its side canyons.

We recorded the vegetation and habitat characteristics using a standardized datasheet (Appendix C). We characterized habitat characteristics by recording the classification relevé slope, aspect, elevation, soil characteristics, topographic position, and landform types. We also recorded the community types (either wetland or upland). We also took two photographs that best represented the vegetation of the site and recorded the angles they were photographed from. Site UTM (NAD 83 datum), recorded by a Precision Lightweight Global Positioning System (GPS) Receiver (PLGR), landownership, and USGS quad were documented. We recorded basic vegetation descriptions of class, strata layer, and percent cover for all vascular plant species within a classification relevé. We subdivided the species into three different strata layers (tree, shrub, and ground layer) and estimated total percent cover of all species within each stratum. We estimated total vegetation cover and cover by strata layer (total tree, shrub, and ground cover). Since cover was estimated independently for each stratum, areas with dense canopy cover may have greater than 100% total cover. We also measured each tree with >10 cm dbh (diameter at breast height). In addition, we included separate calculations of percent cover for individual exotic and sensitive species as well as estimated total percent cover in each classification relevé.

The field data were entered into a Microsoft Access 2000 database. Plant names were standardized to the PLANTS (USDA, NRCS 1999) nomenclature. However, if The Nature

Conservancy (TNC) western preliminary alliances descriptions (Reid et. al. 1999) used synonymous nomenclature for a species name, this name was used instead in order to standardize our vegetation classification. After the data was entered, we also performed a spatial and data entry quality control check.

Vegetation classification and characterization

We based vegetation classification on guidelines developed from the National Vegetation Classification (NVC) (TNC and ERSI 1994b) and the Vegetation Classification Standard (NVCS) adopted by the FGDC (1997). The NVC classifies vegetation on seven hierarchical levels with the finest levels of the classification being the alliance and the association (Figure 9).

Physiognomic and Floristic Hierarchy

SYSTEM: TERRESTRIAL
CLASS woodland
SUBCLASS evergreen woodland
GROUP temperate or subpolar evergreen needle-leaved woodland
SUBGROUP natural/semi-natural
physiognomic levels FORMATION rounded-crowned temperate or subpolar evergreen needle-leaved woodland
floristic levels ALLIANCE *Pinus ponderosa* Woodland Alliance
ASSOCIATION *Pinus ponderosa / Bouteloua gracilis* Woodland

Figure 9. An example of the NVCS physiognomic and floristic hierarchy using the *Pinus ponderosa* / *Bouteloua gracilis* 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 coarser 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 alliance is based on the dominant and diagnostic species, and include at least one species from the uppermost stratum in the alliance name.

We initially analyzed the vegetation using multivariate classification analyses. We organized matrices of species absolute cover by relevé (typically row) and species (typically column). These were extracted from an Access database and transferred to a vegetation classification and ordination software program, PC-Ord, v 4.10 (McCune and Mefford 1999). Six matrices 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. Cover estimates needed to be summed, since the total vegetation calculated in the field was based on the strata layer, not on the lifeform. Many species occur in all three strata layers (for example, ponderosa pine commonly occurred in the ground (small saplings), shrub (medium saplings), and tree layer). We based the percentage used to separate each lifeform type on criteria for NVCS formation classes developed by the FGDC as interpreted by NatureServe (Grossman et al. 1998, Reid 2000 pers. comm.). Some relevés had greater than 25% total cover but less than 25% of tree, shrub or herbaceous cover. In those cases the relevé was assigned a formation class based on the dominant lifeform.

We used multivariate ordination algorithms within PC-Ord to examine species association patterns in each matrix. An agglomerate unweighted pair group method with arithmetic mean (UPGMA) group averaging method, commonly known as cluster analysis, we next applied with the distance measure defined as Sorensen's coefficient (also known as the Czekanowski or Jaccard coefficient). We examined preliminary descriptions of alliances from An Alliance Level Classification of Vegetation of the Coterminous Western United States (Reid et. al. 1999) referred to hereafter as the TNC western preliminary alliances, to identify potential alliances. We labeled each relevé in the cluster analysis with an appropriate alliance and association label based on iterative examination of the alliance descriptions, the matrix of relative cover scores for each species, and the cluster analysis graphic dendrogram.

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 NVCS, 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 NVCS (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 NVCS 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 NVCS, 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 WACA 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 2001 accuracy assessment field season. We used the key in the 2001 data collection for accuracy assessment. We made slight modifications before using the key in the second round of accuracy assessment observations collection during the 2002 field season (Appendix D).

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

A relatively simple vegetation and land use classification was prepared to guide a preliminary aerial photointerpretation, completed by RSGIG in June 1999. CPRS ecologists also used this preliminary work to better examine the landscape and vegetation features of the project area during vegetation relevé sampling activities. So as not to bias field researchers, each polygon delineated was given a consecutive number, with attributes for each polygon number listed in a separate table.

Final WACA map classes used for interpreting the aerial photographs were derived (1) from plant associations described by CPRS, (2) from the Anderson (1976) Level II land use classification system, and (3) from special requests by NPS staff.

The Vegetation Mapping Program standard is a one-to-one correspondence between NVCS plant associations and map classes. Anderson Level II land use classes describe polygons that are not covered adequately by the NVCS, including modified landscapes and developed areas. Finally, special vegetation types, habitats, and land use recognized by NPS staff but not part of the NVCS were mapped. In some cases, one NVCS 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 two mountain meadow grassland associations (*Bouteloua gracilis* Herbaceous Vegetation and *Muhlenbergia montana* Herbaceous Vegetation) into a Blue Grama – Mt. Muhly Grassland Group map class.

In some instances, NVCS association map classes provided less detail than could be photo delineated. In these instances, we defined and mapped additional information of species composition (e.g. Ponderosa Pine – Pinyon Pine – Juniper / Blue Grama Woodland and Ponderosa Pine / Mixed Graminoid Woodland Complex map classes are both derived from the *Pinus ponderosa / Bouteloua gracilis* Woodland association). This level of detail provided additional refinement in the mapping classes and provides additional information to park management.

The Anderson Level II land use classes included semi-natural vegetation and cultural types, i.e. roads, facilities, residential land, reservoirs and pastures, etc. We developed special map classes

to represent the geologic and landform features with sparse vegetation and include Sparsely Vegetated Coconino Sandstone, Sparsely Vegetated Kaibab Limestone, and Sparsely Vegetated Intermittent Drainage Channel. We developed a map class to represent NVCS vegetation associations defined only through the photointerpretative process, Introduced Western Wheatgrass Grassland. Finally, we developed a special map class for prairie dog towns, Common Horehound – Prairie Dog Town, that is not represented in the NVCS. The crosswalk showing how associations relate to map classes is shown in Table 1.

Aerial photograph interpretation

RSGIG identified patches of homogenous vegetation (areas on the photos with similar tone, texture, color and landscape position) using NVCS-derived map classes, field notes, photointerpretative observations, and classification relevés to prepare the GIS vegetation database.

We conducted photointerpretation using aerial photographs 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, with only the center portion of each aerial photograph 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.

Digital transfer

The transfer process removes much of an aerial photograph's inherent distortion and ties the interpreted polygons to real-world coordinates so they can be digitally automated. An ArcInfo GIS database was built for WACA vegetation using in-house protocols.

The protocols consist of a shell of Arc Macro Language (AML) scripts and menus (nearly 100 files) that automate the transfer process, thus insuring that all spatial and attribute data are consistent and stored properly. 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). The actual transfer of polygons and their attributes 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. Once all the transfer work was complete, all the individual vegetation coverages were combined into one seamless coverage.

The scanning transfer technique used for WACA involved a multi-step process whereby the Mylar overlay sheets produced by the photointerpreters were scanned into a digital form. We then converted the digital image file (.tif) created from the scanned sheet 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 10).

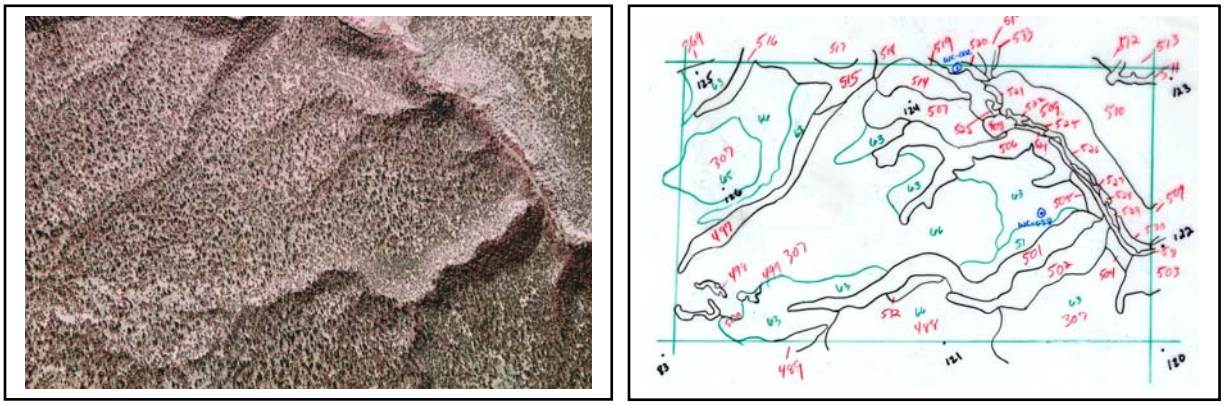

Figure 10. An example of photointerpretation at WACA of aerial photo 3-004 and corresponding (scanned) Mylar overlay.

Any remaining land use classes not already scanned (such as roads) we transferred by means of on-screen digitizing. This process entered interpreted line work on the Mylar sheets into the GIS database 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, we 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 WACA was given attributes pertaining to map classes, the corresponding aerial photograph number, NVCS information (ecosystem, physiognomy, association, alliance, class, subclass, group, subgroup, formation, and database codes), and other comments related to the distribution and photointerpretation.

<u>Map validation</u>
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, we applied photointerpretative observations and classification relevés over the vegetation map to determine if the polygon labels matched the field data.

Finally, map validation occurred prior to the accuracy assessment. Staff from RSGIG conducted a field trip in conjunction with other meetings in Flagstaff, AZ in January 2001 to refine and assess the initial mapping effort. On this trip we collected additional photointerpretative observations and ground-truthed aerial photograph signatures using landmarks and GPS waypoints. Map classes were lumped or split to account for inadequacies in the final photointerpretation.

Metadata

Metadata are required for all spatial data produced by the federal government. RSGIG used SIMMS™ software and CPRS used ArcCatalogue software to create the FGDC-compliant metadata files attached to the spatial databases and to this report (see Appendix A). The metadata files explain the vegetation coverage and ancillary coverages created by RSGIG, the classification relevé data coverage created by CPRS, and the accuracy assessment observation data created by CPRS.

Accuracy assessment

CPRS field staff conducted the formal accuracy assessment of the WACA vegetation map and vegetation association key. We conducted field surveys in two phases, from September 4 to September 25, 2001 and from October 25 to December 12, 2002. Phase one of sampling was designed using a preliminary vegetation map and allowed a majority of the field accuracy observations to be collected for all the map classes. Phase two was planned with the final vegetation map and the design ensured that all necessary sampling points were collected for assessment of the final vegetation map. We pooled the accuracy assessment observations from 2001 and 2002 to create the reference dataset to assess the accuracy of the map classes on the 2001 final vegetation map using both standard criteria for accuracy (exact match) and 'fuzzy' categorization criteria for accuracy (acceptable, understandable, vaguely similar, and complete error).

Before developing the sampling design for accuracy assessment observations, we checked the topology and data structure for the vegetation coverage by running a check for node errors and label errors. We combined joining polygons with the same attribute.

Field sampling locations were then selected for each map class based on the total cover of each vegetation class in the coverage, where map classes with more cover had more reference points assigned, and vice versa. 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 and selected the required numbers of polygons for each map class 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 accuracy assessment sampling numbers.

Scenario	Description	Polygons in map class	Area occupied by map class	Recommended number of samples in map 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

We initially identified 461 accuracy assessment sampling locations in 2001 and 566 in 2002, including alternate locations in case a targeted point could not be evaluated. We observed 270 locations in the field in 2001 and 126 in 2002. Some observations from 2001 were not included in the pooled 2001 and 2002 accuracy assessment observation dataset used to calculate the accuracy statistics. We eliminated observation data when both 2001 and 2002 accuracy assessment observations occurred within a single polygon on the final vegetation map. In such cases, the accuracy assessment point assessed in 2001 that assessed the largest area of the polygon was selected to be included in the pooled accuracy assessment observation dataset.

In 2001, sampling locations in polygons greater than the MMU of 0.5 ha were visited; however, if the required number of samples for a map class could not be obtained in polygons greater than the MMU, polygons less than the MMU were then visited for field observations. In 2002 all polygons were included in the sampling design regardless of the size of the polygon. In both 2001 and 2002, polygons that were greater than the MMU had sampling locations randomly assigned in the polygon excluding a 5-m buffer from the polygon edges. In 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. In 2001, polygons greater than the MMU, a 0.5 ha area

(MMU) was surveyed. In polygons less than the MMU, a radius (less than the MMU) was provided to the field team to ensure that they would not survey in an adjacent polygon and they were to survey the entire radius prior to determining the map class. If the polygon size was less than a 10-m radius (0.03 ha), than a polygon map was provided to the field team to orient them within the polygon and the whole polygon was to be surveyed. In 2002, the field team had a polygon map for all polygons sampled. In polygons greater than the MMU, the field team was to survey an area equivalent to the MMU prior to making a final determination of the map class. In polygons less than the MMU, the entire polygon was surveyed.

Data collection

The CPRS field team had a list of UTM coordinates for each sampling point, the area and length of the polygon, and the shortest distance to an adjacent map class. In the first phase, for those polygons with less than the MMU (<0.5 ha), maps were provided of each small polygon to be observed that showed a distance scale and direction orientation. In the second phase, the field ecologists had polygon maps for all polygons observed including those >0.5 ha. 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 (2002) or within an assigned radius about the sampling location (2001). Sampling radii were predetermined such that the area observed was contained within the polygon being assessed. We recorded accuracy assessment observations, including the following: the plant association or map class within the assigned radius about 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 if less than exact (including alternative map class possibilities), UTM coordinates (easting, northing), altitude, and GPS error (using the Garmin 45XL, Garmin Corporation, 1996). See Appendix C for an example datasheet. The field biologists 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 locations.

During the accuracy assessment fieldwork, ongoing discussions between the field biologists and project ecologists/botanists allowed for refinement of the NVCS plant association and map class key, as well as some of the vegetation classifications. We implemented these changes in the key and reflect some changes between the first and second round of sampling in the interpretation of the association map class concepts. Revisions to the 2001 key included, in some cases, relaxation of some of the quantitative criteria to identify the plant associations so that more qualitative evaluation of the label was possible in the field. We made this change to allow more breadth in the interpretation of the map classes so that variability in the label that may not have been measured on the classification relevés could be accounted for within the field 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). 2001 and 2002 field observation data, except for those observations that were remotely assessed in 2002, were overlain onto the final vegetation map to determine the corresponding map class for each location. In these cases, the map class that was identified for the target polygon in the sampling design was assigned to the map class data rather than the 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 producers accuracy), commission accuracy (also known as users 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, we use five criteria: exact match, acceptable error, understandable error, vague similarity, and complete error, to assess the fit between the reference data and map class for each sampling location (Table 2). We included only criteria 5, 4, and 3 in our analysis, since criteria 2 and 1 did not provide any additional information.

Table 2. WACA definitions used in the 'fuzzy set' analysis classifications.

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 than 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, adjusting for National Map Accuracy Standards for horizontal accuracy (Robinson et al. 1984), 2) The reference label is in a 2001 polygon that became an inclusion below the MMU in 2002 and had similar floristic and structural composition of the larger 2002 polygon, 3) The reference data has an alternative reference label that was described in the field, which was correct for the map class, 4) The reference label described using the 2001 plant association field key was an alternative correct map class described using the 2002 map class field key, or 5) The reference label is the same NVCS association as 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 similarity in the species or structural composition.

A contingency table was created for three criteria: 1) exact match— 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 label was represented by exact (criteria 5) and acceptable (criteria 4) matches between reference data and map class data, and 3) understandable error—a correct label 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 are 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 the map class Limestone Rim Complex mapped as Pinyon Pine – Utah Juniper / Blue Grama Woodland. In this example, the field observation was 9 m from the nearest polygon, with a GPS error of 5 m, and the closest polygon was labeled Limestone Rim Complex. Due to the vertical relief in this area and the close proximity of the accuracy assessment observation to a polygon with a matching map class, we believed that the misidentification may be a locational error either on the map or in the field rather than a photointerpretation misclassification.

Acceptable error was also determined where interpretation of the field observation differed between the preliminary and final map. For example, a field observation of Blue Grama – Mt. Muhly Grassland Group was made in 2001 and its location was in a small (1.6 ac/0.661 ha) polygon in the preliminary map. However, on the final map, the sampling location for this observation was now included in a larger polygon (2,548 ac/1,031 ha) labeled Ponderosa Pine / Mixed Graminoid Woodland Complex. The notes for the original observation described the field situation as high tree cover. In this case, where the scale of consideration changed, we considered the field observation an acceptable match to the final map class.

Another case of acceptable error was where the accuracy assessment observation was classified as Pinyon Pine – Utah Juniper / Blue Grama Woodland, and on the field sheet it was described as poorly fitting the polygon with an explanation that the polygon also might contain the map class Ponderosa Pine / Gambel Oak Woodland. The map class was actually Ponderosa Pine / Gambel Oak Woodland. In this case two different map classes may have occurred within the same polygon and since this map class was listed on the field sheet as an alternative map class, the accuracy assessment observation was considered an acceptable error.

Better understanding of the photointerpretation criteria resulted in some changes in the field key. We considered alterations of the field key from the version used in 2001 to the version used in 2002 in assigning acceptable error. For example, in the 2001 field key the map class Snakeweed / Modified Grassland Complex was identified by the presence of a few non-native or native weedy NVCS associations; whereas the map class was photointerpreted in 2002 to represent any area of recent landscape disturbance. In this case, native NVCS associations that were described as occurring in an area of human disturbance were re-evaluated using these new criteria and assigned acceptable error if the map class was Snakeweed / Modified Grassland Complex.

Another example of an acceptable error was where an accuracy assessment observation of Ponderosa Pine / Blue Grama Woodland was mapped as Ponderosa Pine - Pinyon Pine - Juniper / Blue Grama. The accuracy assessment observation was classified as the NVCS association *Pinus ponderosa / Bouteloua gracilis* Woodland, where the mapped class is *Pinus ponderosa*

(Pinus edulis – Juniperus osteosperma) / Bouteloua gracilis Woodland. For this map class, pinyon pine (*Pinus edulis*) and Utah Juniper (*Juniperus osteosperma*) do not necessarily need to be present in order to be placed into this association. Since the field observation contained the required ponderosa pine (*Pinus ponderosa*) and blue grama (*Bouteloua gracilis*) to match the map class, it was assigned to the acceptable error category.

An example of understandable error occurred where the accuracy assessment observation had a similar species composition and structure as the map class assigned to the polygon containing the observation. For example, Ponderosa Pine –Pinyon Pine - Juniper / Gambel Oak Woodland as the reference label and Ponderosa Pine –Pinyon Pine - Juniper / Blue Grama Woodland as the map class have the same structure and species composition, except for the understory community. In this case, it is likely that it was difficult for the photointerpreters to delineate the understory community.

Vaguely similar would include the case where the accuracy assessment observation (Ponderosa Pine / Mixed Graminoid Woodland Complex) structure was similar to the map class (Pinyon Pine – Utah Juniper/ Blue Grama Woodland); however, the species composition is not similar. An example of complete error was where the reference label (Pinyon Pine – Utah Juniper / Blue Grama Woodland) had no similarity with the map class (Sparsely Vegetated Coconino Sandstone) in terms of structure or species composition.

Where the accuracy assessment observation was determined to 'fit' the map class for a particular criteria, the accuracy assessment 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 accuracy assessment observation/map class pairs that were matches under the particular criteria being applied.

Overall total accuracy for each contingency table criteria as 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 was divided by the total number of samples classified or mapped to that vegetation association.

Equations to calculate statistics for each criteria are described in the program documents, 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, Cary, NC) 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, a Kappa index (Foody 1992; TNC and ERSI 1994c) was calculated also using JMP statistical software.

4. RESULTS

Field surveys

Forty-six photointerpretation observation sites were field sampled by RSGIG photointerpreters (Figure 11). One hundred and nine classification relevés, including 10 laser obtained relevés, were field sampled (Figure 12). At each classification relevé, we took two photos. Information recorded for each classification relevé and classification relevé photos are on the project CD (see Appendix A).

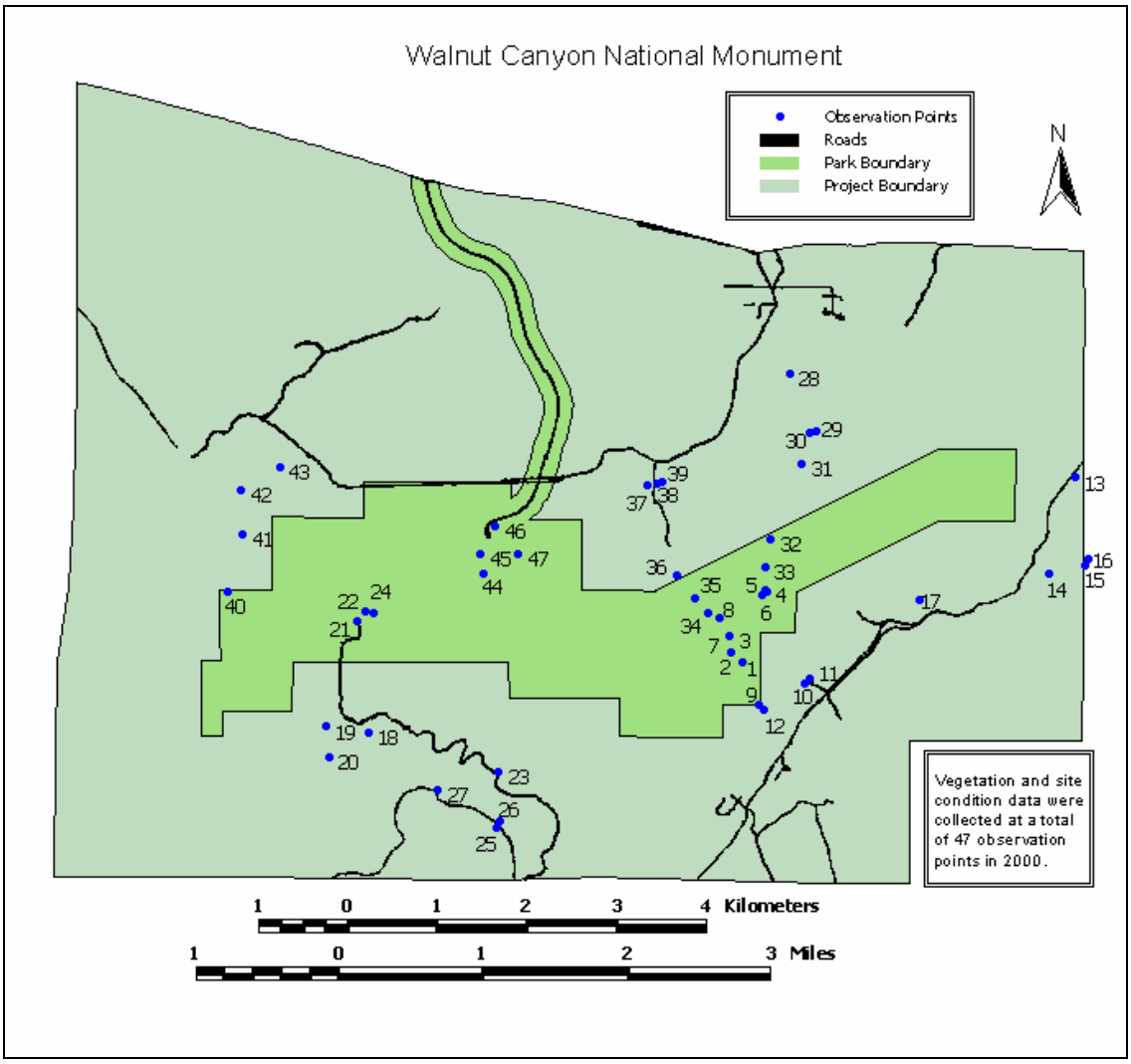

Figure 11. WACA photointerpretation observation point locations.

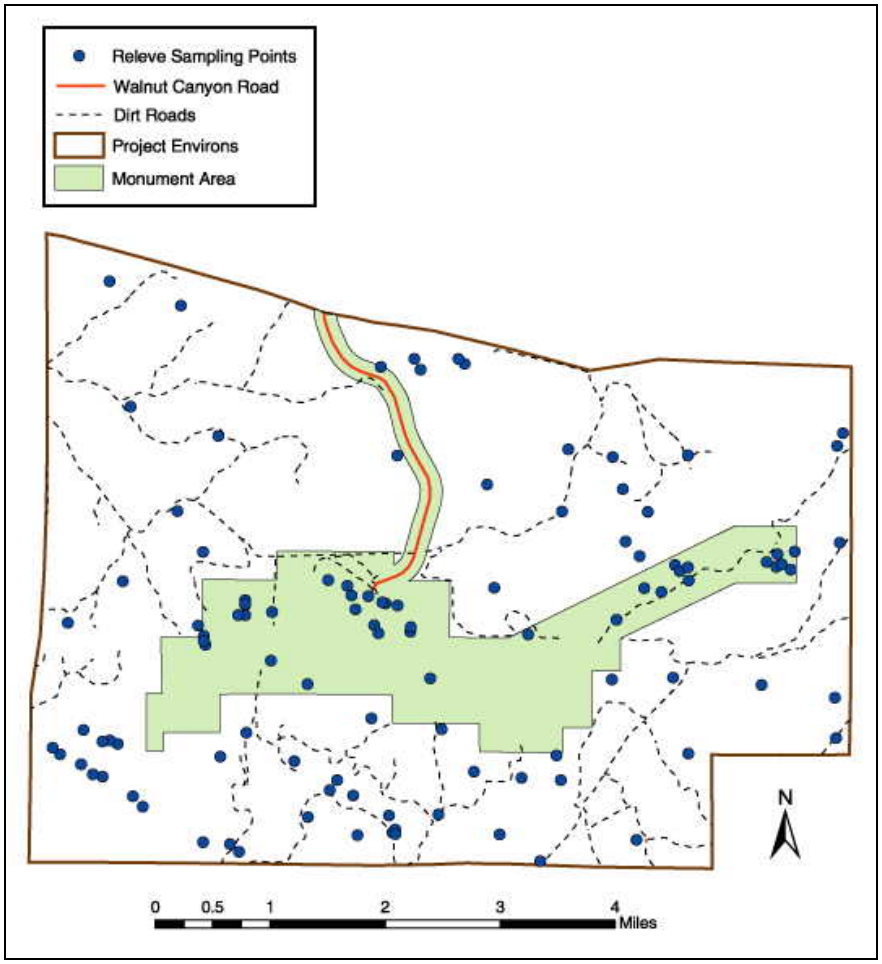

Figure 12. WACA classification relevé locations.

Vegetation classification

The NVCS classification resulted in a total of 13 alliances, 14 associations, one provisional alliance and two provisional associations, three Monument specific local assemblages, and one alliance and association described only through photointerpretation (Table 3). Full descriptions of the WACA vegetation associations, provisional associations, and local assemblages are located in Appendix E. A listing of all species identified during the course of this study can be found in Appendix F. Three local assemblages were identified as possibly being unique to WACA, these assemblages need further sampling on the Colorado Plateau to determine if they represent local vegetation types unique to WACA or if they are distributed across the landscape. We described one provisional alliance and two provisional associations as occurring frequently enough during the course of the study to be included as provisional in the NVCS, but they will need additional field data collected in other localities on the Colorado Plateau to support their addition as a NVCS alliance and association. Two alliances and three associations were newly described in the NVCS. The alliances, as grouped by formation, consist of one forest, four woodland, two shrubland one dwarf-shrubland, and seven herbaceous classes and the associations consist of one forest, six woodland, five shrubland, one dwarf-shrubland, and seven herbaceous classes. A field key to both the map classes and alliance/association classifications is listed in Appendix D.

Table 3. WACA National Vegetation Classification assignments.

Formation Class	Assignment	NVC Alliance	NVC Association	Relevé #
Forest	Association	*Pseudotsuga menziesii* Forest Alliance	*Pseudotsuga menziesii / Quercus gambelii* Forest	WC-005, WC-006, WC-009, WC-011, WC-013, WC-020, WC-021
Woodland	Alliance	*Juniperus osteosperma* Woodland Alliance	No Association	WC-068
	Alliance	*Juniperus scopulorum* Woodland Alliance	No Association	WC-012, WC-069
	Association	*Pinus edulis* Woodland Alliance	*Pinus edulis – (Juniperus osteosperma) / Bouteloua gracilis* Woodland	WC-003, WC-017, WC-018, WC-026, WC-027, WC-030, WC-031, WC-032, WC-043, WC-046, WC-047, WC-050, WC-061, WC-062, WC-076, WC-089, WC-092, WC-100
	Association	*Pinus edulis* Woodland Alliance	*Pinus edulis - (Juniperus* spp.*) / Cercocarpus montanus* Woodland	WC-016
	Association	*Pinus edulis* Woodland Alliance	*Pinus edulis – (Juniperus osteosperma) / Purshia stansburiana* Woodland	WC-028
	Association	*Pinus ponderosa* Woodland Alliance	*Pinus ponderosa – (Pinus edulis – Juniperus osteosperma) / Bouteloua gracilis* Woodland; *Pinus ponderosa / Bouteloua gracilis* Woodland	WC-025, WC-035, WC-044, WC-049, WC-053, WC-057, WC-058, WC-059, WC-060, WC-088
	Association	*Pinus ponderosa* Woodland Alliance	*Pinus ponderosa – (Pinus edulis – Juniperus osteosperma) / Quercus gambelii* Woodland; *Pinus ponderosa / Quercus gambelii* Woodland	WC-001, WC-004, WC-014, WC-019, WC-022, WC-023, WC-024, WC-045, WC-054, WC-055, WC-056, WC-064, WC-065, WC-066, WC-071, WC-072, WC-075, WC-077; WC-094
	Association	*Pinus ponderosa* Woodland Alliance	*Pinus ponderosa / Muhlenbergia montana* Woodland	WC-036, WC-037, WC-039, WC-040, WC-041, WC-070, WC-095
Dwarf-Shrubland	Provisional Association	*Gutierrezia sarothrae* Dwarf-shrubland	*Gutierrezia sarothrae* Modified Dwarf-shrubland	WC-067, WC-079, WC-082, WC-090, WC-098, WC-101
Shrubland	Provisional Alliance and Association	*Chamaebatiaria millefolium* Shrubland Alliance	*Chamaebatiaria millefolium - (Mahonia fremontii) – Yucca baccata* Shrubland	WC-002, WC-007, WC-008, WC-010
	Local Assemblage		*Chamaebatiaria millefolium - Forestiera pubescens* Shrubland	WC-015
	Local Assemblage		*Ericameria nauseosa - Gutierrezia sarothrae* Shrubland	WC-087
	Local Assemblage		*Acer negundo / Forestiera pubescens – Symphoricarpos rotundifolius* Temporarily Flooded Shrubland	WC-051, WC-052
	Association	*Quercus gambelii* Shrubland Alliance	*Quercus gambelii / Robinia neomexicana / Symphoricarpos rotundifolius* Shrubland	WC-029, WC-033, WC-034, WC-074

Formation Class	Assignment	NVC Alliance	NVC Association	Relevé #
Herbaceous	New Association	*Aristida purpurea* Herbaceous Alliance	*Aristida purpurea* Herbaceous Vegetation	WC-102
	Association	*Bouteloua eriopoda* Herbaceous Alliance	*Bouteloua eriopoda* Semi-desert Herbaceous Vegetation	WC-080
	Association	*Bouteloua gracilis* Herbaceous Alliance	*Bouteloua gracilis* Herbaceous Vegetation	WC-038
	New Alliance and Association	*Bromus tectorum* Semi-Herbaceous Alliance	*Bromus (tectorum, rubens)* Semi-natural Herbaceous Vegetation	WC-086
	New Alliance and Association	*Ericameria nauseosa* Shrub Short Herbaceous Alliance	*Ericameria nauseosa / Bouteloua gracilis* Shrub Herbaceous Vegetation	WC-078, WC-081, WC-083, WC-084, WC-085, WC-091, WC-093
	Association	*Muhlenbergia montana* Herbaceous Alliance	*Muhlenbergia montana* Herbaceous Vegetation	WC-042, WC-073
	Association	*Pascopyrum smithii* Herbaceous Alliance	*Pascopyrum smithii* Herbaceous Vegetation	This association was not sampled in the field; it was identified only in the photointerpretation

The classification relevés are categorized as non-vegetated (less than 5% total vegetation cover) or by NVC formation: forest, woodland, shrubland, shrub herbaceous (steppe), or herbaceous vegetation. Three map class complexes, however, are not categorized by a single formation but have intermixing of formations in these map classes. These complexes consist of the Limestone Rim Complex (the Kaibab limestone canyon rim), Canyon Floor Complex (the canyon bottom community), and Snakeweed / Modified Grassland (a recently disturbed/modified landscape).

Unvegetated patches at WACA are considered a land cover class and comprise less than 1% (94 ac/38 ha) of the total area mapped. The unvegetated to sparsely vegetated patches persist on the limestone and sandstone canyon walls as well as on the canyon bottom of Walnut Canyon in localized patches along the drainage channel. In small seeps on the canyon walls, various hanging garden species often occur. The drainage channel is unvegetated in areas where water scours the canyon bottom; however, the drainage channel has intermediate water flow with opportunistic riparian species emerging periodically between scouring events.

Forests are rare at WACA (~2% of the project area, 440 ac/180 ha) and only occur in small mesic areas, often on north-facing slopes of canyon walls, the canyon bottom, and side canyons. Douglas-fir (*Pseudotsuga menziesii*) is the only tree that was identified as occurring with high enough canopy cover to have a forest stand structure. The Douglas-fir forest often has Gambel oak (*Quercus gambelii*) in the understory.

Woodlands are the predominant vegetation type, covering approximately 80% of the project area (16,500 ac/6,680 ha). They occur on all landforms including uplands, canyon walls, canyon bottoms, and canyon rims. Woodlands comprise five alliances and nine associations of the 13 alliances and 17 associations described. None of the woodland alliances or associations are newly described, since many of the woodland communities at WACA commonly occur on the Colorado Plateau.

The main woodland tree species at WACA are ponderosa pine (*Pinus ponderosa*), pinyon pine (*Pinus edulis*), and Utah juniper (*Juniperus osteosperma*). The most common tree in the mapping area is ponderosa pine, ranging from the mid elevation ecotonal areas to the highest elevations in the project area. This species' density varies significantly in the project area, depending on fire and land use history. Mountain muhly (*Muhlenbergia montana*), blue grama (*Bouteloua gracilis*), and Gambel oak commonly occur in the understory of the ponderosa pine canopy. At the mid elevations ponderosa pine, pinyon pine, and Utah juniper woodlands co-dominate the canopy. This co-dominance occurs in approximately one-third of the project area. Even though this mix of species is not defined in the NVC as a separate association, we mapped these broad ecotonal communities as unique map classes since we believe they are unique ecologically. At the lower elevations, pinyon pine, and Utah juniper woodland with blue grama understory typically occurs on upland and canyon walls. In addition to these lower elevation areas, Utah juniper occurs in small homogenous stands in WACA's lower elevation uplands.

None of the NVC shrubland formations were mapped as separate map classes. All of the shrublands were combined into the Snakeweed / Modified Grassland Complex, Canyon Floor Complex, and Limestone Rim Complex, which are described below.

Grasslands in WACA often occur only as small patches amidst woodlands or shrublands. Only one grassland map class, Blue Grama and Mt. Muhly Group, was mapped. This map class combines a blue grama and mountain muhly association and occurs in 1% (240 ac/95 ha) of the entire map. Blue grama and mountain muhly typically dominate small meadows that are often adjacent to ponderosa pine, pinyon pine, and Utah juniper woodlands. Other grassland species also are common in the moister meadows of the Blue Grama and Mt. Muhly Group including muttongrass (*Poa fendleriana*), little bluestem (*Schizachyrium scoparium*), and squirreltail (*Elymus elymoides*). The rest of the grassland associations were mapped as the Snakeweed / Modified Grassland Complex. The map class Introduced Western Wheatgrass was not identified in the classification relevés; however, this map class does have a corresponding NVC herbaceous association (*Pascopyrum smithii* Herbaceous Vegetation) and was identified through the photointerpretation process.

Shrub herbaceous (steppe) vegetation associations are mapped in moderate distributions in the eastern section of the project. Shrub herbaceous vegetation associations form a steppe vegetation structure with a dominance of herbaceous cover and greater than ten percent shrub cover. Map class Rabbitbrush (*Ericameria nauseosa*) / Blue Grama Shrub Herbaceous Vegetation is the only shrub herbaceous association mapped; this association covers 2% (452 ac/180 ha) of the project area. The only other shrub herbaceous association (*Gutierrezia Sarothrae* Dwarf-Shrubland [provisional]) is mapped as part of the Snakeweed / Modified Grassland Complex.

Canyon Floor Complex occurs in the mesic canyon bottom of Walnut Canyon and its side canyons. This complex consists of linear polygons and covers less than 1% of the mapping area (150 ac/60 ha). Five associations and one alliance comprise the Canyon Floor Complex (three shrubland associations, one woodland association, one woodland alliance, and one forest association). Two of these associations also co-occur as upland associations in other map classes. For those associations that occur in the uplands and in the canyon bottom, the vegetation density and diversity tends to be higher in the canyon bottom habitat. The main tree and shrub

species along canyon bottom consist of box elder (*Acer negundo*), Arizona walnut (*Juglans major*), Arizona rose (*Rosa arizonica*), Gambel oak, Douglas-fir, Rocky Mountain juniper (*Juniperus scopulorum*), stretchberry (*Forestiera pubescens* var. *pubescens*), roundleaf snowberry (*Symphoricarpos rotundifolius*), chokecherry (*Prunus virginiana*), and New Mexico locust (*Robinia neomexicana*). Riparian obligates include narrow-leaf cottonwood (*Populus angustifolia*), dogwood (*Cornus stolonifera*), and willow (*Salix* spp.). A diverse grass and forb community persists in the wet meadows, with fringed brome (*Bromus ciliatus*) often occurring as the main grass species. However, these grass and forb communities often occur in small patches and are included as some of the main understory species in the woodland and shrubland associations.

Limestone Rim Complex occurs on the rim of Walnut Canyon and its side canyons as well as on the limestone terrace canyon walls of Walnut Canyon. This complex covers 5% of the mapping area (950 ac/380 ha). Four associations comprise the Canyon Floor Complex (three woodland associations, one shrubland association). One of these associations also co-occurs as an upland association in another map class. The main tree species on the canyon rim is pinyon pine and it can co-occur with Utah juniper in the tree canopy, mountain mahogany (*Cercocarpus montanus*) and Stansbury Cliffrose (*Purshia stansburiana*) in the shrub layer, and blue grama in the herbaceous layer. A unique shrubland association commonly occurs on the limestone terraces on the north rim, which have a warm southern exposure, with common species including fernbush (*Chamaebatiaria millefolium*), barberry (*Mahonia fremontii*), banana yucca (*Yucca baccata*), cliffrose (*Purshia stansburiana*), and mountain mahogany (*Cercocarpus montanus*).

Snakeweed / Modified Grassland Complex occurs in disturbed areas in the northeastern section of the mapping area. This complex covers 12% (2,520 ac/1,020 ha) of the project area, with 90% of this complex occurring outside of the Monument. Four associations and one alliance comprise the Snakeweed / Modified Grassland Complex (two herbaceous association, one herbaceous alliance, one dwarf-shrubland, one shrubland association). Many of these associations resulted from chaining of trees, thought to increase the forage potential of the area. Gunnison's prairie dog (*Cynomys gunnisoni*) colonies also thrive in this area. The common shrubs and herbaceous species include a diverse array of native and non-native grass and shrub species including blue grama, rabbitbrush, fernbush, snakeweed (*Gutierrezia sarothrae*), horehound (*Marrubium vulgare*), western wheatgrass, little hogweed (*Portulaca oleracea*), and cliffrose. In these areas the native grasses often include blue grama, Fendler's threeawn (*Aristida purpurea*), and black grama (*Bouteloua eriopoda*). Non-native grasses in these areas include the invasive cheatgrass (*Bromus tectorum*) and western wheatgrass, a grass often used in reseeding efforts.

Vegetation map classes

The WACA vegetation mapping project used a total of 24 map classes: three geological classes, 13 vegetation classes and 8 Anderson Level II land-use classes (Anderson et al. 1976). The vegetation associations, Anderson land-use classes, and geologic exposures are related to the aerial photointerpretation map classes and are listed in Table 4. The final map classes were selected by CPRS, NPS and RSGIG personnel at a meeting held in May 2001. The units reflect the results of fieldwork, photointerpretation, and the NVC vegetation classification developed by

the CPRS. The final map classes deviated from NVC associations when either 1) a NVC vegetation association could not be distinguished on the aerial photos as in the case of some of the dense woodland types, or 2) when special units were requested by Monument staff to aid with their management.

The final map class list for WACA contains four categories:

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 WACA and can be recognized on the aerial photography.
4) Geologic formations/exposures and land-use classes that are not addressed by the NVC.

Three of the map classes; Sparsely Vegetated Coconino Sandstone (map code 1), Sparsely Vegetated Kaibab Limestone (map code 2), and Sparsely Vegetated Intermittent Drainage Channel (map code 3); were developed as land use geologic classes. For the NVC associations *Pinus ponderosa* / *Bouteloua gracilis* Woodland and *Pinus ponderosa* / *Quercus gambelii* Woodland, two map classes are described for each association since the one-to-one relationship of NVC association to map class did not describe the ecological variation that we observed in the broad ecotonal landscape at WACA. *Pinus ponderosa* / *Bouteloua gracilis* Woodland is represented on the map as Ponderosa Pine / Mixed Graminoid Woodland Complex (map code 15) and Ponderosa Pine – Pinyon Pine – Juniper / Blue Grama Woodland (map code 12). Ponderosa Pine / Mixed Graminoid Woodland Complex shows the homogenous ponderosa pine canopy and Ponderosa Pine – Pinyon Pine – Juniper / Blue Grama Woodland shows a mixed ponderosa pine, pinyon pine, and juniper canopy. *Pinus ponderosa* / *Quercus gambelii* Woodland is represented on the map as Ponderosa Pine / Gambel Oak Woodland (map code 14) and Ponderosa Pine – Pinyon Pine – Juniper / Gambel Oak Woodland (map code 13), where Ponderosa Pine / Gambel Oak Woodland shows a pure ponderosa pine canopy and Ponderosa Pine – Pinyon Pine – Juniper / Gambel Oak Woodland shows a mixed ponderosa pine, pinyon pine, and juniper canopy.

Table 4. WACA map classes and their NVC components

Map Code	Map class	Associated NVC Plant Associations
1	Sparsely Vegetated Coconino Sandstone	none (Land Cover Class)
2	Sparsely Vegetated Kaibab Limestone	none (Land Cover Class)
3	Sparsely Vegetated Intermittent Drainage Channel	none (Land Cover Class)
4	Blue Grama – Mt. Muhly Grassland Group	*Bouteloua gracilis* Herbaceous Vegetation, *Muhlenbergia montana* Herbaceous Vegetation
5	Introduced Western Wheatgrass Grassland	*Pascopyrum smithii* Herbaceous Vegetation (described during photointerpretation process)
6	Common Horehound - Prairie Dog Town	none (described during photointerpretation process)
7	Snakeweed / Modified Grassland Complex	*Aristida purpurea* Herbaceous Vegetation, *Bromus (tectorum, rubens)* Semi-natural Herbaceous Alliance, *Bouteloua eriopoda* Semi-desert Herbaceous Vegetation, *Ericameria nauseosa - Gutierrezia sarothrae* Shrubland (local assemblage), *Gutierrezia sarothrae* Modified Dwarf-shrubland [provisional]
8	Rabbitbrush / Blue Grama Shrub Herbaceous Vegetation	*Ericameria nauseosa / Bouteloua gracilis* Shrub Herbaceous Vegetation
9	Limestone Rim Complex	*Pinus edulis – (Juniperus* spp.*) / Cercocarpus montanus* Woodland, *Pinus edulis –(Juniperus osteosperma) / Purshia stansburiana* Woodland, *Pinus edulis – (Juniperus osteosperma) / Bouteloua gracilis* Woodland, *Chamaebatiaria millefolium - (Mahonia fremontii) – Yucca baccata* Limestone Terrace Shrubland [provisional]
10	Canyon Floor Complex	*Acer negundo / Forestiera pubescens – Symphoricarpos rotundifolius* Temporarily Flooded Shrubland (local assemblage), *Quercus gambelii / Robinia neomexicana / Symphoricarpos rotundifolius* Shrubland, *Juniperus scopulorum* Woodland Alliance, *Pseudotsuga menziesii / Quercus gambelii* Forest, *Pinus ponderosa / Quercus gambelii* Woodland, *Chamaebatiaria millefolium – Forestiera pubescens* Shrubland (local assemblage)
11	Pinyon Pine - Utah Juniper / Blue Grama Woodland	*Pinus edulis – (Juniperus osteosperma) / Bouteloua gracilis* Woodland, *Juniperus osteosperma* Woodland Alliance
12	Ponderosa Pine - Pinyon Pine - Juniper / Blue Grama Woodland	*Pinus ponderosa – (Pinus edulis – Juniperus osteosperma) / Bouteloua gracilis* Woodland
13	Ponderosa Pine - Pinyon Pine - Juniper / Gambel Oak Woodland	*Pinus ponderosa – (Pinus edulis – Juniperus osteosperma) / Quercus gambelii* Woodland
14	Ponderosa Pine / Gambel Oak Woodland	*Pinus ponderosa / Quercus gambelii* Woodland
15	Ponderosa Pine / Mixed Graminoid Woodland Complex	*Pinus ponderosa / Bouteloua gracilis* Woodland, *Pinus ponderosa / Muhlenbergia montana* Woodland
16	Douglas-fir / Gambel Oak Forest	*Pseudotsuga menziesii / Quercus gambelii* Forest
17	Rural Residential	- none (Anderson Land Use class)
18	Ranch Developments	- none (Anderson Land Use class)
19	NPS Facilities	- none (Anderson Land Use class)
20	Utility Corridors	- none (Anderson Land Use class)
21	Transportation Routes	- none (Anderson Land Use class)
22	Pastures	- none (Anderson Land Use class)
23	Reservoirs	- none (Anderson Land Use class)
24	Stock Tanks and Dams	- none (Anderson Land Use class)

Each map class for WACA 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
8	Rabbitbrush / Blue Grama Shrub Herbaceous Vegetation *Ericameria nauseosa / Bouteloua gracilis* Shrub Herbaceous Vegetation
12	Ponderosa Pine - Pinyon Pine - Juniper / Blue Grama Woodland *Pinus ponderosa – (Pinus edulis – Juniperus osteosperma) / Bouteloua gracilis* Woodland
13	Ponderosa Pine - Pinyon Pine - Juniper / Gambel Oak Woodland *Pinus ponderosa – (Pinus edulis – Juniperus osteosperma) / Quercus gambelii* Woodland
14	Ponderosa Pine / Gambel Oak Woodland *Pinus ponderosa / Quercus gambelii* Woodland
16	Douglas-fir / Gambel Oak Forest *Pseudotsuga menziesii / Quercus gambelii* 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*
4	Blue Grama – Mt. Muhly Grassland Group *Bouteloua gracilis* Herbaceous Vegetation *Muhlenbergia montana* Herbaceous Vegetation
7	Snakeweed / Modified Grassland Complex *Aristida purpurea* Herbaceous Vegetation *Bromus (tectorum, rubens)* Semi-natural Herbaceous Alliance *Bouteloua eriopoda* Semi-desert Herbaceous Vegetation *Ericameria nauseosa - Gutierrezia sarothrae* Shrubland (local assemblage) *Gutierrezia sarothrae* Modified Dwarf-shrubland [provisional]

9 Limestone Rim Complex
Pinus edulis – (Juniperus spp.*) / Cercocarpus montanus* Woodland
Pinus edulis –(Juniperus osteosperma) / Purshia stansburiana Woodland
Pinus edulis – (Juniperus osteosperma) / Bouteloua gracilis Woodland
Chamaebatiaria millefolium - (Mahonia fremontii) – Yucca baccata Limestone Terrace Shrubland [provisional]

10 Canyon Floor Complex
Acer negundo / Forestiera pubescens – Symphoricarpos rotundifolius Temporarily Flooded Shrubland (local assemblage)
Quercus gambelii / Robinia neomexicana / Symphoricarpos rotundifolius Shrubland
Juniperus scopulorum Woodland Alliance
Pseudotsuga menziesii / Quercus gambelii Forest
Pinus ponderosa / Quercus gambelii Woodland
Chamaebatiaria millefolium – Forestiera pubescens Shrubland (local assemblage)

15 Ponderosa Pine / Mixed Graminoid Woodland Complex
Pinus ponderosa / Bouteloua gracilis Woodland
Pinus ponderosa / Muhlenbergia montana Woodland

Park Special Map Classes

Only one vegetation map class at WACA is considered a park special. This map class was developed based on photointerpretation observation data.

Map Code	Map Class NVC *Plant Association*
5	Introduced Western Wheatgrass Grassland *Pascopyrum smithii* Herbaceous Vegetation

Aerial photograph interpretation

RSGIG interpretation of the aerial photographs for WACA relied heavily on substrate and landscape position. The usual aids to interpretation, color, shape, and texture, were less helpful in this case, partly because the aerial photos were flown in October when grasses were dormant and long tree shadows obscured the forest floor. A brief description of each map class follows. The number in parentheses indicates the map code. A more detailed, illustrated guide to the map classes appears in Appendix G.

<u>Sparsely Vegetated Coconino Sandstone</u> (1)
Coconino sandstone is intermittently exposed near the bottom of Walnut Canyon. It is a massive, cross-bedded sandstone whose outcrops are pale gray in color or white on the aerial photos. The only vegetation that occurs on outcrops is scattered patches of lichens and mosses,

and a few vascular plants supported in occasional crevices.

Sparsely Vegetated Kaibab Limestone (2)
The majority of the walls of Walnut Canyon are vegetated Kaibab limestone. Small areas of sparsely vegetated limestone occur intermittently throughout the canyon in areas where the rock is vertical and unbroken. Kaibab limestone is easily distinguished from the Coconino sandstone because the limestone occurs in ledges and layers 2-6 ft (0.7-2 m) thick, giving the photosignature a striated appearance. This type was mapped where individual plants were too small or too scattered to see on the aerial photos and the dominant signature was the white of the bedrock.

Sparsely Vegetated Intermittent Drainage Channel (3)
Although water flows only rarely through Walnut Canyon, some areas of bare soil persist on the canyon floor. 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.

Blue Grama - Mountain Muhly Grassland Group (4)
Although patches of this type occur in the disturbed northeastern part of the mapping area (see map code 5), they cannot reliably be separated from the introduced grasslands on the aerial photos. Therefore, this type was only mapped in the undisturbed ponderosa pine woodlands, where it is a rare type occurring only in small patches along swales and in the larger woodland openings.

Introduced Western Wheatgrass Grassland (5)
We identified this map class in two areas based on fieldwork. It has a uniform, smooth signature and occurs in areas where the original vegetation was removed, then seeded with western wheatgrass.

Common Horehound – Prairie Dog Town (6)
This map unit was found to occur in one relatively large area in the northeast quadrant of the project area. This area was likely impacted both from past agricultural and land-management activity (mainly chaining, grazing, and re-seeding) and recent prairie dog activity. The continual impact to ground caused by burrowing likely contributed to the abundance of weedy non-native plants in area, especially common horehound. This class is considered a local, project specific type and is recognized on the aerial photos by the white stipple pattern of the prairie dog burrows and the smooth, bright texture of the weedy plants.

Snakeweed / Modified Grassland Complex (7)
This map class describes a large area in the northeastern part of the mapping area where the original pinyon-juniper woodland was chained and the ground seeded with a mix of native and introduced grasses. Very small areas of original vegetation survived this treatment, but cannot be reliably distinguished on the aerial photos. The complex photosignature reflects the disturbed, patchy nature of the vegetation.

Rabbitbrush / Blue Grama Shrub Herbaceous Vegetation (8)
This is the native grassland type, occurring in broad open park-like environments within the pinyon-juniper woodlands in the eastern half of the project area. It has been somewhat modified through grazing, which has caused rabbitbrush to increase in density. Although the color is similar to the grassland map classes, the texture is grittier due to the presence of shrubs.

Limestone Rim Complex (9)
This map class represents a complex of unique shrubland and woodland associations that are restricted to the south-facing slopes of Walnut Canyon, expanding onto the north-facing slopes at the broader east end of the canyon. Many of the species are characteristic of limestone soils, such as fernbush (*Chamaebatiaria millefolium*), barberry (*Mahonia fremontii*), banana yucca (*Yucca baccata*), cliffrose (*Purshia stansburiana*), and mountain mahogany (*Cercocarpus montanus*). The photosignature is varied, but dominated by the white of the underlying limestone. The vegetation appears as brownish red specks and patches.

Canyon Floor Complex (10)
The floor of Walnut Canyon is made up of a complex mosaic of several deciduous and grassland associations. The associations mostly occur in patches too small to map, so it was necessary to lump them in a mosaic. The mosaic includes woodlands of cottonwood (*Populus angustifolia*) and box elder (*Acer negundo*), Gambel oak thickets, and stands of deciduous shrubs such as chokecherry (*Prunus virginiana*) and wild rose (*Rosa arizonica*). Small upland stands of Gambel oak occur south of the canyon; because there is no separate Gambel oak map class, these stands were lumped with those occurring in the canyon.

Pinyon Pine - Utah Juniper / Blue Grama Woodland (11)
Walnut Canyon occupies a transition zone between low-elevation pinyon-juniper woodlands and the ponderosa pine woodlands that cover much of the Coconino Plateau. The eastern part of the mapping area was originally mostly this map class, although much of the original woodland was removed to improve grazing. A significant stand of old-growth pinyon-juniper occurs on basalt substrates on the northeastern face of Anderson Mesa. This type is recognizable on the aerial photos because of the short stature of the trees and the dull, dark color of the tree crowns.

Ponderosa Pine - Pinyon Pine - Juniper / Blue Grama Woodland (12)
This type forms a transition zone between the pinyon-juniper woodlands in the eastern half of the project area and the ponderosa pine woodlands in the western half. It is best developed southeast of the confluence of Cherry Canyon and Walnut Canyon.

Ponderosa Pine - Pinyon Pine - Juniper / Gambel Oak Woodland (13)
This type forms a transition zone between the pinyon-juniper woodlands in the eastern half of the project area and the ponderosa pine woodlands in the western half. It occurs mainly in the moister draws of the canyon floors and walls.

Ponderosa Pine / Gambel Oak Woodland (14)
Some of the best-developed examples of this map class occur south of Walnut Canyon in the western part of the project area, especially around the base of Anderson Mesa.

Ponderosa Pine / Mixed Graminoid Woodland Complex (15)
Much of the ponderosa pine woodland north of Walnut Canyon is this type, although scattered stems and copses of Gambel oak are scattered throughout. In general, this type of woodland has a more open canopy that allows sun-loving blue grama and mountain muhly to grow.

Douglas-fir / Gambel Oak Woodland (16)
The steep, north-facing walls of Walnut Canyon and its major tributaries support stands of Douglas fir. Gambel oak is the only species that occurs consistently in the understory.

Rural Residential (17)
Rural residential areas include scattered homes as well as denser subdivisions.

Ranch Developments (18)
This type was distinguished from Rural Residential primarily based on the isolation of buildings and their association with typical ranch features such as corrals and pastures.

NPS Facilities (19)
This map class includes the Visitor Center, the sewage ponds, and other aboveground developments associated with operation of the Monument.

Utility Corridors (20)
One telephone line cuts through the project area north of the visitor center. We identified this class in the field, and it appears on the photos as a narrow deforested corridor supporting grasses and a few shrubs.

Transportation Routes (21)
Mapped roadways include the main paved access roads as well as major USDA-FS and county dirt roads.

Pastures (22)
We delineated pastures based on their proximity to ranch developments, their distinctive smooth texture (rhizomatous grasses) and their linear boundaries (fence lines).

Reservoirs (23)
An historic reservoir site, now silted in, occupies a private inholding on the floor of Walnut Canyon. The stone dam structure is clearly visible, as is an area upstream of it that is periodically flooded and now supports a community of weedy annual plant species.

Stock Tanks and Dams (24)
These features are easily recognizable because of their characteristic location, size and shape.

GIS database and maps

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

1) Accuracy assessment observation points.
2) Classification relevé points.
3) DOQQ and USGS Quad maps for Sunset Crater, Wupatki, and Walnut Canyon National Monuments.
4) DOQQ basemap imagery.
5) Flightline boundary for Sunset Crater, Wupatki, and Walnut Canyon National Monuments.
6) WACA park boundary.
7) Photointerpretative observation points.
8) Project boundary.
9) Seeps and springs.
10) Vegetation map clipped to the National Monument boundary.
11) Vegetation map for the entire project area. This main product coverage consists of 802 classified polygons covering a total area of approximately 20,732 ac (8,390 ha). Table 5 shows the total number of polygons and ha 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 H).

Table 5. Map class occurrence in Walnut Canyon National Monument and environs.

Map Code	Map Class Common Names	Monument		Environs	
		Polygons	Hectares	Polygons	Hectares
1	Sparsely Vegetated Coconino Sandstone	27	22	11	8
2	Sparsely Vegetated Kaibab Limestone	10	4	1	0
3	Sparsely Vegetated Intermittent Drainage Channel	1	1	3	3
4	Blue Grama - Mt. Muhly Grassland Group	12	4	72	88
5	Introduced Western Wheatgrass Grassland	1	0.4	11	6
6	Common Horehound - Prairie Dog Town			2	20
7	Snakeweed / Modified Grassland Complex	10	41	28	978
8	Rabbitbrush / Blue Grama Shrub Herbaceous Vegetation	13	15	56	169
9	Limestone Rim Complex	34	239	32	145
10	Canyon Floor Complex	39	48	23	13
11	Pinyon Pine - Utah Juniper / Blue Grama Woodland	35	422	90	1721
12	Ponderosa Pine - Pinyon Pine - Juniper / Blue Grama Woodland	43	151	98	701
13	Ponderosa Pine - Pinyon Pine - Juniper / Gambel Oak Woodland			28	148
14	Ponderosa Pine / Gambel Oak Woodland	22	80	35	686
15	Ponderosa Pine / Mixed Graminoid Woodland Complex	30	300	40	2023
16	Douglas-fir / Gambel Oak Forest	29	129	13	48
17	Rural Residential			15	9
18	Ranch Developments			5	8
19	NPS Facilities	3	1		
20	Utility Corridors	2	0.3	3	4
21	Transportation Routes	3	11	10	57
22	Pastures			15	78
23	Reservoirs	1	4		
24	Stock Tanks and Dams			17	4
	Total	**315**	**1,472**	**597**	**6,910**

Accuracy assessment

In the 2001 sampling season, 227 accuracy assessment observations were included in the reference data out of the total 270 observations collected. We eliminated 43 observations since they represented duplicate observations in polygons in the final vegetation map. In these duplicate cases, we selected the observation that assessed the largest area of the polygon as the data to be used in the accuracy assessment analysis. For 2002, we added 126 additional accuracy assessment observations to the reference data making a combined total of 353 reference data points (Figure 13). Information recorded for each accuracy assessment observation is maintained in an MS Access database with its corresponding metadata and is located on the

project CD (Appendix A). 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). However, these classes we retained on the contingency table, see Table 7, 8, and 9. For the final accuracy assessment analysis, the total number of reference data points used to calculate overall exact match accuracy was 337, acceptable accuracy was 347, and understandable accuracy was 352. 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 a high percentage of occurrences 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).

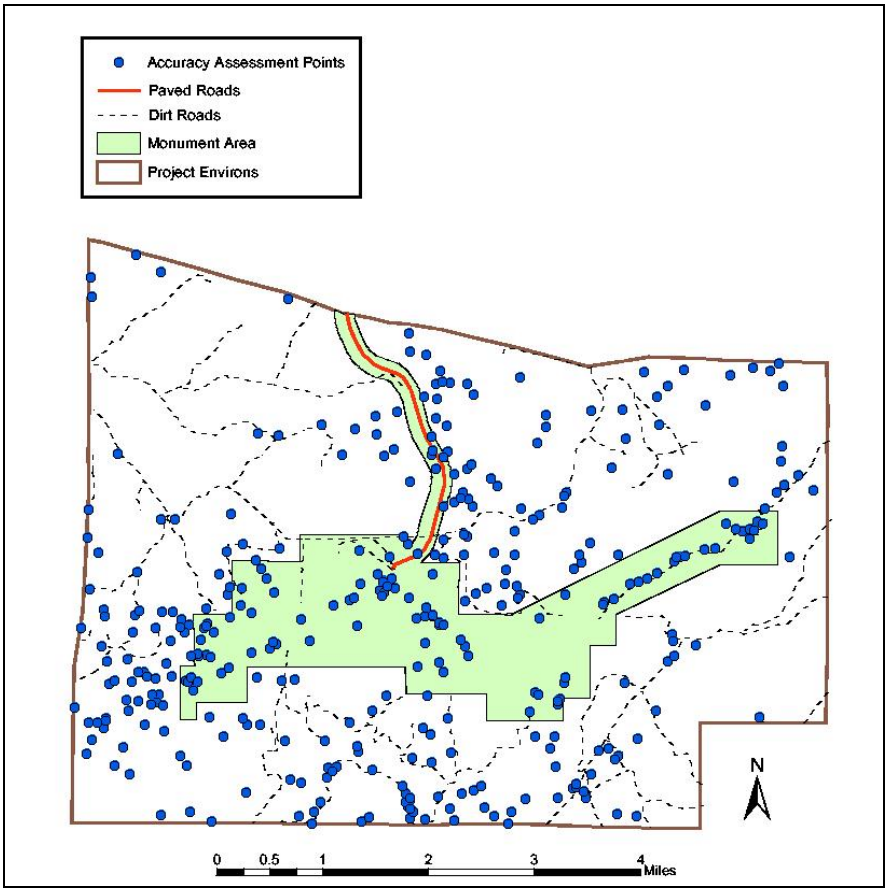

Figure 13. Location of accuracy assessment observations for the 2001 and 2002 combined reference data set.

Evaluation of the performance of each map class provides insight on map error. For each map class we report below the criteria at which the classes met the standard of 80% or greater for commission and omission accuracy (Table 6).

Table 6. WACA map class performance.

Map Code	Map Class	Commission Accuracy, (Criteria and %)	Omission Accuracy, (Criteria and %)	Comments
1	Sparsely Vegetated Coconino Sandstone	Acceptable 94%	Exact 83%	This type is considered adequate as mapped.
2	Sparsely Vegetated Kaibab Limestone	Acceptable 100%	Acceptable 100%	This type is considered adequate as mapped.
3	Sparsely Vegetated Intermittent Drainage Channel	N/A	N/A	Only two accuracy assessment observations of the total six polygons where sampled due to the inaccessibility of polygons on the canyon floor. All of the accuracy assessment observations were misidentified, resulting in the inability to rank commission and omission error. This map class was misclassified in both cases as Blue Grama – Mt. Muhly Grassland Group and as Canyon Floor Complex.
4	Blue Grama – Mt. Muhly Grassland Group	Exact 80%	Understandable 91%	When labeled incorrectly, this class was often confused with Snakeweed / Modified Grassland Complex or Rabbitbrush/Blue Grama Shrub Herbaceous Vegetation (omission error).
5	Introduced Western Wheatgrass Grassland	Acceptable 83%	Understandable 100%	When labeled incorrectly, this class was confused with Pinyon Pine-Utah Juniper/Blue Grama or Blue Grama – Mt. Muhly Grassland Group (omission error).
6	Common Horehound – Prairie Dog Town	Understandable 100%	Exact 100%	Only two polygons of this map class are on the vegetation map and both of these polygons were sampled. One polygon was misinterpreted as a Snakeweed/Modified Grassland Complex (commission error).
7	Snakeweed/Modified Grassland Complex	Understandable 95%	Understandable 95%	When labeled incorrectly, this class was often confused with the native community of Blue Grama – Mt. Muhly Grassland Group and Rabbitbrush / Blue Grama Shrub Herbaceous Vegetation (commission and omission error).

Map Code	Map Class	Commission Accuracy, (Criteria and %)	Omission Accuracy, (Criteria and %)	Comments
8	Rabbitbrush / Blue Grama Shrub Herbaceous Vegetation	Understandable 89%	Understandable 93%	On the map this class was misclassified as Snakeweed/Modified Grassland Complex (omission error). In the field, areas where this class was found were mapped as Blue Grama – Mt. Muhly Grassland Group (commission error).
9	Limestone Rim Complex	Understandable 96%	Understandable 92%	This class was misclassified as Pinyon Pine – Utah Juniper / Blue Grama Woodland and Ponderosa Pine – Pinyon Pine – Juniper / Blue Grama Woodland (commission and omission error).
10	Canyon Floor Complex	Acceptable 96%	Understandable 100%	On the map this class was misclassified as Rabbitbrush / Blue Grama Shrub Herbaceous Vegetation, Sparsely Vegetated Coconino Sandstone, and Blue Grama – Mt. Muhly Grassland Group (omission error).
11	Pinyon Pine – Utah Juniper / Blue Grama Woodland	Acceptable 80%	Understandable 76%	This type was often misclassified on the map as Limestone Rim Complex, Ponderosa Pine – Pinyon Pine – Juniper / Blue Grama, and Ponderosa Pine – Pinyon Pine – Juniper / Gambel Oak Woodland (omission error).
12	Ponderosa Pine – Pinyon Pine – Juniper / Blue Grama Woodland	Understandable 93%	Understandable 97%	This map class was misidentified as Ponderosa Pine / Mixed Graminoid Woodland Complex and Limestone Rim Complex (omission error) and misclassified as Pinyon Pine – Utah Juniper / Blue Grama Woodland and Ponderosa Pine - Pinyon Pine – Juniper / Gamble Oak Woodland (commission error).
13	Ponderosa Pine – Pinyon Pine – Juniper / Gambel Oak Woodland	Understandable 90%	Understandable 100%	This map class is often misclassified on the map as Pinyon Pine – Utah Juniper / Blue Grama Woodland (omission error) and in the field areas where it was found were misidentified as Ponderosa Pine / Gambel Oak Woodland (commission error).

Map Code	Map Class	Commission Accuracy, (Criteria and %)	Omission Accuracy, (Criteria and %)	Comments
14	Ponderosa Pine / Gambel Oak Woodland	Understandable 93%	Understandable 90%	This map class was often confused with Douglas-fir / Gambel Oak Forest (commission error) and Ponderosa Pine – Pinyon Pine – Juniper / Gambel Oak (omission error).
15	Ponderosa Pine / Mixed Graminoid Woodland Complex	Acceptable 85%	Acceptable 88%	This type is considered adequate as mapped.
16	Douglas-fir / Gambel Oak Forest	Acceptable 85%	Exact 87%	This type is considered adequate as mapped.
17	Rural Residential	N/A	N/A	Only one accuracy assessment observation was collected in this map class due to restricted access. The one polygon was misclassified on the map as Stock Tanks and Dams.
18	Ranch Developments	Exact 100%	Exact 100%	This type is considered adequate as mapped.
19	NPS Facilities	Acceptable 100%	Exact 100%	This type is considered adequate as mapped.
20	Utility Corridors	Exact 100%	Exact 100%	This type is considered adequate as mapped.
21	Transportation Routes	Acceptable 86%	Acceptable 100%	This type is considered adequate as mapped.
22	Pastures	Understandable 60%	Acceptable 100%	This type was often confused with Blue Grama – Mt. Muhly Grassland Group and Rabbitbrush / Blue Grama Shrub Herbaceous Vegetation (commission error).
23	Reservoirs	N/A	N/A	This map class had only one polygon on the entire vegetation map. This reservoir is located on private land and was not sampled due to restricted access to this land.
24	Stock Tanks and Dams	Acceptable 80%	Acceptable 80%	This type is considered adequate as mapped.

Standard analysis of map accuracy criteria 5, exact match category, suggested that overall accuracy was low (50.0%; 90% confidence interval of 47.0% to 53.0%) and a Kappa index of 45.3% (Table 7). For criteria 4 acceptable error, accuracy of the map is 69.2% (90% confidence interval of 64.1% and 71.8%) and Kappa index of 66.7% (Table 8). Criteria 3 (levels 5, 4 and 3 combined), understandable error, accuracy is 96.9 % (90% confidence interval of 95.6% and 98.2%) and a Kappa index of 93.9% (Table 9). Omission and commission accuracies for each individual map class, including two-tailed, 90% confidence intervals, are also shown for each in individual contingency table.

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 Observations)																									Total	Commission Error	90% Confidence Intervals	
	Map Code*	Other*[1]	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	N	(% Correct)	-	+
Map Class Data	1	1	10	1							1	4	1														18	55.6	36.9	72.8
	2		1	1							1		1														4	25.0	5.7	64.4
	3				0	1						1															2	N/A	N/A	N/A
	4					24			1				3	2													30	80.0	65.7	89.3
	5					2	1						3														6	16.7	3.8	50.2
	6							1	1																		2	50.0	12.1	87.9
	7					9			3	6			1														19	15.8	6.5	33.6
	8	2				10	1		2	3	1	5	2			2											28	10.7	4.4	24
	9										13		6			5	2	1									27	48.1	33.2	63.4
	10	2	1						1		2	21	2														29	72.4	57.3	83.7
	11					4			1	1	2		20			1							1				30	66.7	51.7	78.9
	12	1				2				1		1	6	13	4	2											30	43.3	29.6	58.1
	13					1					3	3	7	1	1	2	1										19	5.3	1.2	20.5
	14	1				1						1	2	3	8	8	3	3									30	26.7	15.7	41.5
	15	1				1					1		3	5	1		16										28	57.1	41.8	71.2
	16										1	1				4		20									26	76.9	61.2	87.6
	17																		0							1	1	N/A	N/A	N/A
	18																			1							1	100	27	100
	19													1							2						3	66.7	25.4	92.2
	20																					3					3	100	52.6	100
	21					1			1			1				1							3				7	42.9	18.6	71.1
	22					3				2														0			5	N/A	N/A	N/A
	23																								0		0	N/A	N/A	N/A
	24								1				1													3	5	60.0	27.2	85.7
Total	N	8	12	2	0	59	2	1	11	13	25	38	58	31	16	17	23	23	0	1	2	3	4	0	0	4	**Total Sampling Points: 337*[2]**			
Omission Error	(% Correct)	N/A	83.3	50.0	N/A	40.7	50.0	100	27.3	23.1	52.0	55.3	34.5	41.9	.63	47.1	69.6	87	N/A	100	100	100	75.0	N/A	N/A	75.0	**Total Correct: 167**			
90% Confidence Intervals	-	N/A	60.1	12.1	N/A	30.8	12.1	27.0	11.5	9.6	36.2	42.1	25.1	28.6	1.4	29	52.4	71.5	N/A	27.0	42.5	52.6	35.6	N/A	N/A	52.6	**Overall Accuracy: 50.0%**			
	+	N/A	94.3	87.9	N/A	51.4	87.9	100	52.0	45.8	67.4	67.7	45.2	56.6	23.7	66	82.6	94.7	N/A	100	100	100	94.2	N/A	N/A	100	**Kappa Index: 45.3%** **90% Confidence Interval: -47%, +53%**			

*[1] Other was recorded in cases where none of the map classes available adequately described the vegetation

*[2]Total Sampling Points excludes undescribed (map class other), land cover, and land use classes (map classes 3, 17, 22, and 23) that do not satisfy the Kappa statistic assumption

* See Table 5 for list of map codes and labels.

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

		Reference Data (Field Accuracy Assessment Observations)																									Total	Commission Error	90% Confidence Intervals	
	Map Code*	Other*[1]	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	N	(% Correct)	-	+
Map Class Data	1	1	16										1														17	94.1	71.4	21.5
	2			4																							4	100	59.7	100
	3				0	1						1															2	N/A	N/A	N/A
	4					27			1				2														30	90.0	77.4	95.9
	5					1	5																				6	83.3	49.8	96.2
	6							1	1																		2	50.0	12.1	87.9
	7					8			4	6			1														19	21.1	9.8	39.5
	8	1				3	2		4	13	1	2	1	1													26	50.0	31.9	61.6
	9										16		4	4	2	1											28	57.1	43.6	73.2
	10		1						2			26															27	96.3	76.7	95.8
	11					2			1		1		24	1		1											30	80.0	65.7	89.3
	12					2				1		1	5	19		2											29	65.5	50.2	78.1
	13					1					2	3	7		5		1										19	26.3	13.4	45.1
	14					1						1	2	3		18	2	2									29	62.1	45.1	73.3
	15	1				1					1		3		1		22										26	84.6	63.6	88.5
	16											1				3		22									26	84.6	69.8	92.9
	17																		0							1	1	N/A	N/A	N/A
	18																			1							1	100	27	100
	19																				3						3	100	52.6	100
	20																					3					3	100	52.6	100
	21					1																	6				7	85.7	54.7	96.7
	22					3				1														1			5	20.0	45.6	65.5
	23																								0		0	N/A	N/A	N/A
	24												1													4	5	80.0	43.5	95.4
Total	N	3	17	4	0	51	7	1	13	21	21	35	51	28	8	25	25	24	0	1	3	3	6	1	0	5	**Total Sampling Points: 347*[2]**			
Omission Error	(% Correct)	N/A	94.1	100	N/A	52.9	71.4	100	30.8	61.9	76.2	74.3	47.1	67.9	62.5	72	88	91.7	N/A	100	100	100	100	100	N/A	80.0	**Total Correct: 240**			
90% Confidence Intervals	-	N/A	77.4	59.7	N/A	41.6	40.9	27.0	14.6	44.1	58.5	60.7	36.0	52.3	34.8	55.7	73.5	77.7	N/A	27.0	52.6	52.6	68.9	27.0	N/A	43.5	**Overall Accuracy: 69.2%**			
	+	N/A	98.7	100	N/A	64.0	90.0	100	53.5	77.0	87.9	84.4	58.4	80.2	83.9	84	95.1	97.2	N/A	100	100	100	100	100	N/A	95.4	**Kappa Index: 66.7%**			
																											90% Confidence Interval: 64.1-%, 71.8+%			

*[1] Other was recorded in cases where none of the map classes available adequately described the vegetation

*[2]Total Sampling Points excludes undescribed (map class other), land cover, and land use labels (map classes 3, 17, and 23) that do not satisfy the Kappa statistic assumption

* See Table 5 for list of map codes and labels.

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

		Reference Data (Field Accuracy Assessment Observations)																								Total	Commission Error	90% Confidence Intervals	
	Map Code*	Other*[1]	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	N	(% Correct)	-	+
Map Class Data	1	1	16										1														18	88.9	71.4	96.3
	2			4																							4	100	59.7	100
	3				2																						2	100	42.5	100
	4					30																					30	100	91.7	100
	5						6																				6	100	68.9	100
	6							2																			2	100	42.5	100
	7								18				1														19	94.7	73.8	96.6
	8									25	1		1	1													28	89.3	76	95.6
	9										26					1											27	96.3	85	99.2
	10											29															29	100	90.9	100
	11								1				29														30	96.7	86.4	99.3
	12									1				28		1											30	93.3	81.7	97.8
	13					1							1		17												19	89.5	86.3	100
	14					1							2			27											30	90	77.4	95.9
	15										1		3				24										28	85.7	71.1	93.4
	16																	26									26	100	90.6	100
	17																		1								1	100	27.0	100
	18																			1							1	100	27.0	100
	19																				3						3	43.3	52.6	100
	20																					3					3	100	52.6	100
	21																						7				7	100	72.1	100
	22					1				1														3			5	60.0	52.6	100
	23																								0		0	N/A	N/A	N/A
	24																									5	5	80.0	59.7	100
Total	N	1	16	4	2	33	6	2	19	27	28	29	38	29	17	29	24	26	1	1	3	3	7	3	0	4	**Total Sampling Points: 352*[2]**			
Omission Error	(% Correct)	N/A	100	100	100	90.9	100	100	94.7	92.6	92.9	100	76.3	96.6	100	93.1	100	100	100	100	433.3	100	100	100	N/A	100	**Total Correct: 341**			
90% Confidence Intervals	-	N/A	85.5	59.7	42.5	79.3	68.9	42.5	79.5	79.9	80.6	77.4	63.5	85.9	72.7	81.2	89.9	90.6	27.0	27.0	52.6	52.6	72.1	27.2	N/A	43.5	**Overall Accuracy: 96.9%**			
	+	N/A	100	100	100	96.3	100	100	98.8	97.5	97.6	95.9	85.7	99.2	96.5	97.7	100	100	100	100	100.0	100	100	85.7	N/A	95.4	**Kappa Index: 93.9%**			
																											90% Confidence Interval: 95.6-%, 98.2+%			

*[1] Other was recorded in cases where none of the map classes available adequately described the vegetation

*[2] Total Sampling Points excludes the undescribed map class (other) since it does not satisfy the Kappa statistic assumption

* See Table 5 for map codes and labels.

5. DISCUSSION

The vegetation at WACA varies by elevation, has unique ecotonal associations, and includes diverse vegetation associations in the mesic canyons. These, in addition to limestone canyon terraces and modified, disturbed landscapes, represent some unique challenges in describing and mapping the landscape. The challenges to vegetation mapping at WACA are summarized below:

1) Vegetation associations are difficult to photointerpret in modified landscapes. We combined four vegetation associations and one alliance into a single map class (Snakeweed / Modified Grassland Complex) because the photointerpreter was unable to directly pick out each association within the highly variable landscape. These modified landscapes include native and non-native species inter-fingering into unique assemblages of herbaceous, shrub, and shrubby herbaceous vegetation. This map class occurs in a large portion of the northeastern section of the project boundary with few map polygons (12% of the total project area, 28 polygons). Many of the accuracy assessment observations within this disturbance type were assigned to native non-disturbed map classes. The vegetation may have changed during the interval between the aerial photography acquisition in 1996 and the photointerpretation in 1999-2002. Alternatively, the nature of the vegetation mosaic could not be distinguished at the 0.5 ha resolution with the aerial photographs, and as a result the polygons were sufficiently dissected.

2) Areas on the aerial photography that are masked by landscape features are difficult to photointerpret to the association level. This was especially true on the canyon walls and canyon bottoms where we lumped the vegetation into complexes of associations to create a map class. The photointerpreters were not able to delineate separate associations in areas that appeared as linear bands on the aerial photography, they were also likely under sampled due to poor accessibility. As the canyon bottoms and canyon walls appeared to be diverse, we think that with additional field sampling along the canyon bottoms, rims, and walls, additional NVC vegetation associations may be described for WACA. Phillips (1990) mapped the WACA riparian corridor with several different vegetation associations using the Brown and Lowe (1974) vegetation classification system in the canyon bottom. We suspect that this study can be used to augment the current vegetation map; however, new data collection would be important to attain due to the temporal sensitivity of the data. Accuracy assessment positioning was also challenging in these map classes, where polygons were often small and linear.

3) The number and variability of vegetation signatures sometimes made them difficult to distinguish and interpret consistently. Environmental factors such as moisture gradients, slope exposure, presence and density of exotic grasses and forbs, and soil diversity result in several photographic signatures for the grassland and some shrub and woodland classes. In many cases, broad ecotones between map classes resulted in the field crew selecting a single map class in areas where more than one map class was present within a single polygon. In these cases, the accuracy assessment field crew described the complexity of the polygon on the field sheet and often identified where more than one map class occurred within a single polygon. In cases where polygons appear to contain characteristics of two map classes, the

map classes may need to be merged to increase the map class accuracy. This happened most of the time at accuracy assessment observations where the tree cover was moderate and the grass or shrub cover was high.

4) Changes in the photointerpretative style between the preliminary map in 2001 and the final map in 2002 influenced the accuracy assessment results. Polygons that were assessed in 2001 often were significantly different in size and shape from the 2002 final vegetation map polygons. In some cases, the placement of the 2001 accuracy assessment observations that were assessed were not optimal for assessment of the 2002 final map. Funding limitations prevented us from completely redoing the accuracy assessment using the final vegetation map.

5) Small polygon sizes are difficult to confidently locate in the field. Twenty-eight percent of the polygons 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. This also increased the number of required polygons for accuracy assessment. For example, Canyon Floor Complex routinely occurs in small linear patches on the canyon floor of Walnut Canyon. These small polygons may have contributed to apparent misclassification of map classes during the accuracy assessment. We considered possible locational errors during the accuracy assessment analysis; however, it is likely that map users may also experience the same problems with determining exact locations.

6) The classification relevés (1999), photointerpretation observations (1999, 2000, and 2001), and accuracy assessment observations (2001 and 2002), may be measuring land cover characteristics that are different from those shown on the 1996 photography used for map creation. Land surface changes since the 1996 aerial photography acquisition could include trail development, increased recreational activities, non-native plant invasions, native plant increases or decreases, and changes in the riparian annual plant community composition associated with changing hydrologic regime in the canyon bottom. This is especially applicable to the USDA-FS lands surrounding the Monument that have evidence of recent modifications. Trees that were present in the aerial photography were subsequently removed, and were not present during the accuracy assessment. In addition, modified landscapes are sometimes easier to detect remotely using the aerial photography than on the ground. On the aerial photography the landscape appeared in some cases to be significantly different than the adjacent areas due to human modification of the landscape; however, when visited in the field, native species were prevalent and no visible evidence of recent human modification was obvious. This different perception of modification most often resulted in confusion between Snakeweed / Modified Grassland Complex, Rabbitbrush / Blue Grama Shrub Herbaceous Vegetation, and Blue Grama – Mt. Muhly Grassland Group. Also, 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 1999, 2000, 2001, and 2002. This difference can cause ecologists in the field and photointerpreters to give the same area different names. These vegetation changes may occur frequently enough to cause misclassified polygons and therefore decrease the measured total accuracy assessment.

7) Because the aerial photos were flown late in the year, shadows created interpretation problems. Long shadows partially to completely obscured the understory communities and made it more difficult to discern the diagnostic understory stratum. Due to the long shadows, it was difficult to locate control points in the wooded parts of the mapping area for aerial photograph registration. This was true for both the aerial photography (October 1996) and the photography used to generate the DOQQ base maps (October 1997). Locating enough control points became very time-consuming. Acquiring new aerial photography and generating an orthophoto base map from that photography could avoid this problem. In addition, there would be no ground condition difference between the photos used for interpretation and the base map. Another advantage would be the age of this database. If new photography were used at the start of this project, the database's ground condition would be only three years old instead of six years old when the project was completed.

Vegetation classification and map class development

Two new alliances, three new associations, one provisional alliance and two provisional associations, and three unique Monument specific assemblages were newly defined during the course of this project. The remainder of the vegetation types were described primarily using existing NVC community classification. Although the woodland associations comprised over 80% of the mapping area, almost half of the diversity in associations was described in the shrubland and herbaceous formation classes. In all of the Shrubland, dwarf-shrubland, and herbaceous associations, each association described fell under a unique alliance description and all of the new, provisional, and local assemblages were also described in these formation classes. This diversity and uniqueness in shrubland, dwarf-shrubland, and herbaceous associations is in part an artifact of most previous data having been collected in forest and woodland formations and less data collected in the shrubland and herbaceous formations. With additional information collected in these formations on the Colorado Plateau, the NVC alliance and association designations may change. In addition, the provisional associations and local assemblages, if significantly described elsewhere, may eventually be included as confirmed associations within the NatureServe Explorer database.

Only six of the possible 23 associations and alliances described had one-to-one correspondence with a map class; the remaining associations and alliances were combined to form ecologically unique complexes of associations. Limited direct correspondence of the associations to the map classes was due to the complexity of associations on the canyon walls, canyon bottoms, and on disturbed lands, as well as limitations in photointerpreting grassland associations. For two map classes we were able to map additional vegetation community detail, currently designated as a phase of a NVC association, by mapping the broad ecotonal communities of mixed ponderosa pine (*Pinus ponderosa*), pinyon pine (*Pinus edulis*), and Utah Juniper (*Juniperus osteosperma*) with either blue grama (*Bouteloua gracilis*) or Gambel oak (*Quercus gambelii*) understories. These ecotonal areas we believed were ecologically significant and important to resource management.

Woodlands comprised the major part of the mapping effort. They gradate in the lower elevation uplands from pinyon pine and Utah juniper associations to the higher elevation ponderosa pine associations. The density of trees in these associations varies depending on land use history and

fire regime. In some areas ponderosa pine form thick stands and could be considered a forest association with greater than 60% total canopy cover; however, these stand structures are not considered ecologically different at this time in the NVC and were maintained as woodland associations. Douglas-fir (*Pseudotsuga menziesii*) / Gambel oak forests were the only true forests described at WACA, due to the high density of the Douglas-fir canopy. Douglas-fir and Rocky Mountain juniper are common canyon bottom and north-facing cooler, moister plant associations. These associations, although commonly found at higher elevations elsewhere on the Colorado Plateau, persist in the cool moist canyons at WACA.

Although we described five shrublands and one dwarf-shrubland association during the course of this project, we could not directly map any of these associations. Many of the shrubland associations occurred on canyon walls and in highly transitional disturbed lands. Shrublands and Dwarf-Shrublands were included in the Limestone Rim Complex, Canyon Floor Complex, and Snakeweed / Modified Grassland Complex map classes.

Seven herbaceous associations, including all of our new associations and alliances, were described in the herbaceous formation class. However, only one of these associations was directly translated into a map class. The associations were not easily mapped due to the similarity in photosignatures between tightly inter-fingering associations in the disturbed areas. The herbaceous map class aggregates include the Snakeweed / Modified Grassland Complex and the Blue Grama – Mt. Muhly Grassland Group. The only directly translatable map class is Rabbitbrush / Blue Grama Shrub Herbaceous Vegetation, a shrub herbaceous association. Two additional map classes, Introduced Western Wheatgrass Grassland and Common Horehound - Prairie Dog Town, were identified as unique herbaceous vegetation assemblages during the photointerpretation process but were not observed during the relevé classification. However, these map classes were considered ecologically important and, as they were easily delineated by the photointerpreters, were included on the vegetation map.

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% overall map accuracy and for each class. Overall, the map meets this standard using the understandable accuracy criteria. Acceptable accuracy criteria accounted for a number of apparent misclassifications that may have occurred because of differences between the preliminary and final maps that could not be accounted for in the development of the 2001 sampling design. Understandable accuracy includes all acceptable errors as well as mistakes in interpretation in understory communities, which are often very sparse 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 kept in mind when the map is being used for management purposes. Most error in the map can be directly attributed to known sources and not to gross error in photointerpretation.

Aggregation of the main grassland and steppe map classes together (map classes 4, 7, 8 Blue Grama – Mt. Muhly Grassland Group, Snakeweed / Modified Grassland Complex, Rabbitbrush / Blue Grama Shrub Herbaceous Vegetation) would increase map accuracy. If these map classes were aggregated, it would improve the overall map accuracy to 76%, an increase of 7% using the acceptable criteria. However, this aggregation would not allow the user to distinguish between native or recently modified landscapes as well as between steppe and grassland communities. This aggregation would reduce the detail of the map; however, increase the map accuracy.

Applications

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

This map will provide the baseline vegetation data that will support sound 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.

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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 useful 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 labels derived from accuracy assessment relevés to the labels 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 in.

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-NVC 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 vegetation types sharing a definite physiognomy 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 environ-mental 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 ac.

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 tech-

nology. 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 NVC 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 Canyon Floor Complex has a map code of 10.

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 in = 1000 ft can also be expressed as 1:12,000 (i.e., 1 in on the map equals 12,000 in 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 ha.

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 NVCS. 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 Relevé.

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 in (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 ac of valuable lands and waters worldwide. TNC was the original caretaker of the National Vegetation Classification, 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.

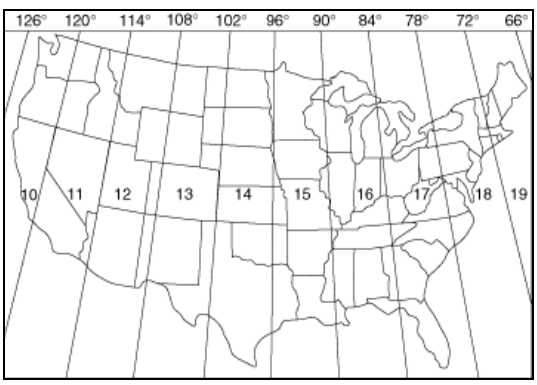
United States Geological Survey (USGS). Established in 1879, the USGS is the natural science agency for the Department of the Interior. The USGS is one of the host agencies, along with the National Park Service, for the USGS-NPS Vegetation Mapping Program.

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 ft

1:2,400	1"=200'	+/- 6.67 ft
1:4,800	1"=400'	+/- 13.33 ft
1:9,600	1"=800'	+/- 26.67 ft
1:10,000		+/- 27.78 ft
1:12,000	1"=1000'	+/- 33.33 ft
1:24,000	1"=2000'	+/- 40.00 ft
1:63,360	1"=one mi	+/- 105.60 ft
1:100,000		+/- 166.67 ft

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.

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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 WACA 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 shape file, 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: Walnut Canyon National Monument. A digital spatial database (ArcInfo). U.S. Geological Survey.

    b. Park_bndry- Boundary of Walnut Canyon National Monument
    Citation:
    Flagstaff Area National Monuments. 2004. Boundary: Walnut Canyon National Monument, AZ. A digital spatial database (ArcInfo). U.S. Geological Survey.

    c. Proj_bndry- Boundary for vegetation map for Walnut Canyon National Monument
    Citation:
    U.S. Bureau of Reclamation Remote Sensing and GIS Group. 2004. Project Boundary: Walnut Canyon National Monument Vegetation Mapping Project. 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 Walnut Canyon 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 Walnut Canyon National Monument. The MrSid images can be viewed as images in ArcView using the MrSid extension.

Citation:
U.S. Geological Survey. 2004. DOQQ Basemap: Walnut Canyon 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 "WC-***a/b/c" where the WC stands for Walnut Canyon, 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 WC-032 two photos were taken and are listed as WC-032a and WC-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 (WACA_veg.apr). Further information can be found in the included readme.txt file.

5. Project_Report - The folder contains the entire report (WACA_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 point cover, seeps and springs cover, accuracy assessment points cover and classification relevé cover) and databases (Vegetation Relevé Database) used to create the final vegetation map as well as associated metadata.
   a. Accuracy Assessment
      1. Database-Microsoft access database named WACA_AAdatabase.mdb with all the information collected in the field during the accuracy assessment observations
         Citation:
         Hansen, M. and K. Thomas. 2004. Walnut Canyon National Monument: Accuracy Assessment Database. A MS Access database. U.S. Geological Survey.
      2. Metadata-All associated metadata for the spatial data and the accuracy assessment database
      3. Spatial data- A coverage and shapefile of the accuracy assessment points used in the accuracy assessment analysis
      4. waca_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: Walnut Canyon 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 Walnut Canyon National Monument boundary
3. waca_clip_veg.e00-An Arc/Info export format (.e00) of the cover of vegetation map clipped to the Walnut Canyon National Monument boundary

   Citation:

   U.S. Bureau of Reclamation Remote Sensing and GIS Group. 2004. Clipped Vegetation Coverage: Walnut Canyon National Monument Vegetation Mapping Project. A digital spatial database (ArcInfo). U.S. Geological Survey.

c. Observation_Points

1. Metadata- Associated metadata for the spatial data
2. Spatial data- A point coverage and shapefile of the observation points used to help with the photointerpretative work
3. waca_obs.e00-An Arc/Info export format (.e00 files) 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: Walnut Canyon National Monument Vegetation Mapping Project. A digital spatial database (ArcInfo). U.S. Geological Survey.

d. Releve_Plots

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

   Citation:

   Hansen, M. and K. Thomas. 2004. Walnut Canyon 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. waca_releve.e00-An Arc/Info export format (.e00) of the cover of field relevé points sampled in the Walnut Canyon project boundary

   Citation:

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

e. Seeps_Springs_Wetlands

1. Metadata-Associated metadata for the spatial data
2. Spatial data- A coverage and shapefile of the occurrence of seeps, springs, and wetlands in the Walnut Canyon Vegetation Mapping Project

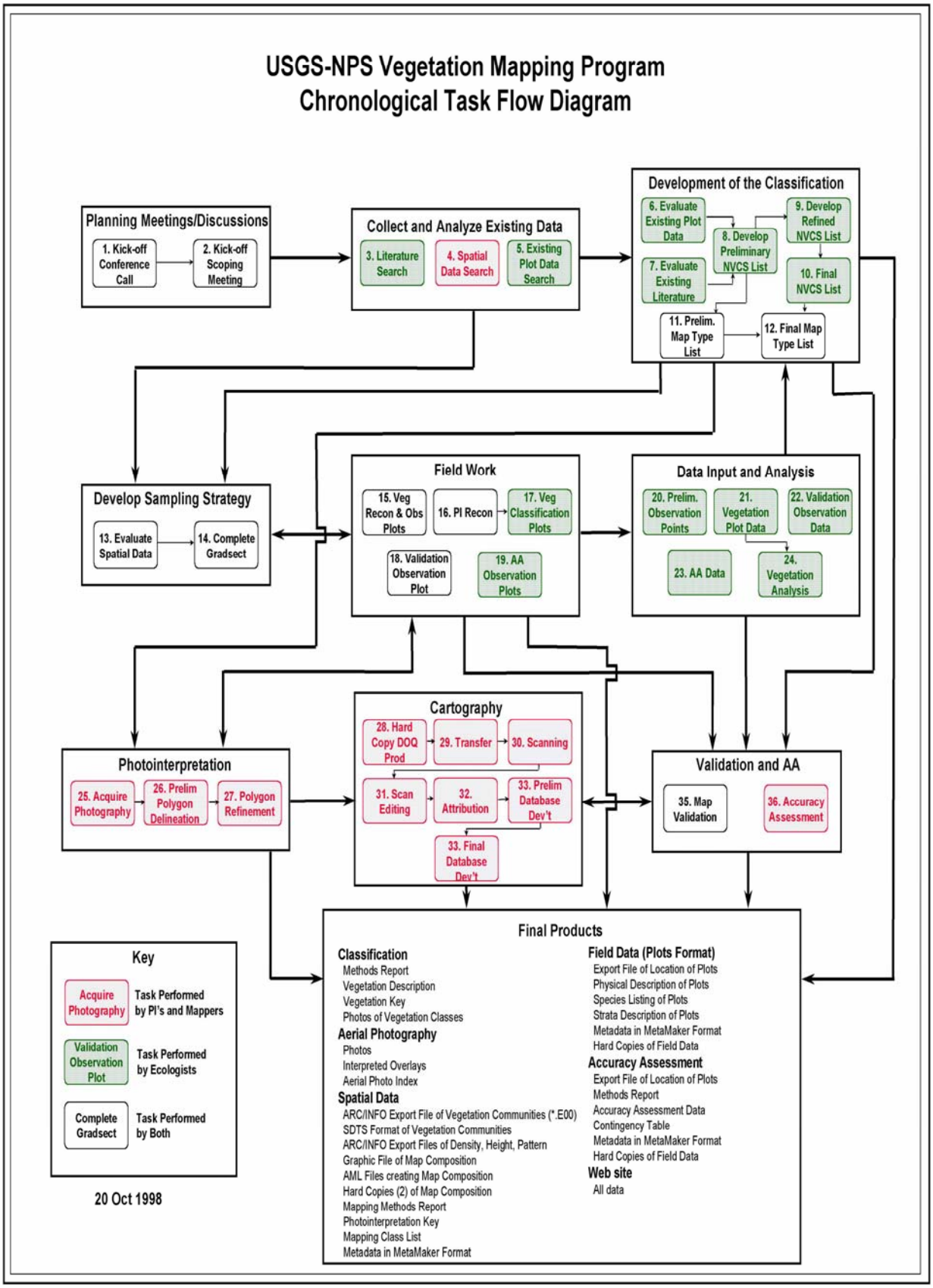
3. waca_seeps.e00-An Arc/Info export format (.e00) of the cover of seeps, springs, and wetlands in the project boundary
   Citation:
   U.S. Bureau of Reclamation Remote Sensing and GIS Group. 2004. Seeps, Springs, and Wetlands Coverage: Walnut Canyon National Monument. A digital spatial database (ArcInfo). 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 Walnut Canyon National Monument and the project environs
   3. waca_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. Walnut Canyon National Monument Vegetation Map. A digital spatial database (ArcInfo). U.S. Geological Survey.

APPENDIX B

B. 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 C

C. 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

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

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	
Trees and Shrubs ___Evergreen ___Cold-deciduous ___Drought-deciduous ___Mixed evergreen - cold-deciduous ___Mixed evergreen - drought-deciduous Herbs ___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 02 03 04 05 06 07 08 09 10 11	5% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%	01 02 03 04 05 06 07 08 09 10	<0.5 m 0.5-1m 1-2 m 2-5 m 5-10 m 10-15 m 15-20 m 20-35 m 35 - 50 m >50 m

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=22.6 for 400m^2

Directions to Plot_____
_____
_____

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

ENVIRONMENTAL DESCRIPTION

Elevation_____ (m.) Slope_____ % Aspect_____

Topographic position:_____Landform:_____(enter number from Code Sheet)

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

__Estuarine	__Semipermanently Flooded	__Permanently Flooded	Salinity/Halinity
__Riverine	__Seasonally Flooded	__Permanently Flooded-tidal	Modifiers:
__Palustrine	__Saturated	__Tidally Flooded	__Saltwater
__Laustrine	__Temporarily Flooded	__Artificially Flooded	__Brackish
	__Intermittently Flooded		__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
6__Annual	8__Extremely xeromorphic	
7__Perennial	9__Hydromorphic	

Additional Comments:

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 (cryptogram moss, lichen
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 cliff face
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)

ACCURACY ASSESSMENT OBSERVATION FORM

SURVEY AND SITE INFORMATION

Park Name: Walnut Canyon Date:_____
Surveyors_____
Plot Code_____

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

PLEASE CIRCLE CLOSEST MAP CLASS REPRESENTING SITE:

Vegetation:
Blue Grama - Mt. Muhly Grassland Group
Canyon Floor Complex
Common Horehound - Prairie Dog Town
Douglas-fir / Gambel Oak Forest
Introduced Western Wheatgrass Grassland
Limestone Rim Complex
Pinyon Pine - Utah Juniper / Blue Grama Woodland
Ponderosa Pine - Pinyon Pine - Juniper - / Gambel Oak Woodland
Ponderosa Pine - Pinyon Pine - Juniper / Blue Grama Woodland
Ponderosa Pine / Gambel Oak Woodland
Ponderosa Pine / Mixed Graminoid Woodland Complex
Rabbitbrush / Blue Grama Shrub Herbaceous Vegetation
Snakeweed / Modified Grassland Complex

Geomorphology:
Sparsely Vegetated Coconino Sandstone
Sparsely Vegetated Intermittent Drainage Channel
Sparsely Vegetated Kaibab Limestone

Land Use:
NPS Facilities
Pastures
Ranch Developments
Rural Residential
Stock Tanks and Dams
Transportation Routes
Utility Corridors

CONFIDENCE: Exact Good (Some problems) Poor None that fit

Please explain all reasons for Good, Poor or None Confidence

PLEASE CIRCLE CLOSEST ASSOCIATION/ALLIANCE REPRESENTING SITE:

Acer negundo / Forestiera pubescens – Symphoricarpos rotundifolius Temporarily Flooded Shrubland *Aristida purpurea* Herbaceous Vegetation *Bouteloua eriopoda* Herbaceous Vegetation *Bouteloua gracilis He*rbaceous Vegetation *Bouteloua gracilis* Herbaceous Vegetation *Bromus* (*tectorum, rubens*) Semi-natural Herbaceous Alliance *Chamaebatiaria millefolium - (Mahonia fremontii) – Yucca baccata* Limestone Terrace Shrubland *Chamaebatiaria millefolium - Forestiera pubescens* Shrubland *Ericameria nauseosa - Gutierrezia sarothrae* Shrubland *Ericameria nauseosa / Bouteloua gracilis* Shrub Herbaceous Vegetation *Gutierrezia sarothrae* Modified Dwarf-shrubland [provisional] *Juniperus osteosperma* Woodland Alliance *Juniperus scopulorum* Woodland Alliance	*Muhlenbergia montana* Herbaceous Vegetation *Pascopyrum smithii* Herbaceous Vegetation *Pinus edulis –(Juniperus osteosperma) / (Bouteloua gracilis)* Woodland *Pinus edulis / Cercocarpus montanus* Woodland *Pinus edulis / Purshia stansburiana* Woodland *Pinus ponderosa – (Pinus edulis – Juniperus osteosperma) / Bouteloua gracilis* Woodland *Pinus ponderosa – (Pinus edulis – Juniperus osteosperma) / Quercus gambelii* Woodland *Pinus ponderosa / Quercus gambelii* Woodland *Pinus ponderosa / Bouteloua gracilis* Woodland *Pinus ponderosa / Muhlenbergia montana* Woodland *Pseudotsuga menziesii / Quercus gambelii* Woodland *Quercus gambelii / Robinia neomexicana / Symphoricarpos rotundifolius* Shrubland

CONFIDENCE: Exact Good (Some problems) Poor None that fit

Please explain all reasons for Good, Poor or None Confidence

APPENDIX D

D. Field Key for the Walnut Canyon National Monument Vegetation Community Descriptions and Map classes

1. Site sparsely vegetated (<5%) geomorphic feature, i.e. bedrock and streambeds, sparsely vegetated prairie dog colony, or anthropogenic land use, i.e. developments or agriculture. (go to 29)
1. Site with >5% vegetation, including limestone or sandstone substrates with greater than 5% vegetation. (go to 2)

2. Site characterized by tree and/or shrub cover. If tree or shrub cover is greater than 25%, grasses and forbs may have higher cover, but the woody plants are given dominance. If tree or shrub cover less than 25%, grasses and forbs, if present, have less cover than either trees or shrubs. (go to 3)
2. Site characterized by grasses and forbs, trees or shrubs may be present with less than 25% cover and with less cover than grasses and forbs. (go to 16)

3. Site characterized by trees, most of which are evergreen. (go to 4)
3. Site characterized by shrubs, deciduous trees may be present but shrub cover predominate. (go to 23)

TREES

4. Tree species occurring on the limestone canyon rims or on the canyon floor of Walnut Canyon. (5)
4. Tree species occurring in all other environments. (6)

5. Tree species occurring on the limestone canyon rim of Walnut Canyon, often a mix of tree and shrub species. Map class: **Limestone Rim Complex** (continue to use the key to get to specific vegetation associations represented within this map class). (6)
5. Tree species occurring in the canyon floor of Walnut Canyon. Map class: **Canyon Floor Complex** (continue to use the key to get to specific vegetation associations represented within this map class). (6)

6. *Pinus ponderosa*, *Pinus edulis*, and *Juniperus osteosperma* are all present with 5% or greater cover of each species. *Juniperus deppeana* or *Quercus gambelii* may be present with equal cover or less. (7)
6. Dominant tree species not as above. (8)

7. Understory cover dominated by *Quercus gambelii*. *Pinus edulis* or *Juniperus osteosperma* co-dominant. Map class: **Ponderosa Pine – Pinyon Pine – Juniper / Gambel Oak Woodland**. Association is ***Pinus ponderosa / (Pinus edulis-Juniperus osteosperma) Quercus gambelii* Woodland**. (see picture below)

7. Understory cover is dominated by *Bouteloua gracilis*; *Muhlenbergia montana*, if present, has less cover than *Bouteloua gracilis*. *Pinus edulis* or *Juniperus osteosperma* are present. Map class: **Ponderosa Pine – Pinyon Pine – Juniper / Blue Grama Woodland**. Association is ***Pinus ponderosa* – (*Pinus edulis* – *Juniperus osteosperma*) / *Bouteloua gracilis* Woodland.** (see picture below)

8. Dominant tree species is *Pinus ponderosa*. *Pinus edulis* or *Juniperus osteosperma*, if present, have less than 5% cover each. *Pseudotsuga menziesii* may be present, but with less cover than *Pinus ponderosa*. (9)
8. Dominant tree species not *Pinus ponderosa* or if so, *Pseudotsuga menziesii* is co-dominant. (11)

9. Herbaceous cover is the dominant understory lifeform. Woody understory cover generally less than 10% and is not dominated by *Quercus gambelii*. If shrub cover is more than 10%, the shrub cover is still less than the herbaceous cover. (10)
9. Understory cover dominated by Quercus *gambelii*. Map class: **Ponderosa Pine / Gambel Oak Woodland** unless occurring on the canyon floor, than this map class is included in the Map class: **Canyon Floor Complex**. Association is ***Pinus ponderosa* / *Quercus gambelii* Woodland.** (see picture below)

10. Herbaceous cover is dominated by *Bouteloua gracilis*. *Muhlenbergia montana*, if present, has less cover than *Bouteloua gracilis*. Map class: **Ponderosa Pine / Mixed Graminoid Woodland Complex**. Association is ***Pinus ponderosa* / *Bouteloua gracilis* Woodland.** (see picture below)

10. Herbaceous cover is dominated by *Muhlenbergia montana*. *Bouteloua gracilis*, if present, has less cover than *Muhlenbergia montana*. Map class: **Ponderosa Pine / Mixed Graminoid Woodland Complex**. Association is ***Pinus ponderosa* / *Muhlenbergia montana* Woodland**. (see picture below)

11. Dominant or associated dominant tree species is *Pseudotsuga menziesii* and *Quercus gambelii* is present with at least 5% cover in the understory. *Pinus ponderosa* may also

be present with less than or equal cover to *Pseudotsuga menziesii*. Map class: **Douglas-fir / Gambel Oak Forest** unless occurring on the canyon floor, than this map class is included in the Map class: **Canyon Floor Complex**. Association is ***Pseudotsuga menziesii / Quercus gambelii* Forest.** (see picture below)

11. Dominant tree not as above. (12)

12. Dominant tree species is *Pinus edulis*. *Juniperus osteosperma* may be co-dominant but does not need to be present. *Juniperus deppeana* may be present. (13)

12. Dominant trees are *Juniperus osteosperma* or *Juniperus scopulorum*. (15)

13. *Juniperus osteosperma* may be present. Shrub cover, if present, has less cover than the herbaceous cover. Herbaceous cover, if present, characterized by *Bouteloua gracilis*. Map class: **Pinyon Pine – Utah Juniper / Blue Grama Woodland** unless occurring on the on limestone canyon rim, then this map class is included in the Map class: **Limestone Rim Complex**. Association is ***Pinus edulis* – (*Juniperus osteosperma*) / *Bouteloua gracilis* Woodland**. (see picture below)

13. *Cercocarpus montanus* or *Purshia stansburiana* characterize shrub understory. (14)

14. *Cercocarpus montanus* is the main understory shrub. Map class: **Limestone Rim Complex.** Association is ***Pinus edulis* - (*Juniperus* spp.) / *Cercocarpus montanus* Woodland.** (see picture below)

14. *Purshia stansburiana* is the main understory shrub. Map class: **Limestone Rim Complex.** Association is ***Pinus edulis* - (*Juniperus osteosperma*) / *Purshia stansburiana* Woodland.** (see picture below)

15. *Juniperus osteosperma* is the dominant tree**.** Map class: **Pinyon Pine – Utah Juniper / Blue Grama Woodland.** Alliance is ***Juniperus osteosperma* Woodland**. (see picture below)

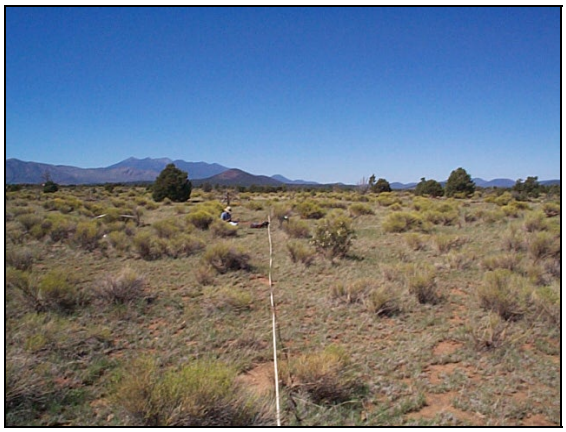
15. *Juniperus scopulorum* is the dominant tree. Map class: **Canyon Floor Complex.** Alliance is ***Juniperus scopulorum* Woodland**. (see picture below)

GRASSES

16. Herbaceous cover is dominated by *Bouteloua gracilis*. *Ericameria nauseosa* with less than 15% cover. *Muhlenbergia montana*, if present, has less cover than *Bouteloua gracilis*. Map class: **Blue Grama – Mt. Muhly Grassland Group**. Association is ***Bouteloua gracilis* Herbaceous Vegetation**. (see picture below)

16. Dominant grass not as above or *Ericameria nauseosa* with greater than 15% cover. (17)

17. Herbaceous cover is dominated by *Bouteloua gracilis*. *Ericameria nauseosa* present with more than 15% cover. *Muhlenbergia montana*, if present, has less cover than *Bouteloua gracilis*. Map class: **Rabbitbrush / Blue Grama Shrub Herbaceous Vegetation**. Association is ***Ericameria nauseosa* / *Bouteloua gracilis* Shrub Herbaceous Vegetation**. (see picture below)

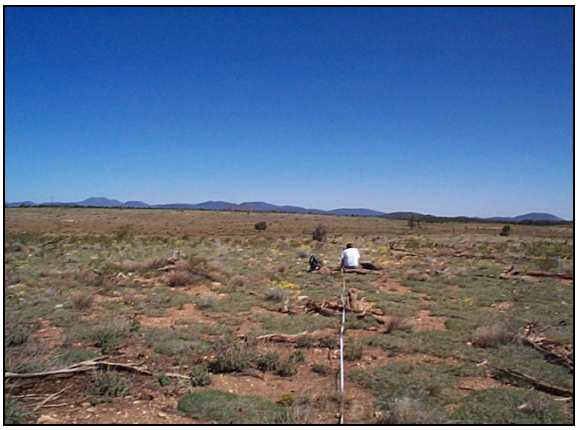


17. Dominant grass not as above. (18)

18. Herbaceous cover is dominated by *Muhlenbergia montana*. *Bouteloua gracilis*, if present, equal or less cover than *Muhlenbergia montana*. Map class: **Blue Grama – Mt. Muhly Grassland Group**. Association is ***Muhlenbergia montana*** **Herbaceous Vegetation.** (see picture below)

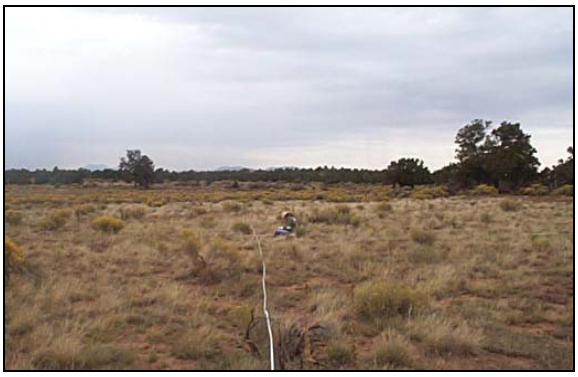
18. Dominant grass not as above (19).

19. Herbaceous cover is dominated by *Bouteloua eriopoda*. Shrubs such as *Robinia neomexicana* may be present. Map class: **Snakeweed / Modified Grassland Complex**. Association is ***Bouteloua eriopoda*** **Semi-desert Herbaceous Vegetation**. (see picture below)



19. Dominant grass not as above (20).

20. Herbaceous cover is dominated by *Aristida purpurea*. Map class: **Snakeweed / Modified Grassland Complex**. Association is ***Aristida purpurea* Herbaceous Vegetation.** (see picture below)

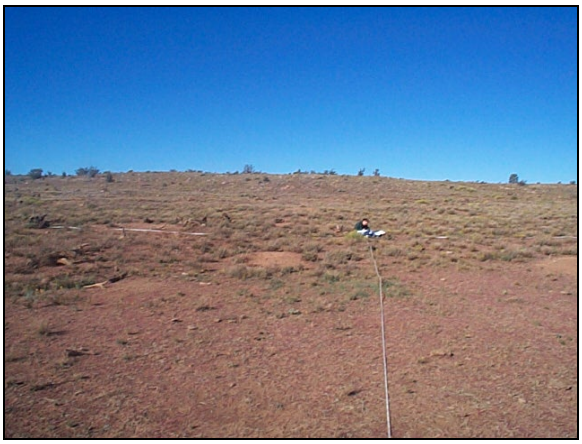


20. Herbaceous cover is dominated by non-native exotic species such as *Bromus tectorum* or *Pascopyrum smithii*. Disturbance adopted forbs such as *Portulaca oleracea* and/or *Marrubium vulgare* are often present. *Gutierrezia sarothrae* often present. (21)

21. Herbaceous cover is dominated by *Bromus* species. Map class: **Snakeweed / Modified Grassland Complex**. Alliance is ***Bromus* (*tectorum, rubens*) Semi-natural Herbaceous Alliance.** (see picture below)

21. Dominant grass not as above. (22)

22. Herbaceous cover mixed forbs and grasses, such as *Portulaca oleracea*, *Pascopyrum smithii*, *Marrubium vulgare* or *Bouteloua gracilis*. *Gutierrezia sarothrae* is the dominant shrub. Map class: **Snakeweed / Modified Grassland Complex**. Association is ***Gutierrezia sarothrae* Dwarf-shrubland**. (see picture below)



22. Herbaceous cover is dominated by *Pascopyrum smithii***.** Map class: **Introduced Western Wheatgrass Grassland**. Association is ***Pascopyrum smithii* Herbaceous Vegetation.** (no picture available, identified only during photointerpretation)

SHRUBS

23. Shrub species occurring on the limestone canyon rims or on the canyon bottom of Walnut Canyon. (24)
23. Shrub species occurring in other environments. (25)

24. Shrub species occurring on the limestone canyon rim of Walnut Canyon, often a mix of tree and shrub species. Map class: **Limestone Rim Complex** (Continue to use the key to get to specific vegetation associations represented within this map class.) (25)

24. Shrub species occurring on the canyon bottom of Walnut Canyon. Map class: **Canyon Floor Complex**. (Continue to use the key to get to specific vegetation associations represented within this map class.) (25)

25. *Forestiera pubescens* is the dominant or co-dominant shrub. (26)
25. Dominant shrub not as above. (27)

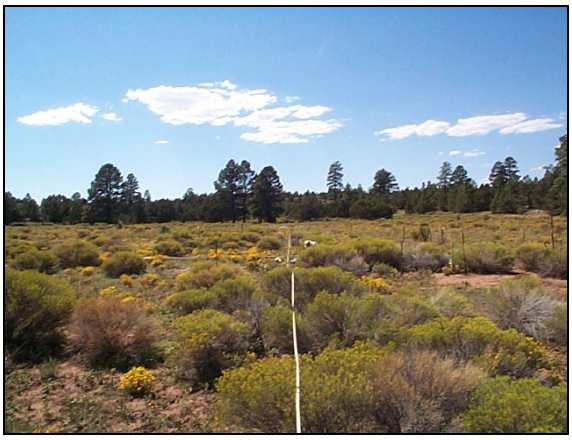
26. *Symphoricarpos rotundifolius* is a co-dominant shrub. *Acer negundo* present but with lower cover than shrubs. Found predominantly in riparian areas. Map class: **Canyon Floor Complex**. Association is ***Acer negundo / Forestiera pubescens - Symphoricarpos rotundifolius* Temporarily Flooded Shrubland (local assemblage).** (see picture below)

26. *Chamaebatiaria millefolium* is the co-dominant shrub. Typical of the canyon bottom in the eastern half of the project area. Map class: **Canyon Floor Complex**. Association is ***Chamaebatiaria millefolium - Forestiera pubescens* Shrubland (local assemblage).** (see picture below)

27. *Quercus gambelii, Robinia neomexicana,* and *Symphoricarpos rotundifolius* are the dominant shrubs. Map class: **Canyon Floor Complex.** Association is ***Quercus gambelii / Robinia neomexicana / Symphoricarpos rotundifolius Shrubland.*** (see picture below)

27. Dominant shrub not as above. (28)

28. *Ericameria nauseosa* and *Gutierrezia sarothrae* are the dominant shrubs. Map class: **Snakeweed / Modified Dwarf-shrub Herbaceous Vegetation**. Association is ***Ericameria nauseosa – Gutierrezia sarothrae* Shrubland (local assemblage).** (see picture below)



28. *Chamaebatiaria millefolium*, *Mahonia fremontii* and *Yucca baccata* all present. Typical of limestone canyon rims. The three shrubs and limestone rim habitat are diagnostic, even though other shrub species may occur. Map class: **Limestone Rim Complex**. Association is ***Chamaebatiaria millefolium - (Mahonia fremontii) - Yucca baccata* Limestone Terrace Shrubland (provisional)**. (see picture below)

SPARSE VEGETATION

29. Site characterized by geomorphology. (30)
29. Site characterized by human or animal land use. (32)

30. Site characterized by bedrock. (31)
30. Site characterized by intermittent drainage channel. Map class: **Sparsely Vegetated Intermittent Drainage Channel**
(no picture available)

31. Substrate Coconino sandstone. Map class: **Sparsely Vegetated Coconino Sandstone.**
(no picture available)
31. Substrate Kaibab Limestone. Map class: **Sparsely Vegetated Kaibab Limestone**.
(no picture available)

32. Site characterized by land use (Map classes' below)
    a. **Pastures**
    b. **NPS Facilities**
    c. **Rural Residential**
    d. **Transportation Routes**
    e. **Reservoirs**
    f. **Stock tanks and Dams**
    g. **Ranch Developments**
    h. **Utility Corridors**
32. Site characterized as a sparsely vegetated prairie dog colony and often contains exotic species such as *Marrubium vulgare*. Map class: **Common Horehound – Prairie Dog Town** (no picture available, identified only during photointerpretation).

APPENDIX E

E. National Vegetation Classification (NVC) Local and Global Descriptions for Walnut Canyon 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 the local classification and compiled the global classification.)

The following vegetation descriptions are derived from the 109 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 Walnut Canyon National Monument.

Each description is separated into twelve sections. Many of the sections are subdivided into a 'Walnut Canyon National Monument' or 'Globally' subsection. After the Walnut Canyon 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 combined at the end of Appendix E.

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 wetland classification system ranking crosswalked to NVCS 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 for 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 Walnut Canyon 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. Diameter Base Height (DBH) is provided in inches (in) and centimeters (cm) if trees were present in the relevés.
Conservation Rank	The conservation rank is a ranking system used to identify and prioritize conservation areas applied to NVCS 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 Walnut Canyon National Monument.
Comments	Comments particular to the vegetation description locally at Walnut Canyon National Monument and globally.
Dynamics	Information on the global vegetation dynamics.

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 (NVCS Associations) organized by NVCS structure:

NVCS Association	Page
Pseudotsuga menziesii / Quercus gambelii Forest	E-5
Juniperus osteosperma Woodland Alliance	E-8
Juniperus scopulorum Woodland Alliance	E-11
Pinus edulis – (Juniperus osteosperma) / Bouteloua gracilis Woodland	E-15
Pinus edulis – (Juniperus spp.*) / Cercocarpus montanus* Woodland	E-18
Pinus edulis – (Juniperus osteosperma) / Purshia stansburiana Woodland	E-21
Pinus ponderosa / Bouteloua gracilis Woodland	E-24
Pinus ponderosa – (Pinus edulis – Juniperus osteosperma) / Bouteloua gracilis Woodland	E-27
Pinus ponderosa / Muhlenbergia montana Woodland	E-29
Pinus ponderosa / Quercus gambelii Woodland	E-32
Pinus ponderosa – (Pinus edulis – Juniperus osteosperma) / Quercus gambelii Woodland	E-35
Acer negundo / Forestiera pubescens – Symphoricarpos rotundifolius Temporarily Flooded Shrubland (Local Assemblage)	E-37
Chamaebatiaria millefolium – Forestiera pubescens Shrubland (Local Assemblage)	E-39
Chamaebatiaria millefolium – (Mahonia fremontii) – Yucca baccata Limestone Terrace Shrubland (Proposed)	E-41
Ericameria nauseosa – Gutierrezia sarothrae Shrubland (Local Assemblage)	E-43
Quercus gambelii / Robinia neomexicana / Symphoricarpos rotundifolius Shrubland	E-45
Gutierrezia sarothrae Modified Dwarf-shrubland [Provisional]	E-48
Ericameria nauseosa / Bouteloua gracilis Shrub Herbaceous Vegetation	E-50
Aristida purpurea Herbaceous Vegetation	E-52
Bouteloua eriopoda Semi-desert Herbaceous Vegetation	E-54
Bouteloua gracilis Herbaceous Vegetation	E-57
Bromus (tectorum, rubens) Semi-natural Herbaceous Alliance	E-59
Muhlenbergia montana Herbaceous Vegetation	E-62
Pascopyrum smithii Herbaceous Vegetation	E-65

Pseudotsuga menziesii / Quercus gambelii Forest

MAP CLASS	Douglas-fir / Gambel Oak Forest, Canyon Floor Complex
COMMON NAME	Douglas-fir / Gambel Oak Forest
PHYSIOGNOMIC CLASS	Forest (I.)
PHYSIOGNOMIC SUBCLASS	Evergreen forest (I.A.)
PHYSIOGNOMIC GROUP	Temperate or subpolar needle-leaved evergreen forest (I.A.8.)
PHYSIOGNOMIC SUBGROUP	Natural/Semi-natural (I.A.8.N.)
FORMATION	Conical-crowned temperate or subpolar needle-leaved evergreen forest (I.A.8.N.c.)
ALLIANCE	*Pseudotsuga menziesii* Forest

CLASSIFICATION CONFIDENCE LEVEL Moderate

USFS WETLAND SYSTEM Upland

RANGE

Walnut Canyon National Monument

Douglas-fir / Gambel Oak Forest is a common association within the more mesic habitats at Walnut Canyon NM and its environs. This association was only found in side drainages at higher elevations and cooler north and east facing slopes of the southwestern section of the project boundary on Walnut Canyon NM and the Forest Service lands.

Globally

This *Pseudotsuga menziesii* forest association occurs in the southern Rocky Mountains and southwestern U.S. and is found on foothills, mountains and plateaus from Colorado to Trans-Pecos Texas, west to Arizona and Utah.

ENVIRONMENTAL DESCRIPTION

Walnut Canyon National Monument

This association occurs mainly on higher elevation sites from 1980-2130m (average 2,050m). All of the relevés occurred within side drainages on steep or gradual slopes ranging from 15-65% slope (average 50%) and with northern or eastern exposures.

Globally

This forest association occurs on mountains and plateaus from Colorado to Trans-Pecos Texas, west to Arizona and Utah. Elevation ranges from 1370-2870 m (4500-9400 ft). Stands are found along drainages, gentle to moderate lower and middle slopes, steep upper slopes and ridgetops. Aspects are variable. This forest occurs as both a non-obligate riparian community on the outer margins of riparian areas in desert canyons and steep draws, and as an upland forest forming extensive stands on typically north-facing hillslopes (southern aspects at higher elevations). Soils vary, but are often shallow and rocky, ranging from sandy loams to clay. The surface is generally largely covered with a thin layer of litter. Parent materials include fractured limestone, sandstone, basalt and andesite.

MOST ABUNDANT SPECIES

Walnut Canyon National Monument

Stratum	Species
Tree canopy	*Pseudotsuga menziesii*
Tall Shrub	*Quercus gambelii*

Globally

Stratum	Species
Tree canopy	*Pseudotsuga menziesii, Pinus ponderosa, Pinus strobiformis,*
Tall Shrub	*Quercus gambelii*

ASSOCIATED SPECIES
Walnut Canyon National Monument
Juniperus scopulorum, Pinus ponderosa (all occur with >5% cover)

Globally
Acer glabrum, Achillea millefolium, Amelanchier spp., *Arctostaphylos patula, Bromus* spp., *Carex rossii, Cercocarpus montanus, Festuca arizonica, Holodiscus dumosus, Juniperus deppeana, Juniperus osteosperma, Koeleria macrantha,Lathyrus lanszwertii* var. *leucanthus, Mahonia repens, Muhlenbergia montana, Muhlenbergia virescens, Paxistima myrsinites, Pinus edulis, Pinus ponderosa, Pinus strobiformis, Poa fendleriana, Prunus virginiana, Ribes cereum, Robinia neomexicana, Rosa woodsii, Symphoricarpos oreophilus, Thalictrum fendleri, Vicia americana*

VEGETATION DESCRIPTION
Walnut Canyon National Monument
Douglas-fir / Gambel Oak Forest total vegetation cover ranged from 41-75% (average 59%) with 28-62% absolute cover (average 45%) in the tree layer, 6-20% (average 10%) in the shrub layer, and 4-15% (average 9%) in the herbaceous layer. The total species diversity ranged from 12-30 species (average 23) within the 7 relevés sampled.

The tree layer was dominated by *Pseudotsuga menziesii* with 16-62% absolute cover (average 29%) with DBH ranging from 4-26 in (11-67 cm) (average 8 in/21 cm). *Juniperus scopulorum* and *Pinus ponderosa* may co-dominate or have high cover within this association; however, they never dominate the tree canopy. The shrub layer consistently was dominated by *Quercus gambelii* with 4-22% absolute cover (average 16%); however, it occurred within the ground and tree layer as well. DBH for the larger tree layer ranged from 4-12 in (11-31 cm) (average 6 in/16 cm). The herbaceous layer contained a variety of herbs and grasses including *Artemisia ludoviciana, Bromus ciliatus, Poa fendleriana, Ptelea trifoliata, Thalictrum fendleri, Valeriana arizonica,* and *Vicia americana.*

Globally
This association is characterized by a relatively sparse to moderately dense evergreen tree canopy dominated by *Pseudotsuga menziesii* sometimes with scattered large *Pinus ponderosa, Pinus strobiformis, Pinus edulis,* or *Juniperus* spp. (especially on drier sites). *Abies concolor* is typically not present. *Quercus gambelii* dominates both the subcanopy (tree form, if present) and the moderately dense tall-shrub layer that consists of dense clumps of oak. *Quercus gambelii* must have at least 5% cover, but there is frequently over 25%. At higher elevations, the *Quercus gambelii* are more tree-like and *Symphoricarpos oreophilus* will be present with significant cover in the short-shrub layer. At lower elevations, scattered *Pinus edulis, Juniperus osteosperma*, or *Juniperus deppeana* are often present. Other common shrub species depending on range may include *Acer glabrum, Arctostaphylos patula, Amelanchier* spp., *Cercocarpus montanus, Holodiscus dumosus, Mahonia repens, Paxistima myrsinites, Prunus virginiana, Ribes cereum, Robinia neomexicana*, and *Rosa woodsii*. The generally sparse herbaceous layer is composed of mostly graminoids with scattered forbs, but ranges to moderately dense and diverse. Associated graminoids may include *Bromus* spp., *Carex rossii, Festuca arizonica, Koeleria macrantha, Muhlenbergia montana, Muhlenbergia virescens*, and *Poa fendleriana*. Common forbs include *Achillea millefolium, Lathyrus lanszwertii* var. *leucanthus, Thalictrum fendleri*, and *Vicia americana*. The shrub layer has equal or greater cover than graminoids. This open conifer forest transitions to *Quercus gambelii* woodlands in drier sites and at lower elevations.

CONSERVATION RANK G5

DATABASE CODE CEGL000452

MAP CLASSES
The association Douglas-fir / Gambel Oak Forest is represented by map classes Douglas-fir / Gambel Oak Forest (map code 16) and Canyon Floor Complex (map code 10).

This association has a broad distribution within two map classes: one occurring in more mesic habitat, Canyon Floor Complex, and one occurring in cooler rim and side drainage habitats, Douglas-fir / Gambel Oak Forest. The distinguishing feature between the Douglas-fir / Gambel Oak Forest and the Canyon Floor Complex is that the Canyon Floor Complex occurs within the more mesic Walnut Creek canyon bottom. The total area of Douglas-fir / Gambel Oak Forest within Walnut Canyon NM is 320 ac (129 ha) within 29 polygons and the total area in the park

environs is 120 ac (48 ha) within 13 polygons. The total area of Canyon Floor Complex within Walnut Canyon NM is 120 ac (48 ha) within 39 polygons and the total area in the park environs is 32 ac (13 ha) within 23 polygons.

COMMENTS

Walnut Canyon National Monument

Due to Walnut Canyon and the adjacent side canyons often having a narrow canyon bottom, it was difficult to distinguish unique occurrences of this association within the Canyon Floor Complex. Therefore, this association was mapped as part of the Canyon Floor Complex map class, when it occurred within the riparian areas.

Globally

Within the habitat type literature there are four phases mentioned: *Festuca arizonica* phase, *Holodiscus dumosus* phase, *Muhlenbergia virescens* phase (all defined by having at least 5% cover of both *Quercus gambelii* and the nominal species), and *Quercus gambelii* (typic) phase by a undeveloped herbaceous layer (Alexander et al. 1984, Alexander et al. 1987, DeVelice et al. 1986, Fitzhugh et al. 1987, Johnston 1987, Larson and Moir 1987, Muldavin et al. 1996, Stuever and Hayden 1997b). There are 3 similar NVCS *Pseudotsuga menziesii* associations that use these phase species as the nominal species. These phases represent "intermediate" vegetation. Review of these associations is needed to clarify relationships between associations.

DYNAMICS

Globally

This association represents mid- to late-seral forests that are dominated by *Pseudotsuga menziesii* with the diagnostic *Quercus gambelii*-dominated understory. Large, often fire-scarred *Pinus ponderosa* trees may be present to codominant in the canopy, but do not reproduce (Alexander et al. 1984, DeVelice et al. 1986).

REFERENCES

Alexander et. al. 1984, Alexander et. al. 1987, Bader 1932, Blackhawk Coal Company 1981, Bourgeron et. al. 1993, Bourgeron et. al. 1995, Bourgeron and Engelking 1994, Devalice et. al. 1986, Diamond 1993, Fitzhugh et. al. 1987, Freeman and Dick-Peddie 1970, Hess and Wesser 1982, Johnston 1987, Keammerer 1974, Kittel et. al. 1994, Kittel et. al. 1999a, Kittel et. al. 1999b, Kamarakova et. al. 1988a, Kamarakova et. al. 1988b, Larsen and Moir 1987, Muldavin et. al. 1996, Stuever and Hayden 1997b, Tiedeman and Terwilliger 1997b, Western Ecology Working Group of Nature Serve, Youngblood and Mauk 1985

Note:

This association is found in two different map classes:

1) Canyon Floor Complex
2) Douglas-fir / Gambel Oak Forest

Juniperus osteosperma Woodland Alliance

MAP CLASS	Pinyon Pine – Utah Juniper / Blue Grama Woodland
COMMON NAME	Utah Juniper Woodland Alliance
PHYSIOGNOMIC CLASS	Woodland (II.)
PHYSIOGNOMIC SUBCLASS	Evergreen woodland (II.A.)
PHYSIOGNOMIC GROUP	Temperate or subpolar needle-leaved evergreen woodland (II.A.4.)
PHYSIOGNOMIC SUBGROUP	Natural/Semi-natural (II.A.4.N.)
FORMATION	Rounded-crowned temperate or subpolar needle-leaved evergreen woodland (II.A.4.N.a.)
ALLIANCE	*Juniperus osteosperma* Woodland Alliance

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

USFS WETLAND SYSTEM Upland

RANGE
Walnut Canyon National Monument
Utah Juniper Woodland Alliance was only identified from one relevé within Forest Service lands on Anderson Mesa.

Globally
These woodlands are distributed across the Great Basin and Colorado Plateau from the central Rocky Mountains of central Wyoming and western Colorado, through southern Idaho, Utah, and Nevada to the northern Mojave region of California. A second substantial range occurs along interior slopes the transverse ranges of southern California.

ENVIRONMENTAL DESCRIPTION
Walnut Canyon National Monument
Only one relevé was assigned to this alliance; it occurred in a flat area with an elevation of 6,955 ft (2,120 m).

Globally
Vegetation within the *Juniperus osteosperma* Woodland Alliance (A.536) is distributed across the Intermountain West from the eastern Sierra Nevada to the central and southern Rocky Mountains. Stands along the Bighorn Range in Wyoming are near the eastern side of the Rockies. The alliance usually occupies semi-arid, lower to middle slopes of the many mountain ranges and plateaus of the region, occurring between 3,281 and 8,694 ft (1,000 and 2,650 m) in elevation. Average annual precipitation is usually between 10-20 in (25-50 cm), but the seasonal distribution varies across the range of the alliance. Generally, winter precipitation in the form of westerly storms is maximal along the northwest edge of the range and summer moisture increases to the east and south. Distribution of the alliance is also correlated with 'thermal belts' which occur above the areas of cold air drainage in high intermountain basins. Adjacent vegetation is usually *Artemisia* shrub-steppe at the lower elevation margin and montane and subalpine coniferous vegetation at the upper margin. Communities in this alliance are often closely associated with *Pinus edulis* or *Pinus monophylla* woodlands. *Juniperus osteosperma* usually forms monotypic stands on drier or colder sites than where the pines occur.

MOST ABUNDANT SPECIES
Walnut Canyon National Monument

Stratum	Species
Tree canopy	*Juniperus osteosperma*

Globally

Stratum	Species
Tree canopy	*Juniperus osteosperma, Pinus edulis, Pinus monophylla*

ASSOCIATED SPECIES
Walnut Canyon National Monument
Bouteloua gracilis, Penstemon linarioides, Poa fendleriana, Quercus gambelii (all occur with >5% cover)

Globally
Achnatherum hymenoides (= Oryzopsis hymenoides), Amelanchier alnifolia, Artemisia arbuscula, Artemisia nova, Artemisia tridentata, Cercocarpus intricatus, Cercocarpus ledifolius, Cercocarpus montanus, Chrysothamnus spp., *Elymus elymoides, Festuca idahoensis, Juniperus scopulorum, Juniperus monosperma, Pinus aristata, Pinus flexilis, Pinus ponderosa, Pleuraphis jamesii (= Hilaria jamesii), Prunus virginiana, Purshia tridentata, Pseudotsuga menziesii, Pseudoroegneria spicata, Symphoricarpos oreophilus, Stipa* spp., *Quercus gambelii*

VEGETATION DESCRIPTION
Walnut Canyon National Monument
Utah Juniper Woodland Alliance total vegetation cover was 62%, with 47% absolute cover in the tree layer, 10% absolute cover in the shrub layer, and 16% absolute cover in the herbaceous layer. The species diversity, within the one relevé sampled, was 16 species.

The tree layer was dominated by *Juniperus osteosperma* with 35% absolute cover. DBH ranged from 4-12 in (11-30 cm) (average 7 in/19 cm). The shrub layer was not dominated by a single species; however, *Quercus gambelii* was the most common shrub species. *Bouteloua gracilis, Poa fendleriana,* and *Penstemon linarioides* were the most common understory herbaceous species; although, none of these species were dominant within the community.

Globally
These communities are characterized by an open canopy of *Juniperus osteosperma*, quite often in association with *Pinus monophylla* or *Pinus edulis*. The majority of these stands occur in dry ranges or plateaus of the Colorado Plateau or Great Basin. *Cercocarpus ledifolius* is a common associate in these interior stands. Less common tree associates include *Pinus ponderosa, Pinus flexilis, Pinus aristata,* or *Pseudotsuga menziesii*, where these communities grade into montane coniferous forest, or *Juniperus scopulorum*, and *Juniperus monosperma* in the central and southern Rockies. Widespread shrub associates include *Artemisia tridentata, Artemisia arbuscula, Artemisia nova, Symphoricarpos oreophilus, Amelanchier alnifolia, Cercocarpus intricatus, Cercocarpus montanus, Chrysothamnus* spp., *Quercus gambelii, Prunus virginiana*, and *Purshia tridentata*. The herbaceous layer is usually somewhat sparse and dominated by cespitose perennial grasses, including *Pseudoroegneria spicata, Festuca idahoensis, Pleuraphis jamesii (= Hilaria jamesii), Achnatherum hymenoides (= Oryzopsis hymenoides), Elymus elymoides*, and *Stipa* spp. Some stands in rocky terrain may lack an understory entirely.

DATABASE CODE A.536

MAP CLASSES
The alliance Utah Juniper Woodland Alliance is represented as an inclusion within map class Pinyon Pine – Utah Juniper / Blue Grama Woodland (map code 12).

The map class Pinyon Pine - Utah Juniper / Blue Grama Woodland has a broad distribution within the eastern section of the project boundary. The total area mapped within Walnut Canyon NM is 373 ac (151 ha) within 43 polygons and the total area in the park environs is 1,732 ac (701 ha) within 98 polygons.

COMMENTS
Walnut Canyon National Monument
This alliance is unique within map class Pinyon Pine–Utah Juniper / Blue Grama Woodland since the alliance is not characterized by pinyon pine, but the map class is. However, due to having only one measured relevé of this alliance, it was not further classified to the association level and was not mapped as a unique map class.

The Pinyon Pine – Utah Juniper / Blue Grama Woodland, as mapped, may combine inclusions of the Utah Juniper Woodland Alliance. Distinction between the two was not possible from aerial photography, but can be possible from the ground where low cover of *Pinus edulis* and high cover of *Juniperus osteosperma* represent Utah Juniper Woodland Alliance and *Pinus edulis* dominating or co-dominating represent the Two-needle Pinyon – (Utah Juniper) Blue Grama Woodland Association.

Globally
The low-elevation woody vegetation of the Great Basin has been classified as *Pinus monophylla* (singleleaf pinyon) or pinyon-juniper woodlands. Further classification work is needed to differentiate true woodlands from wooded herbaceous stands. Many stands described as woodlands have less than 20% cover in the tree layer (Blackburn et al. 1968a & b, Blackburn et al. 1969) and may actually fit better in the *Juniperus osteosperma* Wooded Herbaceous Alliance (A.1502). While the amount of literature available for pinyon-juniper vegetation is large, relatively little classification work has been done for these vegetation types. Further inventory and review of the classification of pinyon-juniper woodlands and wooded herbaceous communities are needed for the entire west.

DYNAMICS
Globally
Juniperus osteosperma is a very slow-growing, long-lived tree and stands appear somewhat static over time compared to more productive forests. *Juniperus osteosperma* stands have always been widespread, but were formerly restricted to certain habitats (rocky ridges, etc.). These woodlands are expanding into adjacent steppe grasslands in many areas, reportedly in connection with livestock grazing and altered fire regimes (Blackburn 1967). *Juniperus osteosperma* is the first to invade adjacent *Artemisia nova* shrublands, but is eventually succeeded by *Pinus monophylla*. Jameson (1962) inferred a similar relationship between *Juniperus osteosperma* and *Pinus edulis* in the Grand Canyon. They noted that individuals of *Juniperus osteosperma* were older and even-aged, while *Pinus edulis* occupied all age classes. Many of these communities have been severely impacted by past range practices of chaining, tilling, and reseeding with exotic forage grasses. Although the dominant trees appear to regenerate after such disturbances, the effects on understory species are poorly known.

REFERENCES
Baker 1983, Baker 1984, Baker and Kennedy 1985, Blackburn 1967, Blackburn et al. 1968a, Blackburn et al. 1968b, Blackburn et al. 1969, Blackburn et al. 1971, Bradley 1964, Brotherson and Evenson 1983, Caicco and Wellner 1983, Clary et al. 1974, Dalen and Snyder 1987, Dastrup 1963, Despain 1973, Donart et al. 1978, Eddleman and Jaindl 1994, Everett 1986, Isaacson 1967, Jameson 1962, Johnsen 1962, Johnson and Pfister 1982, Johnston 1987, Jones 1989, Kline 1973, Knight et al. 1987, Komarkova et al. 1988a, Komarkova et al. 1988b, Koniak 1985, Larson and Moir 1986, Larson and Moir 1987, Lesica and DeVelice 1992, Marriott and Jones 1989, Milton and Purdy 1983, Moir and Carleton 1987, Rust 1999, Sawyer and Keeler-Wolf 1995, USFS 1983a, USFS 1985a, USFS 1985b, Warren n.d., West et al. 1978, Wight 1965, Wight and Fisser 1968

Juniperus scopulorum Woodland Alliance

MAP CLASS	Canyon Floor Complex
COMMON NAME	Rocky Mountain Juniper Woodland Alliance
PHYSIOGNOMIC CLASS	Woodland (II.)
PHYSIOGNOMIC SUBCLASS	Evergreen woodland (II.A.)
PHYSIOGNOMIC GROUP	Temperate or subpolar needle-leaved evergreen woodland (II.A.4.)
PHYSIOGNOMIC SUBGROUP	Natural/Semi-natural (II.A.4.N.)
FORMATION	Rounded-crowned temperate or subpolar needle-leaved evergreen woodland (II.A.4.N.a.)
ALLIANCE	*Juniperus scopulorum* Woodland Alliance

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

USFS WETLAND SYSTEM Upland

RANGE

Walnut Canyon National Monument

Rocky Mountain Juniper Woodland Alliance was located within Walnut Canyon NM on the north rim in a drainage east of the visitor center and within Forest Service lands on a east facing slope on Anderson Mesa.

Globally

Stands included in this woodland alliance occur on dry slopes in the foothills and lower elevations of the northern and southern Rocky Mountains and the Black Hills. The vegetation extends east to breaks, badlands and canyon slopes in the Great Plains in western Nebraska and the Dakotas and may extend south to escarpments in the panhandle of Texas. *Juniperus scopulorum* trees also occur in Puget Sound in northwestern Washington and British Columbia, Canada, but associations have not been described there.

ENVIRONMENTAL DESCRIPTION

Walnut Canyon National Monument

Only two relevés were assigned to this alliance. Elevation was recorded for one of the relevés at 6,660 ft (2,030 m). Both relevés were recorded from steep east facing slopes (20-90% slope).

Globally

Stands included in this woodland alliance occur on dry rocky slopes in the northern and central Rocky Mountains, the Black Hills, and on escarpments and other topographic breaks in the western Great Plains. Elevations range from 2,133-8,694 ft (650-2,650 m). Climate is semi-arid, continental with most of the 16-24 in (40-60 cm) annual precipitation occurring during the growing season. Sites are typically found on moderate to very steep slopes (35-170%) of rock and boulder outcrops in foothill and montane zone in the mountains, and on bluffs along major drainages, escarpments and badlands in the western plains. The stands occur on all aspects, but several associations are restricted to northerly or southerly aspects. Soils are shallow to moderately deep, stony, and typically coarse-textured loams but range from loamy sand to clay. Stands in this alliance grow more robust on calcareous soils (Eyre 1980). Parent material may include limestone, granite, gneiss, schist, sandstone, scoria or shale. Exposed bedrock is common and many stands have over 50% bare soil. Soil pH ranges from slightly acid to alkaline.

MOST ABUNDANT SPECIES

Walnut Canyon National Monument

Stratum	Species
Tree canopy	*Juniperus scopulorum*

Globally

Stratum	Species
Tree canopy	*Juniperus scopulorum*

ASSOCIATED SPECIES

Walnut Canyon National Monument

Bouteloua gracilis, Juniperus osteosperma, Pinus ponderosa, Quercus gambelii (all occur with >5% cover)

Globally

Achillea millefolium, Achnatherum hymenoides (= Oryzopsis hymenoides), Artemisia ludoviciana, Artemisia nova, Artemisia tridentata, Bouteloua gracilis, Carex rossii, Cercocarpus ledifolius, Cercocarpus montanus, Ericameria nauseosa (= Chrysothamnus nauseosus), Eriogonum umbellatum, Campanula rotundifolia, Festuca idahoensis, Fraxinus pennsylvanica, Galium boreale, Helianthus pumilus, Heterotheca villosa, Heuchera bracteata, Hesperostipa comata (= Stipa comata), Leucopoa kingii (= Festuca kingii), Leymus ambiguus, Maianthemum stellatum, Muhlenbergia montana, Opuntia polyacantha Penstemon virens, Physocarpus monogynus, Pinus ponderosa, Piptatherum micranthum (= Oryzopsis micrantha), Poa secunda, Potentilla fissa, Prunus virginiana, Pseudotsuga menziesii, Pseudoroegneria spicata, Purshia tridentata, Rhus trilobata, Ribes spp., *Rubus deliciosus, Symphoricarpos* spp., *Schizachyrium scoparium, Senecio integerrimus*

VEGETATION DESCRIPTION

Walnut Canyon National Monument

Only two relevés were assigned to the Rocky Mountain Juniper Woodland Alliance with total vegetation cover of 38 and 70%, 26 and 46% absolute cover in the tree layer, 4 and 6% absolute cover in the shrub layer, and 15 and 25% absolute cover in the herbaceous layer. The species diversity in the two relevés sample consisted of 19 and 23 species.

The tree layer was dominated by *Juniperus scopulorum*, with 12 and 25% absolute cover and DBH ranging from 4-24 in (11-61cm) (average 10 in/26 cm). The shrub layer was not dominated by a single species; however, *Quercus gambelii* was the most common shrub species. *Bouteloua gracilis* is the most common understory herbaceous species.

Globally

Woodlands in this alliance are found on dry, rocky slopes in the northern and central Rocky Mountains and east into the western Great Plains on topographic breaks. Stands have a sparse to dense canopy of evergreen trees, usually 7-26 ft (2-8 m) tall. The stands are dominated by *Juniperus scopulorum*, a small scale-leaved tree that is typically under 33ft (10 m) tall, but can reach up to 66 ft (20 m). Scattered individuals of *Pinus ponderosa* or *Pseudotsuga menziesii* may be present in the tree canopy, but are never codominant. In the plains stands the deciduous broad-leaved tree *Fraxinus pennsylvanica* may be present.

The understory varies from sparse under closed canopies to a moderately dense layer of shrubs (2-7 ft, 0.5-2 m tall) or graminoids in open stands. The shrub layer may include several species, but is often dominated by a single species on a given aspect. The dominant shrub species are *Artemisia nova, Artemisia tridentata, Cercocarpus ledifolius, Cercocarpus montanus, Prunus virginiana*, and *Purshia tridentata*. Common, but less abundant shrubs include *Ericameria nauseosa (= Chrysothamnus nauseosus), Physocarpus monogynus, Rhus trilobata, Ribes* spp., *Rubus deliciosus*, and *Symphoricarpos* spp. Scattered dwarf-shrubs such as *Artemisia frigida* or *Leptodactylon pungens* are frequently present. The herbaceous layer is dominated by graminoids typical of dry habitats. These species include *Bouteloua gracilis, Carex rossii, Festuca idahoensis, Leucopoa kingii (= Festuca kingii), Leymus ambiguus, Muhlenbergia montana, Achnatherum hymenoides (= Oryzopsis hymenoides), Piptatherum micranthum (= Oryzopsis micrantha), Poa secunda, Pseudoroegneria spicata, Schizachyrium scoparium*, and *Hesperostipa comata (= Stipa comata)*. Perennial forbs are sparse, but may be fairly diverse. The most common forbs are *Achillea millefolium, Artemisia ludoviciana, Eriogonum umbellatum, Campanula rotundifolia, Galium boreale, Helianthus pumilus, Heterotheca villosa, Heuchera bracteata, Maianthemum stellatum, Penstemon virens, Potentilla fissa*, and *Senecio integerrimus*. The fern *Cystopteris fragilis* and the cactus *Opuntia polyacantha* are often present. In some stands mosses and lichens cover up to 72% of the ground. Annual grasses and forbs are seasonally present.

DATABASE CODE A.506

MAP CLASSES

The Rocky Mountain Juniper Woodland Alliance is represented as an inclusion within map class Canyon Floor Complex (map code 10).

This alliance was mapped together with other more mesic and riparian associations as one map class, the Canyon Floor Complex. This map class is distributed mainly within the bottom of Walnut Canyon; however, it also occurs within side canyons and in a small section on Anderson Mesa. The total area mapped within Walnut Canyon NM is 119 ac (48 ha) within 39 polygons and the total area in the park environs is 32 ac (13 ha) within 23 polygons.

The Canyon Floor Complex is represented by the following alliances and associations: *Acer negundo* / *Forestiera pubescens – Symphoricarpos rotundifolius* Temporarily Flooded Shrubland (local assemblage), *Juniperus scopulorum* Woodland Alliance, *Pinus ponderosa / Quercus gambelii* Woodland, *Pseudotsuga menziesii / Quercus gambelii* Forest, *Chamaebatiaria millefolium – Forestiera pubescens* Shrubland (local assemblage), and *Quercus gambelii / Robinia neomexicana / Symphoricarpos rotundifolius* Shrubland.

COMMENTS

Walnut Canyon National Monument

These two relevés were unique within the Canyon Floor Complex due to high cover of *Juniperus scopulorum* and no cover of *Pinus ponderosa* or *Pseudotsuga menziesii*. These relevés could therefore not be further classified with other associations at Walnut Canyon that contain a high cover of *Juniperus scopulorum*, including *Pinus ponderosa / Quercus gambelii* Woodland or *Pseudotsuga menziesii / Quercus gambelii* Forest. Without further sampling of the *Juniperus scopulorum* stands we cannot define the association.

Globally

At their upper elevational limit, *Juniperus scopulorum* communities may merge with woodlands and forests dominated by *Pinus* species. The dominance of *Juniperus scopulorum* is a diagnostic feature that can usually be used to separate communities within this alliance from other wooded communities. At lower elevations, the boundary between *Juniperus scopulorum* woodlands and communities that are dominated by *Artemisia* spp., or dry prairie, may be difficult to distinguish, as the ecotone may be quite broad. On the upper elevation margins, pine woodlands and forests often merge with this alliance. The dominance of *Juniperus scopulorum* is a diagnostic feature that can usually be used to separate communities within this alliance from other wooded communities. At the lower elevation edges of this alliance it may be difficult to distinguish where *Juniperus scopulorum* Woodland Alliance (A.506) ends and communities that are dominated by *Artemisia* spp. or dry prairie begin.

DYNAMICS

Globally

Woodlands in this alliance are considered to be edaphic or topographic climax communities (Tiedemann et al. 1987, Hansen et al. 1984). *Juniperus scopulorum* is a long-lived species. Hansen and Hoffman (1988) found most trees in stands they sampled to be over 120 years, with some individuals older than 360 years. Fire can be used to control *Juniperus scopulorum* stands on rangeland because the species will not resprout after being burned (Fischer and Bradley 1987, Wright et al. 1979). Young individuals are most vulnerable to fire (Fischer and Bradley 1987, Wright et al. 1979). The effect of a fire on a stand is largely dependent on the tree height and density, fine fuel load on the ground, weather conditions, and season (Wright et al. 1979, Dwyer and Pieper 1967). Trees are more vulnerable in open stands where fires frequently occurs in the spring, the humidity is low, wind speeds are over 10-20 mph, and there is adequate fine fuels to carry fire (Fischer and Bradley 1987, Wright et al. 1979). Under other conditions, burns tend to be spotty with low tree mortality. Large trees are generally not killed unless fine fuels, such as tumbleweeds, have accumulated beneath the tree to provide fuel ladders for the fire to reach the crown. Closed-canopy stands rarely burn because they typically do not have enough understory or wind to carry a fire.

Altered fire regimes, cutting trees for fencing, and improper grazing by livestock have significant impacts on the quality of sites. Grazing by livestock can modify the fire regime by removing the fine fuels that carry fire. Fire, livestock grazing, and trampling by hikers and vehicles disturb cryptogamic soil crusts that help maintain soil structure, reduce soil erosion, provide habitat for plants and preserve biological diversity (Ladyman and Muldavin 1996). More study is needed to understand and manage these woodlands.

REFERENCES

Allard 1990, Badaracco 1971, Bighorn Coal Mine n.d., Brown 1971, Burns and Honkala 1990a, Cooper et al. 1995, DeVelice 1992, DeVelice and Lesica 1993, DeVelice et al. 1995, Diamond 1993, Dwyer and Pieper 1967, Eyre

1980, Faber-Langendoen et al. 1996, Fischer and Bradley 1987, Francis 1983, Goodding 1923, Hansen 1985, Hansen and Hoffman 1988, Hansen et al. 1984, Hess 1981, Hess and Alexander 1986, Jennings 1978, Jennings 1979, Johnston 1987, Ladyman and Muldavin 1996, Lesica and DeVelice 1992, Moran 1981, Ramaley 1909, Steele et al. 1983, Strong 1980, Terwilliger et al. 1979, Tiedemann et al. 1987, Wasser and Hess 1982, Wells 1965, Wells 1970a, Wells 1970b, Wright et al. 1979

Pinus edulis - (Juniperus osteosperma) / Bouteloua gracilis Woodland

MAP CLASS	Pinyon Pine – Utah Juniper / Blue Grama Woodland, Limestone Rim Complex
COMMON NAME	Two-needle Pinyon – (Utah Juniper) / Blue Grama Woodland
PHYSIOGNOMIC CLASS	Woodland (II.)
PHYSIOGNOMIC SUBCLASS	Evergreen woodland (II.A.)
PHYSIOGNOMIC GROUP	Temperate or subpolar needle-leaved evergreen woodland (II.A.4.)
PHYSIOGNOMIC SUBGROUP	Natural/Semi-natural (II.A.4.N.)
FORMATION	Rounded-crowned temperate or subpolar needle-leaved evergreen woodland (II.A.4.N.a.)
ALLIANCE	*Pinus edulis – (Juniperus* spp.*)* Woodland Alliance

CLASSIFICATION CONFIDENCE LEVEL Moderate

USFS WETLAND SYSTEM Upland

RANGE

Walnut Canyon National Monument

Two-needle Pinyon – (Utah Juniper) / Blue Grama Woodland is one of the most common associations within the eastern section of the project boundary. It was located on the north rim of Walnut Canyon, mainly to the east of the visitor center, and on the south rim of Walnut Canyon east of Cherry Canyon, within both the environs and Walnut Canyon NM.

Globally

This woodland association occurs in the cinder fields, mountains and mesas in the southern Colorado Plateau and Mogollon Rim, and may extend into southern Utah and western Colorado.

ENVIRONMENTAL DESCRIPTION

Walnut Canyon National Monument

This association's elevation ranged from 1915-2095m (average 1980m). The topography varied from flat areas to steep canyon walls with 0-80% slope (average 28%).

Globally

This woodland association is known from the mountains and mesas in the southern Colorado Plateau, Mogollon Rim and extends into southern Utah and western Colorado. Elevations normally range from 2,100-2,300 m (6,885-7,540 ft). Sites are variable, but generally are relatively dry and rocky. Stands occur on flat to moderate slopes along drainages and on mesa tops, on gentle to moderate 10-40% rocky slopes of foothills, and at the base of cinder cones. The substrates are variable and range from to deep, coarse textured soil derived from cinder, to sandy loams derived from sandstone or fine-textured soils derived from limestone.

MOST ABUNDANT SPECIES

Walnut Canyon National Monument

Stratum	Species
Tree canopy	*Pinus edulis, Juniperus osteosperma*
Herbaceous	*Bouteloua gracilis*

Globally

Stratum	Species
Tree Canopy	*Pinus edulis, Juniperus osteosperma, Juniperus deppeana, Juniperus scopulorum*
Herbaceous	*Bouteloua gracilis*

ASSOCIATED SPECIES

Walnut Canyon National Monument

Chamaebatiaria millefolium, Gutierrezia sarothrae, Poa fendleriana, Purshia mexicana, Purshia stansburiana, Quercus gambelii, Yucca baccata (all occur with >5% cover)

Globally

Achnatherum hymenoides, Bouteloua curtipendula, Cercocarpus montanus, Ericameria nauseosa, Elymus elymoides, Hesperostipa comata, Hesperostipa neomexicana, Juniperus deppeana, Juniperus scopulorum, Koeleria macrantha, Pleuraphis jamesii, Rhus trilobata, Yucca spp.

VEGETATION DESCRIPTION

Walnut Canyon National Monument

Two-needle Pinyon – (Utah Juniper) Blue Grama Woodland total vegetation cover was 23-86% (average 50%) with 13-100% absolute cover (average 39%) in the tree layer, 0.5-21% (average 7%) in the shrub layer, and 5-26% (average 12%) in the herbaceous layer. The total species diversity ranged from 7-29 species (average 17) within the 18 relevés sampled.

The tree layer was co-dominated by *Pinus edulis*, with 4-68% absolute cover (average 27%), and *Juniperus osteosperma*, with 0-51% absolute cover (average 15%). DBH ranged in *Pinus edulis* from 4-24 in (10-62 cm) (average 7 in/18 cm) and in *Juniperus osteosperma* from 4-24 in (11-62 cm) (average 9 in/22 cm). The shrub layer was not dominated by a single species. *Bouteloua gracilis* always occurred within the herbaceous layer; however, it does not always occur as the dominant understory species. *Bouteloua gracilis* is an indicator species within this association and ranges in absolute cover of 1-23% (average 8%).

Globally

This plant association is characterized by an open to moderately dense tree canopy (10-65% cover) co-dominated by *Pinus edulis* and *Juniperus osteosperma*. *Pinus edulis* may be present with relatively small cover in some stands. *Juniperus deppeana* may replace *Juniperus osteosperma* in southern stands. Other species of *Juniperus* such as *J. scopulorum* may be present in higher elevation stands. Shrub cover is sparse (<10% cover). If *Quercus gambelii* is present, it has less than 5% cover. Other associated shrubs may be present such as scattered *Brickellia californica, Cercocarpus montanus, Ericameria nauseosa, Eriogonum corymbosum, Fallugia paradoxa, Gutierrezia sarothrae, Opuntia* spp., *Purshia stansburiana, Rhus trilobata, Ribes cereum* or *Yucca* spp. The herbaceous layer is typically moderately dense and is dominated by the warm-season, perennial short grass, *Bouteloua gracilis*. Associated graminoids include *Aristida* spp., *Achnatherum hymenoides (= Oryzopsis hymenoides), Bouteloua curtipendula, Elymus elymoides, Koeleria macrantha, Hesperostipa comata (= Stipa comata), H. neomexicana (= Stipa neomexicana),* and *Pleuraphis jamesii (= Hilaria jamesii). Muhlenbergia montana* is absent or scarce (<1% cover). Forb cover is typically low, but may be moderately diverse. Species such as *Artemisia dracunculus, Eriogonum* spp., and *Oxytropis lambertii* are common.

CONSERVATION RANK G5

DATABASE CODE CEGL000778

MAP CLASSES

The association Two-needle Pinyon – (Utah Juniper) Blue Grama Woodland is represented by map class Pinyon Pine – Utah Juniper / Blue Grama Woodland (map code 11) and map class Limestone Rim Complex (map code 9), where it occurs on limestone rims.

The association was mapped as part of the map class Pinyon Pine – Utah Juniper / Blue Grama Woodland and includes stands that are dominated solely by *Juniperus osteosperma*, represented by the Utah Juniper Woodland Alliance. This map class was mapped as occurring throughout the eastern half of the project boundary. It was also mapped as occurring on Anderson Mesa within USDA-FS lands. The total area mapped within Walnut Canyon NM is 1,042 ac (422 ha) within 35 polygons and the total area in the park environs is 4,253 ac (1,721 ha) within 90 polygons. This association was also mapped as part of the mosaic of shrubland and woodland associations represented by the map class Limestone Rim Complex. The following shrubland and woodland associations were combined: *Chamaebatiaria millefolium* - (*Mahonia fremontii*) – *Yucca baccata* Limestone Terrace Shrubland

[provisional], *Pinus edulis – (Juniperus* spp.*) / Cercocarpus montanus* Woodland, *Pinus edulis – (Juniperus osteosperma) / Bouteloua gracilis* Woodland, and *Pinus edulis / Purshia stansburiana* Woodland. The total area mapped within Walnut Canyon NM is 591 ac (239 ha) within 34 polygons and the total area in the park environs is 358 ac (145 ha) within 32 polygons.

COMMENTS

Walnut Canyon National Monument

Two-needle Pinyon - Utah Juniper / Blue Grama Woodland association may be dominated by herbaceous species other than *Bouteloua gracilis*. The presence of *Bouteloua gracilis* is an indicator for this association, as currently classified. Further sampling on the Colorado Plateau is needed to determine if *Bouteloua gracilis* is a consistent indicator for this association.

Globally

The two *Pinus edulis / Bouteloua gracilis* plant associations are treated as phases in Stuever and Hayden (1997a). In the NVCS we are including stands with southern Great Plains, Chihuahua Desert floristic affinities in the *Pinus edulis – (Juniperus monosperma) / Bouteloua gracilis* Woodland (CEGL002151) and stands with the Colorado Plateau and Great Basin floristic affinities in the *Pinus edulis – (Juniperus osteosperma) / Bouteloua gracilis* Woodland (CEGL000778). Both of these associations may include stands codominated by *Juniperus deppeana* in their southern extent. Stuever and Hayden (1997a) also described *Juniperus deppeana* phase (recognized by its dominance in the stand) and hillslope phase, which occurs on slopes > 15% and may have low cover of grasses (<5% cover). More survey is needed to fully understands the distribution and ecological relationships between these 3 species of *Juniperus* and *Pinus edulis*.

DYNAMICS

Globally

Pinus edulis is extremely drought-tolerant and slow-growing (Powell 1988, Little 1987, Muldavin et al. 1998). It is also non-sprouting and may be killed by fire (Wright et al. 1979). The effect of a fire on a stand is largely dependent on the tree height and density, fine fuel load on the ground, weather conditions, and season (Wright et al. 1979, Dwyer and Pieper 1967). Trees are more vulnerable in open stands where fires frequently occurs in the spring, the relative humidity is low, wind speeds are over 10-20 mph, and there is adequate fine fuels to carry fire (Wright et al. 1979). Under other conditions, burns tend to be spotty with low tree mortality. Large trees are generally not killed unless fine fuels, such as tumbleweeds, have accumulated beneath the tree to provide ladder fuels for the fire to reach the crown (Jameson 1962). Closed-canopy stands rarely burn because they typically do not have enough understory or wind to carry a fire (Wright et al. 1979).

Altered fire regimes, cutting trees for fencing, and improper grazing by livestock have significant impacts on the quality of sites. Grazing by livestock can modify the fire regime by removing the fine fuels that carry fire. Fire, livestock grazing, and trampling by recreationalists and vehicles disturb cryptogamic soil crusts that help maintain soil structure, reduce soil erosion, provide habitat for plants and preserve biological diversity (Ladyman and Muldavin 1996). More study is needed to understand and manage these woodlands ecologically.

REFERENCES

Bourgeron and Engelking 1994, Dick-Peddie 1986, Driscoll et. al. 1984, Dwyer and Pieper 1967, Hansen et. al. 2003, Jameson 1962, Kennedy 1983, Ladyman and Muldavin 1996, Larsen and Moir 1987, Moir and Carleton 1987, Muldavin et. al. 1998, Powell 1988, Stuever and Hayden 1997a, U.S. Forest Service 1982, Western Ecology Working Group of NatureServe, Wright et. al. 1979, Wright et. al. 1973

Note:

This association is found in two different map classes:

1) Pinyon Pine – Utah Juniper / Blue Grama Woodland
2) Limestone Rim Complex

Pinus edulis - *(Juniperus* spp.*) / Cercocarpus montanus* Woodland

MAP CLASS	Limestone Rim Complex
COMMON NAME	Two-needle Pinyon Pine - (Juniper species) / Mountain Mahogany Woodland
PHYSIOGNOMIC CLASS	Woodland (II.)
PHYSIOGNOMIC SUBCLASS	Evergreen woodland (II.A.)
PHYSIOGNOMIC GROUP	Temperate or subpolar needle-leaved evergreen woodland (II.A.4)
PHYSIOGNOMIC SUBGROUP	Natural/Semi-natural (II.A.4.N)
FORMATION	Rounded-crowned temperate or subpolar needle-leaved evergreen forest (II.A.4.N.a)
ALLIANCE	*Pinus edulis* – (*Juniperus* spp.*)* Woodland Alliance

CLASSIFICATION CONFIDENCE LEVEL Moderate

USFS WETLAND SYSTEM Upland

RANGE

Walnut Canyon National Monument

Two-needle Pinyon Pine - (Utah Juniper) / Mountain Mahogany Woodland occurs as a member of a complex of vegetation associations along limestone canyon rim of Walnut Canyon and its side canyons. This association was identified in our relevé data from the northeast rim on the limestone canyon rim in Walnut Canyon NM.

Globally

This widespread woodland association is found from southern Colorado and north-central New Mexico to the Mogollon Rim of Arizona, north across the Colorado Plateau into western Colorado and adjacent Utah.

ENVIRONMENTAL DESCRIPTION

Walnut Canyon National Monument

Only one relevé was sampled for this association. It occurred at the top of a limestone canyon rim in Walnut Canyon at an elevation of 6,463 ft (1,970 m) and with a steep slope of 55%.

Globally

This broadly defined woodland association is common on the Colorado Plateau, occurring on dry foothills and mesas from north-central New Mexico and southern Colorado west to the Mogollon Rim of Arizona, and in extreme northwestern Colorado and adjacent Utah. Elevations range from 6,004-8,005 ft (1830-2440 m). Stands occur on gentle to moderately steep slopes on all aspects. The soils are variable, but generally shallow, poorly developed and skeletal, ranging from clayey marl to sandy loam. Rock outcrop and bare soil are common. Parent materials include sandstone and shale.

MOST ABUNDANT SPECIES

Walnut Canyon National Monument

Stratum	Species
Tree canopy	*Pinus edulis, Juniperus osteosperma*
Shrub	*Cercocarpus montanus*

Globally

Stratum	Species
Tree canopy	*Pinus edulis, Juniperus osteosperma, Juniperus monosperma, Juniperus deppeana, Juniperus scopulorum*
Shrub	*Cercocarpus montanus*

ASSOCIATED SPECIES

Walnut Canyon National Monument
Artemisia ludoviciana, Bouteloua gracilis, Cercocarpus montana, Chamaebatiaria millefolium, Eriogonum jonesii, Gutierrezia sarothrae, Heterotheca villosa, Juniperus osteosperma, Mahonia repens, Rhus trilobata, Symphoricarpos rotundifolius, Yucca baccata (all occur with >1% cover)

Globally
Achnatherum hymenoides, Amelanchier utahensis, Andropogon gerardii, Bouteloua curtipendula, Bouteloua gracilis, Bouteloua hirsuta, Carex rossii, Ephedra viridis, Fendlera rupicola, Garrya ovata, Gutierrezia sarothrae, Hesperostipa comata, Koeleria macrantha, Leymus salinus, Mahonia spp., *Muhlenbergia pauciflora, Nolina microcarpa, Pascopyrum smithii, Pleuraphis jamesii, Poa fendleriana, Pseudoroegneria spicata, Quercus gambelii,Quercus grisea, Rhus trilobata, Schizachyrium scoparium*

VEGETATION DESCRIPTION
Walnut Canyon National Monument
Two-needle Pinyon Pine - (Utah Juniper) / Mountain Mahogany Vegetation total vegetation cover was 40% with 23% absolute cover in the tree layer, 12% in the shrub layer, and 12% in the herbaceous layer. Only one relevé was sampled with a total species diversity of 28 species.

The tree layer was dominated by *Pinus edulis* with 19% absolute cover. DBH ranged from 5-15 in (12-38 cm) (average 6 in/16 cm). The shrub layer was dominated by *Cercocarpus montanus* with absolute cover of 10%. The herbaceous layer was dominated by *Bouteloua gracilis* with absolute cover of 4%.

Globally
This association is characterized by an open to moderately dense tree canopy (10-60% cover) codominated by *Pinus edulis* and *Juniperus* spp. The species of *Juniperus* varies with geography and elevation. *Juniperus monosperma* is common in north-central New Mexico and southern Colorado. *Juniperus deppeana* is common in southern New Mexico, and *Juniperus osteosperma* is common from northwestern New Mexico west into Arizona and north into western Colorado and Utah. *Juniperus scopulorum* is more common in higher elevation stands. *Cercocarpus montanus* dominates the moderately dense short-shrub layer (>25% cover). Other shrubs may be present including *Amelanchier* spp., *Ephedra viridis, Gutierrezia sarothrae, Fendlera rupicola, Garrya ovata, Mahonia* spp., *Nolina microcarpa, Quercus gambelii, Quercus grisea, Rhus trilobata*, or species of *Yucca* and *Opuntia*. Herbaceous cover is variable, ranging from sparse to moderately dense, and generally dominated by graminoids (>5% cover) with scattered forbs. Associated graminoids include *Achnatherum hymenoides (= Oryzopsis hymenoides), Andropogon gerardii, Bouteloua curtipendula, Bouteloua gracilis, Bouteloua hirsuta, Carex rossii, Leymus salinus (= Elymus salinus), Hesperostipa comata, Koeleria macrantha, Muhlenbergia pauciflora, Pascopyrum smithii, Pleuraphis jamesii, Poa fendleriana, Pseudoroegneria spicata*, and *Schizachyrium scoparium*. Common forbs include species of *Cryptantha, Eriogonum, Penstemon* and *Phlox*.

CONSERVATION RANK G5

DATABASE CODE CEGL000780

MAP CLASSES
Two-needle Pinyon Pine - (Juniper species) / Mountain Mahogany Woodland is represented within map class Limestone Rim Complex (map code 9).

This association was mapped as part of the mosaic of shrubland and woodland associations represented by Limestone Rim Complex. The following shrubland and woodland associations were combined: *Chamaebatiaria millefolium* - (*Mahonia fremontii*) – *Yucca baccata* Limestone Terrace Shrubland [provisional], *Pinus edulis – (Juniperus* spp.*) / Cercocarpus montanus* Woodland, *Pinus edulis – (Juniperus osteosperma) / Bouteloua gracilis* Woodland, and *Pinus edulis / Purshia stansburiana* Woodland. The total area mapped within Walnut Canyon NM is 591 ac (239 ha) within 34 polygons and the total area in the park environs is 358 ac (145 ha) within 32 polygons.

DYNAMICS

Globally

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

REFERENCES

Baker 1983, Baker 1984, Baker and Kennedy 1985, Bourgeron and Engelking 1994, Bradley et al. 1992, Driscoll et al. 1984, Erdman 1962, Erdman 1969, Hess and Wasser 1982, Isaacson 1967, Johnston 1987, Kennedy 1983, Larsen and Moir 1987, Marr et al. 1979, Moir 1963, Moir and Carleton 1987, Moir and Ludwig 1979, Pase and Lindenmuth 1971, Stuever and Hayden 1997a, USFS 1981a, USFS 1981b, USFS 1983a, USFS 1985c, USFS 1985d, USFS 1985e, Vories 1974, Wright et al. 1979

Pinus edulis - (Juniperus osteosperma) / Purshia stansburiana Woodland

MAP CLASS	Limestone Rim Complex
COMMON NAME	Two-needle Pinyon Pine - (Utah Juniper) / Cliffrose Woodland
PHYSIOGNOMIC CLASS	Woodland (II.)
PHYSIOGNOMIC SUBCLASS	Evergreen woodland (II.A.)
PHYSIOGNOMIC GROUP	Temperate or subpolar needle-leaved evergreen woodland (II.A.4)
PHYSIOGNOMIC SUBGROUP	Natural/Semi-natural (II.A.4.N)
FORMATION	Rounded-crowned temperate or subpolar needle-leaved evergreen woodland (II.A.4.N.a)
ALLIANCE	*Pinus edulis* – (*Juniperus* spp.*)* Woodland Alliance

CLASSIFICATION CONFIDENCE LEVEL Strong

USFS WETLAND SYSTEM Upland

RANGE
Walnut Canyon National Monument
Two-needle Pinyon Pine - (Utah Juniper) / Cliffrose Woodland occurs as a member of a complex of vegetation associations along the limestone canyon rim of Walnut Canyon and its side canyons. This association was identified from the southeastern end of Walnut Canyon NM on the limestone canyon rim.

Globally
This woodland association occurs from central Arizona, western New Mexico, southwestern Colorado, and southern Utah.

ENVIRONMENTAL DESCRIPTION
Walnut Canyon National Monument
Only one relevé was sampled for this association. It occurred on the limestone canyon rim of Walnut Canyon at an elevation of 6,332ft (1,930 m) and with a steep slope of 50%.

Globally
This woodland occurs on the Colorado Plateau south to central Arizona. It occurs on dry hillslopes and mesas. Elevations range from 5,988-6,808 ft (1,825-2,075 m). Stands occur on gentle to moderately steep slopes on all aspects. The soils are generally shallow, calcareous and rocky, ranging from sand to sandy loam in texture. Rock outcrop and bare soil are common. Parent materials include sandstone and shale.

MOST ABUNDANT SPECIES
Walnut Canyon National Monument

Stratum	Species
Tree canopy	*Pinus edulis, Juniperus osteosperma*
Shrub	*Purshia stansburiana*

Globally

Stratum	Species
Tree canopy	*Pinus edulis, Juniperus osteosperma*
Shrub	*Purshia stansburiana, Artemisia tridentata*

ASSOCIATED SPECIES
Walnut Canyon National Monument
Arenaria eastwoodiae, Gutierrezia sarothrae, Poa fendleriana, Purshia stansburiana, Rhus trilobata (all occur with >1% cover)

Globally
Achnatherum hymenoides, Artemisia frigida, Artemisia ludoviciana, Amelanchier utahensis, Arctostaphylos patula, Bouteloua curtipendula, Bouteloua gracilis, Bouteloua hirsuta, Calliandra humilis, Chamaebatiaria millefolium, Elymus elymoides, Ephedra viridis, Gutierrezia sarothrae, Hesperostipa comata, Hesperostipa neomexicana, Koeleria macrantha, Mahonia trifoliolata, Penstemon linarioides, Poa fendleriana, Polygala alba, Quercus gambelii (<5% cover), *Schizachyrium scoparium*

VEGETATION DESCRIPTION
Walnut Canyon National Monument
Two-needle Pinyon Pine - (Utah Juniper) / Cliffrose Woodland total vegetation cover was 34%, with 30% absolute cover in the tree layer, 9% in the shrub layer, and 6% in the herbaceous layer. Only one relevé was sampled with total species diversity of 17.

Pinus edulis dominated the tree cover with 23% absolute cover; DBH ranged from 4-17 in (10-43cm) (average 9 in/24 cm). The shrub layer was dominated by *Purshia stansburiana* with absolute cover of 6%. The herbaceous layer was sparse.

Globally
This association is characterized by an open to moderately dense tree canopy (10-60% cover) codominated by *Pinus edulis* and *Juniperus osteosperma*. *Purshia stansburiana* dominates or codominates the sparse to moderately dense short-shrub layer, often with *Artemisia tridentata* in the northern part of its range. *Cercocarpus montanus* and *Purshia tridentata* are scarce or absent. Other shrubs may be present including *Amelanchier utahensis, Arctostaphylos patula, Artemisia tridentata, Chamaebatiaria millefolium, Ephedra viridis, Gutierrezia sarothrae, Mahonia trifoliolata, Quercus gambelii* (<5% cover), or species of *Yucca* and *Opuntia*. Herbaceous cover is variable, ranging from sparse to moderately dense, but generally dominated by graminoids (>5% cover) with scattered forbs. Associated graminoids include *Achnatherum hymenoides (= Oryzopsis hymenoides), Bouteloua curtipendula, Bouteloua gracilis, Bouteloua hirsuta, Elymus elymoides, Hesperostipa comata, Hesperostipa neomexicana, Koeleria macrantha, Poa fendleriana,* and *Schizachyrium scoparium*. Forbs may include *Artemisia ludoviciana, Artemisia frigida, Calliandra humilis, Penstemon linarioides*, and *Polygala alba*.

CONSERVATION RANK G4?

DATABASE CODE CEGL000782

MAP CLASSES
Two-needle Pinyon Pine - (Utah Juniper) / Cliffrose Woodland is represented within map class Limestone Rim Complex (map code 9).

This association is mapped as part of the mosaic of shrubland and woodland associations occurring within the Limestone Rim Complex. The following shrubland and woodland associations were combined: *Chamaebatiaria millefolium* - (*Mahonia fremontii*) – *Yucca baccata* Limestone Terrace Shrubland [provisional], *Pinus edulis – (Juniperus* spp.*) / Cercocarpus montanus* Woodland, *Pinus edulis – (Juniperus osteosperma) / Bouteloua gracilis* Woodland*, and Pinus edulis / Purshia stansburiana* Woodland*.* The total area of the complex mapped within Walnut Canyon NM is 591 ac (239 ha) within 34 polygons and the total area in the park environs is 358 ac (145 ha) within 32 map classes.

COMMENTS
Globally
Pinus edulis / Purshia mexicana Woodland was changed to *Pinus edulis / Purshia stansburiana* Woodland (CEGL000782) on 2001-09-04 because of a taxonomic change of the nominal species. *Purshia mexicana* var. *stansburiana* (Torr.) Welsh is now recognized as *Purshia stansburiana* (Torr.) Henrickson (Kartesz 1999). *Purshia mexicana* (D. Don) Henrickson, a closely related species, occurs in Chihuahua, Durango and Zacatecas, Mexico, and possibly extreme southern Arizona, and is not known to be present in this association (Cronquist et al. 1997).

DYNAMICS

Globally

Stuever and Hayden (1997a) described two phases of this plant community, an *Artemisia tridentata* phase and a *Purshia stansburiana* phase. Both are restricted geographically with the *Artemisia tridentata* phase common in northern Arizona, southern Utah, northern New Mexico, and southwestern Colorado where winter precipitation is higher than summer, and the *Purshia stansburiana* phase, which lacks *Artemisia tridentata*, occurs in central Arizona where summer monsoon precipitation is higher than winter precipitation (Stuever and Hayden 1997a). Fires in this association are thought to be infrequent because *Pinus edulis*, *Juniperus osteosperma*, and *Juniperus monosperma* are killed or severely damaged by burns and do not resprout (Wright et al. 1979). *Purshia stansburiana* is also generally killed by fire; however, it is known to resprout after cool burns (Britton and Wright 1983, Wright et al. 1979).

REFERENCES

BIA 1979, Baker 1980a, Baker 1984a, Bourgeron and Engelking 1994, Britton and Wright 1983, Cronquist et al. 1997, Driscoll et al. 1984, Isaacson 1967, Kartesz 1999, Larson and Moir 1987, Moir and Carleton 1987, Northcutt 1978, Stuever and Hayden 1997a, USFS 1982, USFS 1985c

Pinus ponderosa / Bouteloua gracilis Woodland

MAP CLASS	Ponderosa Pine / Mixed Graminoid Woodland Complex
COMMON NAME	Ponderosa Pine / Blue Grama Woodland
PHYSIOGNOMIC CLASS	Woodland (II.)
PHYSIOGNOMIC SUBCLASS	Evergreen woodland (II.A.)
PHYSIOGNOMIC GROUP	Temperate or subpolar needle-leaved evergreen woodland (II.A.4.)
PHYSIOGNOMIC SUBGROUP	Natural/Semi-natural (II.A.4.N.)
FORMATION	Rounded-crowned temperate or subpolar needle-leaved evergreen woodland (II.A.4.N.a.)
ALLIANCE	*Pinus ponderosa* Woodland Alliance

CLASSIFICATION CONFIDENCE LEVEL Strong

USFS WETLAND SYSTEM Upland

RANGE

Walnut Canyon National Monument

Ponderosa Pine / Blue Grama Woodland occurs mainly in the non-canyon upland environments within the project boundary. Our two relevés were located on USDA-FS land in Cherry Canyon and in the northwestern section of the project boundary.

Globally

Ponderosa Pine / Blue Grama Woodland occurs in the southern Rocky Mountains, extending east on southern Great Plains escarpments as far as Oklahoma, south to the mountains of West Texas, west to the Colorado Plateau and Mogollon Rim of New Mexico, Arizona, and southern Utah.

ENVIRONMENTAL DESCRIPTION

Walnut Canyon National Monument

This association occurred between 2045-2065m (average 2,055m). It occurred on flatter areas, with 1-6% slope (average 4%).

Globally

This widespread woodland occurs at foothill and lower montane elevations from the southern Rocky Mountains, extending east on southern Great Plains escarpments, south to the mountains of West Texas, west to the Colorado Plateau and Mogollon Rim of New Mexico, Arizona and Utah. Elevation ranges from 1,740-2,610 m (5,700-8,550 ft). Sites occur on dry, gentle to steep slopes on all aspects, but are more common on southern and western aspects, especially at higher elevations. Substrates are quite variable and include shallow sandy loam soils derived from granitic parent materials, coarse cinder soils and clayey soil with or without high coarse fragment content

MOST ABUNDANT SPECIES

Walnut Canyon National Monument

Stratum	Species
Tree canopy	*Pinus ponderosa*
Herbaceous	*Bouteloua gracilis*

Globally

Stratum	Species
Tree canopy	*Pinus ponderosa Pinus edulis, Juniperus monosperma, Juniperus osteosperma, Juniperus deppeana, Juniperus scopulorum*
Herbaceous	*Bouteloua gracilis*

ASSOCIATED SPECIES

Walnut Canyon National Monument

Artemisia dracunculus, Elymus elymoides, Ericameria nauseosa, Festuca arizonica, Gutierrezia sarothrae, Heliomeris multiflora, Pinus edulis, Juniperus osteosperma, Juniperus scopulorum, Rhus trilobata, Sphaeralcea sp. (all occur with >1% cover)

Globally

Artemisia ludoviciana, Bouteloua hirsuta, Carex geophila, Chaetopappa ericoides, Elymus elymoides, Erigeron spp., *Eriogonum racemosa, Hesperostipa comata, Koeleria macrantha, Muhlenbergia montana, Packera neomexicana, Poa fendleriana, Schizachyrium scoparium*

VEGETATION DESCRIPTION

Walnut Canyon National Monument

Two relevés were sampled in the Ponderosa Pine / Blue Grama Woodland with total cover of 50 and 55%. Absolute cover for the tree layer was 15 and 40%, 3 and 4% in the shrub layer, and 15 and 48% in the herbaceous layer. The total species diversity was 15 and 23 species.

Pinus ponderosa dominated the tree layer with 13 and 41% absolute cover. DBH measurements ranged from 5-52 in (12-130 cm) (average 14 in/35 cm). The shrub layer was sparse. *Bouteloua gracilis* dominated the herbaceous layer with 12 and 40% cover.

Globally

This plant association is characterized by an open to moderately dense, evergreen, needleleaf tree canopy 33-98 ft (10-30 m) tall that is either dominated by *Pinus ponderosa* or codominated by *P. ponderosa* and *P. edulis*. *Juniperus monosperma, J. osteosperma, J. deppeana* or *J. scopulorum* may be important subdominants. The typically moderately dense herbaceous layer has greater cover than the shrub layer, and is dominated by graminoids. *Bouteloua gracilis*, the warm-season, sod-forming, shortgrass dominates the herbaceous layer. Common graminoid associates include *Aristida* spp., *Bouteloua hirsuta, Carex geophila, Elymus elymoides, Hesperostipa comata, Koeleria macrantha, Muhlenbergia montana, Poa fendleriana,* or *Schizachyrium scoparium*. *Quercus gambelii* may be present in the sparse shrub layer (<10% cover) with low cover (<5%). Other shrubs may include scattered *Artemisia tridentata, Ceanothus fendleri, Cercocarpus montanus, Chrysothamnus viscidiflorus, Ericameria nauseosa, Fallugia paradoxa, Purshia tridentata, Quercus grisea, Rhus trilobata,* and *Tetradymia canescens.* Forb cover is typially sparse and may include species such as *Antennaria* spp., *Artemisia ludoviciana, Erigeron* spp., *Eriogonum racemosa,Chaetopappa ericoides, Packera neomexicana,* and *Penstemon* spp.

CONSERVATION RANK G4

DATABASE CODE CEGL000848

MAP CLASSES

The association Ponderosa Pine / Blue Grama Woodland is represented by map class Ponderosa Pine / Mixed Graminoid Complex (map code 15).

It was mapped both on the north and south side of Walnut Canyon, mostly within Forest Service lands on the eastern section of the project boundary. Due to the difficulty in distinguishing understory grasses in photointerpretation the two associations (*Pinus ponderosa / Muhlenbergia montana* Woodland, *Pinus ponderosa / Bouteloua gracilis* Woodland) were mapped as a single map class, the Ponderosa Pine / Mixed Graminoid Woodland. The total area of Ponderosa Pine / Mixed Graminoid Woodland within Walnut Canyon NM is 741 ac (300 ha) within 30 polygons and the total area in the park environs is 4,999 ac (2,023 ha) within 40 polygons.

COMMENTS

Globally

This ponderosa pine woodland is a broadly defined plant association. Stuever and Hayden (1997b) report 6 phases: the *Bouteloua gracilis, Schizachyrium scoparium, Andropogon hallii, Artemisia tridentata, Quercus grisea,* and *Q. gambelii* phases. Hanks et al. (1983) described 4 phases of the *Pinus ponderosa / Bouteloua gracilis* Habitat Type from northern Arizona. More classification review is needed to further define the relationships between these

phases and other similar plant associations. Alexander et al. (1987), DeVelice et al. (1986), and Muldavin et al. (1996) also described phases of this habitat type that need further review and cross-walking to NVCS. Youngblood and Mauk (1985) included stands of this association in their broadly defined *Pinus ponderosa / Muhlenbergia montana* Habitat Type.

DYNAMICS

Globally

Both diagnostic species are tolerant of ground fire. *Pinus ponderosa* develops thick fire-resistant bark that protects it from ground fires (Bradley et al. 1992). *Bouteloua gracilis* resprouts after burning and is unharmed by fires in years with above normal winter and spring precipitation, but can be severely damaged during drought years (Wright and Bailey 1980). Most *Pinus ponderosa* stands have relatively frequent fires (every 3-20 years), but fires are less frequent in dry, rocky stands where ground fire is limited by lack of continuous fine fuels (Stuever and Hayden 1997b). Fire-return interval has generally increased because of active fire suppression and historic livestock grazing, which has reduced the fine-fuels needed to carry ground fires (Madany and West 1980, Savage and Swetnam 1990). Absence of fire has led to large acculmulations of ground fuel and has likely resulted in denser stands and establishmen of less fire-adapted, shade tolerant species species such as *Pseudotsuga menziesii*. This has likely increased risk of severe, stand replacing crown fires.

REFERENCES

Alexander et al. 1987, Bradley et al. 1992, Bourgeron and Engelking 1994, DeVelice et al. 1986, Diamond 1993, Driscoll et al. 1984, Fitzhugh et al. 1987, Francis 1986, Hanks et al. 1983, Hoagland 1997, Johnston 1987, Larson and Moir 1987, Madany and West 1980, Stuever and Hayden 1997b, Youngblood and Mauk 1985, Savage and Swetnam 1990. Wright and Bailey 1980

Pinus ponderosa – (Pinus edulis – Juniperus osteosperma) / Bouteloua gracilis Woodland

MAP CLASS	Ponderosa Pine - Pinyon Pine – Juniper / Blue Grama Woodland
COMMON NAME	Ponderosa Pine (Pinyon Pine – Utah Juniper) / Blue Grama Woodland
PHYSIOGNOMIC CLASS	Woodland (II.)
PHYSIOGNOMIC SUBCLASS	Evergreen woodland (II.A.)
PHYSIOGNOMIC GROUP	Temperate or subpolar needle-leaved evergreen woodland (II.A.4.)
PHYSIOGNOMIC SUBGROUP	Natural/Semi-natural (II.A.4.N.)
FORMATION	Rounded-crowned temperate or subpolar needle-leaved evergreen woodland (II.A.4.N.a.)
ALLIANCE	*Pinus ponderosa* Woodland Alliance

CLASSIFICATION CONFIDENCE LEVEL This association is a variation of the association *Pinus ponderosa / Bouteloua gracilis* Woodland. It is not designated a new association, but a variation of the association *Pinus ponderosa / Bouteloua gracilis* Woodland that has a strong classification confidence level.

USFS WETLAND SYSTEM Upland

RANGE
Walnut Canyon National Monument
Ponderosa Pine (Pinyon Pine–Utah Juniper) / Blue Grama Woodland is one of the most common associations within the central section of the project boundary. It is the dominant association in the central section of the project boundary and occurs mainly in the upland environment. All of our relevé data were identified from south of Walnut Canyon in USDA-FS lands mainly from the central portion of the project boundary.

ENVIRONMENTAL DESCRIPTION
Walnut Canyon National Monument
The elevation of this association ranged from 2010-2075m (average 2,045m). The slope varied from flat areas to hill slopes ranging from 0-25% (average 10%).

MOST ABUNDANT SPECIES
Walnut Canyon National Monument

Stratum	Species
Tree canopy	*Pinus ponderosa, Pinus edulis, Juniperus osteosperma*
Herbaceous	*Bouteloua gracilis*

ASSOCIATED SPECIES
Walnut Canyon National Monument
Festuca arizonica, Gutierrezia sarothrae, Heterotheca villosa, Juniperus scopulorum, Purshia mexicana, Quercus gambelii (all occur with >5% cover)

VEGETATION DESCRIPTION
Walnut Canyon National Monument
Ponderosa Pine (Pinyon Pine – Utah Juniper) / Blue Grama Woodland total vegetation cover ranged from 44-80% (average 58%) with 23-52% absolute cover (average 39%) in the tree layer, 2-18% (average 8%) in the shrub layer, and 17-35% (average 23%) in the herbaceous layer. The total species diversity ranged from 18-31 (average 25) in the 8 relevés sampled.

The tree layer was co-dominated by *Pinus ponderosa* with 8-26% absolute cover (average 15%), *Pinus edulis* with 9-30% cover (average 17%), and *Juniperus osteosperma* with 4-16% cover (average 8%). The DBH for *Pinus ponderosa* was 4-28 in (11-71 cm) (average 10in/26 cm), *Pinus edulis* was 4-16 in (11-41 cm) (average 7 in/19 cm), and *Juniperus osteosperma* was 4-28 in (11-71 cm) (average 9 in/23 cm). A single shrub type did not dominate the shrub layer. The herbaceous layer was dominated by *Bouteloua gracilis* with 9-20% cover (average 15%).

CONSERVATION RANK G4

DATABASE CODE CEGL000848

MAP CLASSES
The association Ponderosa Pine (Pinyon Pine – Utah Juniper) / Blue Grama Woodland is represented by map class Ponderosa Pine - Pinyon Pine - Juniper / Blue Grama Woodland (map code 12).

Ponderosa Pine - Pinyon Pine - Juniper / Blue Grama Woodland was mapped both on the north and south side of Walnut Canyon, mostly within USDA-FS lands on the central and eastern section of the project boundary. The total area of Ponderosa Pine - Pinyon Pine - Juniper / Blue Grama Woodland within Walnut Canyon NM is 373 ac (151 ha) within 43 polygons and the total area in the park environs is 1,732 ac (701 ha) within 98 polygons.

COMMENTS
Walnut Canyon National Monument
This association has a co-dominance of Ponderosa Pine, Pinyon Pine, and Utah Juniper. Previous classifications (Ponderosa Pine Series, Pinyon Pine Series, Juniper Woodlands) have defined vegetation with this co-dominance as occurring in Ponderosa Pine, Pinyon Pine, or Utah Juniper dominated types (Stuever and Hayden 1997b). However, our observations suggest that a new association should be defined based on the co-dominance of all three conifers occurring over a large area within Walnut Canyon NM and in its environs. Currently, this type is treated in the NVCS as the *Pinus edulis* phase of the *Pinus Ponderosa* / *Bouteloua gracilis* Woodland (CEGL000848) (see Stuever and Hayden 1997b).

REFERENCES
Stuever and Hayden 1997b

Pinus ponderosa / Muhlenbergia montana Woodland

MAP CLASS	Ponderosa Pine / Mixed Graminoid Complex
COMMON NAME	Ponderosa Pine / Mountain Muhly Woodland
PHYSIOGNOMIC CLASS	Woodland (II.)
PHYSIOGNOMIC SUBCLASS	Evergreen woodland (II.A.)
PHYSIOGNOMIC GROUP	Temperate or subpolar needle-leaved evergreen woodland (II.A.4.)
PHYSIOGNOMIC SUBGROUP	Natural/Semi-natural (II.A.4.N.)
FORMATION	Rounded-crowned temperate or subpolar needle-leaved evergreen woodland (II.A.4.N.a.)
ALLIANCE	*Pinus ponderosa* Woodland Alliance

CLASSIFICATION CONFIDENCE LEVEL Strong

USFS WETLAND SYSTEM Upland

RANGE

Walnut Canyon National Monument

Ponderosa Pine / Mountain Muhly Woodland was found only in non-canyon environments within the project boundary. This association's relevés were only identified in the western half of the project boundary, mainly at higher elevations north of Walnut Canyon on USDA-FS and Arizona State lands.

Globally

This widespread woodland occurs at foothill and lower montane elevations in the southern Rocky Mountains, extending south to the mountains of West Texas, and west to the Mogollon Rim and Colorado Plateau of New Mexico, Arizona and Utah.

ENVIRONMENTAL DESCRIPTION

Walnut Canyon National Monument

The elevation of this association ranged from 6,791-6,906 ft (2,070-2,105 m) (average 6,890 ft/2,100 m). Topography varied from flat areas to hill slopes 5-35% slope (average 15%).

Globally

This widespread woodland occurs at foothill and lower montane elevations in the southern Rocky Mountains, extending south to the mountains of West Texas, and west to the Mogollon Rim and Colorado Plateau. Elevation ranges from 7,050-9,400 ft (2,150-2,870 m). Stands occur on bottomlands, elevated plains, cinder cones, piedmont slopes, mesas, foothills, and mountains. Sites include gentle to steep slopes on all aspects, but are more common on southern and western aspects, especially at higher elevations. Substrates are variable, but are typically shallow, rocky, coarse-textured soils derived from granitic or cinder parent materials. There is considerable cover of bare soil and exposed bedrock.

MOST ABUNDANT SPECIES

Walnut Canyon National Monument

Stratum	Species
Tree canopy	*Pinus ponderosa*
Herbaceous	*Muhlenbergia montana*

Globally

Stratum	Species
Tree canopy	*Pinus ponderosa*
Herbaceous	*Muhlenbergia montana*

ASSOCIATED SPECIES

Walnut Canyon National Monument

Bouteloua gracilis, Brickellia grandiflora, Festuca arizonica, Juniperus osteosperma, Juniperus scopulorum, Poa fendleriana, Rhus trilobata (all occur with >5% cover)

Globally

Artemisia ludoviciana, Artemisia tridentata, Blepharoneuron tricholepis, Bouteloua gracilis, Brickellia californica, Carex geophila, Carex rossii, Ceanothus fendleri, Cercocarpus montanus, Chaetopappa ericoides, Chrysothamnus viscidiflorus, Elymus elymoides, Ericameria nauseosa, Eriogonum racemosa, Fallugia paradoxa, Juniperus deppeana, Juniperus monosperma, Juniperus osteosperma, Juniperus scopulorum, Koeleria macrantha, Lotus wrightii, Mahonia spp., *Oxytropis lambertii, Packera neomexicanaPinus discolor, Pinus edulis, Poa fendleriana, Purshia tridentata, Quercus grisea, Rhus trilobata, Schizachyrium scoparium, Tetradymia canescens, Yucca baccata*

VEGETATION DESCRIPTION

Walnut Canyon National Monument

Ponderosa Pine / Mountain Muhly Woodland total vegetation cover ranged from 44-80% (average 53%) with 20-55% absolute cover (average 36%) in the tree layer, 1-5% (average 3%) in the shrub layer, and 12-36% (average 23%) in the herbaceous layer. The total species diversity ranged from 17-38 (average 26) in the 7 relevés sampled.

Pinus ponderosa dominated the tree layer with 14-40% absolute cover (average 27%), and DBH of 5-28 in (12-71 cm) (average 13 in/32 cm). The shrub layer was sparse. *Muhlenbergia montana* dominated the herbaceous layer with 5-15% absolute cover (average 10%).

Globally

This association is characterized by an open to moderately dense, evergreen, needleleaf tree canopy to 33-98 ft (10-30 m) tall that is dominated or codominated by *Pinus ponderosa*. Associated tree species vary geographically. *Pinus edulis, Pinus discolor, Juniperus monosperma, J. osteosperma, J. deppeana* and *J.scopulorum* may be important in the tree canopy. *Psudotsuga menziesii, Pinus flexilis*, and *Populus tremuloides* may also be present, but are considered accidental. The typically moderately dense herbaceous layer has greater cover than the shrub layer, and is dominated by graminoids. *Muhlenbergia montana*, a warm-season, medium-tall perennial typically dominates the herbaceous layer and is diagnostic of this association. Common graminoid associates include *Aristida* spp., *Blepharoneuron tricholepis, Bouteloua gracilis, Carex geophila, C. rossii, Elymus elymoides, Koeleria macrantha, Poa fendleriana* and *Schizachyrium scoparium*. *Festuca arizonica, Muhlenbergia virescens, M. dubia, M. emersleyi* and *Hesperostipa* spp. are typically absent. *Quercus gambelii* may be present with low cover (to 5%) in the sparse shrub layer (<10% cover). Other scattered shrubs may inclulde *Artemisia tridentata, Brickellia californica, Ceanothus fendleri, Cercocarpus montanus, Chrysothamnus viscidiflorus, Ericameria nauseosa, Fallugia paradoxa, Mahonia* spp., *Purshia tridentata, Quercus grisea, Rhus trilobata, Tetradymia canescens* or *Yucca baccata*. Forb cover is typially sparse and may include species such as *Antennaria* spp., *Artemisia ludoviciana, Erigeron* spp., *Eriogonum racemosa, Chaetopappa ericoides, Lotus wrightii, Oxytropis lambertii, Packera neomexicana*, and *Penstemon* spp.

CONSERVATION RANK G4G5

DATABASE CODE CEGL000862

MAP CLASSES

The association Ponderosa Pine / Mountain Muhly Woodland is represented by map class Ponderosa Pine / Mixed Graminoid Woodland Complex (map code 15).

Ponderosa Pine / Mixed Graminoid Woodland Complex was mapped both on the north and south side of Walnut Canyon, mainly in non-canyon upland environments. Due to the difficulty in distinguishing understory grasses in photointerpretation the two associations (*Pinus ponderosa / Muhlenbergia montana* Woodland, *Pinus ponderosa / Bouteloua gracilis* Woodland) were mapped as a single map class, the Ponderosa Pine / Mixed Graminoid Woodland Complex. The total area of Ponderosa Pine / Mixed Graminoid Woodland within Walnut Canyon NM is 741 ac (300 ha) within 30 polygons and the total area in the park environs is 4,999 ac (2,023 ha) within 40 polygons.

COMMENTS

Globally

This ponderosa pine woodland is a broadly defined plant association. Stuever and Hayden (1997b) suggested the xeric upland and mesic bottomland stands be put into different phases. Fitzhugh et al. (1987) suggested it be divided into regional phases.

DYNAMICS

Globally

Both diagnostic species are tolerant of ground fire. *Pinus ponderosa* develops thick fire-resistant bark and *Muhlenbergia montana* resprouts after burning, although it may take a few years to recover to pre-burn density (Fischer and Bradley 1987, Bradley et al. 1992). This association had frequent fires (every 3-10 years on average) in pre-settlement times, but fires are less frequent in dry, rocky stands where ground fire is limited by lack of continuous fine fuels (Stuever and Hayden 1997b). Fire-return interval has generally increased because of active fire suppression and historic livestock grazing, which has reduced the fine-fuels needed to carry ground fires (Madany and West 1980, Savage and Swetnam 1990). Absence of fire has led to large acculmulations of ground fuel and has likely resulted in denser stands and invasion of less fire-adapted, shade tolerant species species such as *Pseudotsuga menziesii*. This has likely increased risk of stand replacing crown fires

Improper livestock grazing will favor the more grazing-tolerant species such as *Bouteloua gracilis*, and over time can eliminate *Muhlenbergia montana* and convert the stand into a *Pinus ponderosa* / *Bouteloua gracilis* Woodland (CEGL000848).

REFERENCES

Alexander et al. 1987, Bourgeron and Engelking 1994, Bradley et al. 1992, Costello 1944a, DeVelice 1983, DeVelice and Ludwig 1983, DeVelice et al. 1986, Diamond 1993, Driscoll et al. 1984, Fischer and Bradley 1987, Fitzhugh et al. 1987, Hanks et al. 1983, Hess 1981, Hess and Alexander 1986, Madany and West 1980, Johnston 1987, Larson and Moir 1987, Peet 1981, Savage and Swetnam 1990, Stuever and Hayden 1997b, Terwilliger et al. 1979, Wasser and Hess 1982, Youngblood and Mauk 1985

Pinus ponderosa / Quercus gambelii Woodland

MAP CLASS	Ponderosa Pine / Gambel Oak Woodland, Canyon Floor Complex
COMMON NAME	Ponderosa Pine / Gambel Oak Woodland
PHYSIOGNOMIC CLASS	Woodland (II.)
PHYSIOGNOMIC SUBCLASS	Evergreen woodland (II.A.)
PHYSIOGNOMIC GROUP	Temperate or subpolar needle-leaved evergreen woodland (II.A.4.)
PHYSIOGNOMIC SUBGROUP	Natural/Semi-natural (II.A.4.N.)
FORMATION	Rounded-crowned temperate or subpolar needle-leaved evergreen woodland (II.A.4.N.a.)
ALLIANCE	*Pinus ponderosa* Woodland Alliance

CLASSIFICATION CONFIDENCE LEVEL Strong

USFS WETLAND SYSTEM Upland

RANGE

Walnut Canyon National Monument

Ponderosa Pine / Gambel Oak Woodland is a common association within Walnut Canyon NM and in the environs. It is found, from our relevé data, to occur in riparian habitats as well as in non-canyon environments in the western section of the park. The riparian mesic relevés were located in Walnut Canyon as well as in its side canyons, specifically occurring in Cherry Canyon. The non-canyon relevés were found on the north rim west of the visitor's center and on the south rim west of Anderson Mesa.

Globally

This ponderosa pine woodland association is widespread in the southern Rocky Mountains and southwestern U.S. and occurs in foothills, mountains and plateaus from Colorado to Trans-Pecos, Texas, west to Arizona and Nevada.

ENVIRONMENTAL DESCRIPTION

Walnut Canyon National Monument

This association ranged from 6,430-7,218 ft (1,960-2,200 m) (average 6,791 ft/2,070 m). The topography varied from steep canyon walls to flat areas with 0-80% slope (average 17%).

Globally

This woodland association is widespread and has been reported from foothills, mountains and plateaus from Colorado to Trans-Pecos Texas, west to Arizona and Nevada. Elevation ranges from 1,830-2,800 m (6,000-9,200 ft). Stands often occur along drainages, on lower and middle slopes and benches on all aspects. Slopes are typically gentle or moderate, but may also be steep (>45%). Soils are typically shallow and rocky ranging from sandy loams to clay loams. Parent materials are commonly sandstones, but fractured limestone, basalt, andesite, and alluvium are also reported. High litter cover (70-90%) about 2 in (5 cm) deep is common in many stands. Rock outcrop (about 10%) and some bare soil are not uncommon. This conifer woodland transitions to *Quercus gambelii* Shrubland in drier sites and at lower elevations. This community is the highest elevation *Pinus ponderosa* / *Quercus gambelii* Woodland present in Trans-Pecos, Texas. There, it typically grades downslope to *Pinus ponderosa* / *Quercus hypoleucoides* Woodland (CEGL000872).

MOST ABUNDANT SPECIES

Walnut Canyon National Monument

Stratum	Species
Tree canopy	*Pinus ponderosa*
Tall Shrub	*Quercus gambelii*

Globally

Stratum	Species
Tree canopy	*Pinus ponderosa, Pinus strobiformis*
Tall Shrub	*Quercus gambelii*

ASSOCIATED SPECIES

Walnut Canyon National Monument

Bouteloua curtipendula, Bouteloua gracilis, Elymus elymoides, Juniperus osteosperma, Juniperus scopulorum, Poa fendleriana, Pseudotsuga menziesii, Rosa woodsii, Robinia neomexicana, Symphoricarpos rotundifolius (all occur with >5% cover)

Globally

Amelanchier spp., *Arctostaphylos patula, Artemisia ludoviciana, Artemisia tridentata* ssp. *vaseyana, Balsamorhiza sagittata, Bouteloua gracilis, Carex geyeri, Carex rossii, Cercocarpus montanus, Elymus elymoides, Erigeron* spp., *Eriogonum* spp., *Festuca arizonica, Hymenoxys* spp., *Juniperus communis, Juniperus deppeana, Juniperus osteosperma, Juniperus scopulorum, Koeleria macrantha, Lithosperma multiflorum, Mahonia repens, Muhlenbergia longiligula, Muhlenbergia montana, Packera multilobata, Pinus edulis, Pinus strobiformis, Poa fendleriana, Robinia neomexicana, Rosa woodsii, Schizachyrium scoparium, Shepherdia rotundifolia, Symphoricarpos oreophilus, Wyethia amplexicaulis*

VEGETATION DESCRIPTION

Walnut Canyon National Monument

Ponderosa Pine / Gambel Oak Woodland total cover was 30-90% (average 61%) with 15-78% absolute cover (average 48%) in the tree layer, 1-35% (average 9%) in the shrub layer, and 5-48% (average 17%) in the herbaceous layer. The total species diversity ranged from 20-40 species (average 25) within the 16 relevés sampled.

Pinus ponderosa dominated the tree layer with 13-35% absolute cover (average 25%). DBH ranged from 4-48 in (11-122 cm) (average 13 in/33 cm). *Quercus gambelii* dominated the shrub layer with 3-34% absolute cover (average 13%); DBH ranged from 4-19 in (11-49 cm) (average 7 in/17 cm). The herbaceous layer contained a variety of herbs and grasses.

Globally

This broadly defined coniferous woodland is widespread and is characterized by a sparse to moderately dense, evergreen needleleaf tree canopy dominated by *Pinus ponderosa* or sometimes co-dominated by *Pinus edulis* with scattered *Juniperus scopulorum*, *J. monosperma*, or *J. osteosperma*. In southern stands *Juniperus deppeana* and *Pinus strobiformis* may be present to co-dominant. *Pseudotsuga menziesii* is accidental and *Abies concolor* is not present. *Quercus gambelii* dominates both the subcanopy (tree form, if present) and the typically moderately dense tall-shrub layer, which consists of dense clumps of oak. This community must have at least 5% cover of *Quercus gambelii*, but there is frequently over 25%. At higher elevations, the *Quercus gambelii* are more tree-like and *Symphoricarpos oreophilus* will be present with significant cover in a short-shrub layer. At lower elevations, scattered *Artemisia tridentata* ssp. *vaseyana*, *Pinus edulis*, and *Juniperus osteosperma* are often present. Other common shrub species may include *Arctostaphylos patula*, *Amelanchier* spp., *Cercocarpus montanus*, *Juniperus communis*, *Mahonia repens*, *Robinia neomexicana*, *Rosa woodsii*, and *Shepherdia rotundifolia*. The herbaceous layer is generally sparse (<10% cover), but may equal the shrub cover. It is composed of mostly graminoids such as *Bouteloua gracilis*, *Elymus elymoides*, *Festuca arizonica*, *Koeleria macrantha*, *Muhlenbergia longiligula*, *Muhlenbergia montana*, *Poa fendleriana*, *Schizachyrium scoparium*, and *Carex* spp., especially *Carex geyeri* and *Carex rossii*. Scattered forbs include *Artemisia ludoviciana*, *Balsamorhiza sagittata*, *Eriogonum* spp., *Erigeron* spp., *Hymenoxys* spp., *Lithosperma multiflorum*, *Packera multilobata*, and *Wyethia amplexicaulis*.

CONSERVATION RANK G5

DATABASE CODE CEGL000870

MAP CLASSES

The association Ponderosa Pine / Gambel Oak Woodland is represented by map classes Ponderosa Pine / Gambel Oak Woodland (map code 14) and Canyon Floor Complex (map code 10).

The distinguishing feature between the upland map class Ponderosa Pine / Gambel Oak Woodland and the riparian map class Canyon Floor Complex is that the Canyon Floor Complex occurs in more mesic riparian areas. Ponderosa Pine / Gambel Oak Woodland was mapped as occurring in the southwestern half of the project boundary in non-canyon environments and side canyons. The Canyon Floor Complex was mapped as occurring on the canyon

bottom of Walnut Canyon. The total area of Ponderosa Pine / Gambel Oak Woodland within Walnut Canyon NM is 198 ac (80 ha) within 22 polygons and the total area in the park environs is 1,695 ac (686 ha) within 35 polygons. The total area of Canyon Floor Complex within Walnut Canyon NM is 119 ac (48 ha) within 39 polygons and the total area in the park environs is 32 ac (13 ha) within 23 polygons.

COMMENTS

Walnut Canyon National Monument

Due to Walnut Canyon and the adjacent side canyons being narrow, it was difficult to distinguish the occurrence of this association on the aerial photography. Therefore, this association, when it occurs on the canyon bottom, is mapped as part of the Canyon Floor Complex map class.

Globally

This ponderosa pine woodland is a broadly defined plant association. Stuever and Hayden (1997b) report 7 phases for this plant association: the *Quercus gambelii*, *Festuca arizonica*, *Muhlenbergia longiligula*, *Pinus edulis*, *Muhlenbergia montana*, *Bouteloua gracilis*, and *Robinia neomexicana* phases. More classification review is needed to further define the relationships between these phases and other similar plant associations.

DYNAMICS

Globally

Pinus ponderosa is a drought-resistant, shade-intolerant conifer that when mature has thick bark that allows it to withstand ground fires (Bradley et al. 1992). Natural fire frequency is estimated to be 3-20 years for this community (Youngblood and Mauk 1985). *Quercus gambelii* is a fire-adapted species with a well developed root system that draws moisture from a large volume of soil, and allows for rapid resprouting after fire (Clary 1992). Both species are well-adapted to relatively frequent ground fires that prevent *Pseudotsuga menziesii* or *Abies concolor* from regenerating.

These woodlands grade into *Abies concolor* / *Quercus gambelii* Forest (CEGL000261) or *Pseudotsuga menziesii* / *Quercus gambelii* Forest (CEGL000452) as sites become cooler and wetter (DeVelice et al. 1986). Mosaics of *Pinus ponderosa* stands with grass- or oak-dominated understories occur in response to different substrates with *Quercus gambelii* dominating the rocky sites and grass understory woodland types (*Festuca* spp., *Muhlenbergia montana*) in areas with deeper soils (DeVelice et al. 1986, Peet 1981).

REFERENCES

Alexander et al. 1984, Alexander et al. 1987, Bader 1932, Blackburn et al. 1969, Bourgeron and Engelking 1994, Bradley et al. 1992, Bunin 1975, Clary 1992, DeVelice et al. 1986, Diamond 1993, Dixon 1935, Donart et al. 1978, Driscoll et al. 1984, Fitzhugh et al. 1987, Hanks et al. 1983, Hanson and Ball 1928, Harmon 1980, Helm 1977, Hess and Wasser 1982, Madany and West 1980, Muldavin et al. 1996, Johnston 1987, Johnston and Hendzel 1985, Larson and Moir 1987, Marr et al. 1973, Muldavin et al. 1996, Peet 1975, Peet 1981, Roberts et al. 1992, Schmoll 1935, Somers et al. 1980, Stuever and Hayden 1997b, Savage and Swetnam 1990, Terwilliger et al. 1979a, USFS 1983b, Wasser and Hess 1982, Wright et al. 1973, Youngblood and Mauk 1985

Note:

This association is found in two different map classes:

1) Canyon Floor Complex
2) Ponderosa Pine / Gambel Oak Woodland

Pinus ponderosa – (*Pinus edulis–Juniperus osteosperma*) / *Quercus gambelii* Woodland

MAP CLASS	Ponderosa Pine – Pinyon Pine – Juniper / Gambel Oak Woodland
COMMON NAME	Ponderosa Pine (Pinyon Pine–Utah Juniper) Gambel Oak Woodland
PHYSIOGNOMIC CLASS	Woodland (II.)
PHYSIOGNOMIC SUBCLASS	Evergreen woodland (II.A.)
PHYSIOGNOMIC GROUP	Temperate or subpolar needle-leaved evergreen woodland (II.A.4.)
PHYSIOGNOMIC SUBGROUP	Natural/Semi-natural (II.A.4.N.)
FORMATION	Rounded-crowned temperate or subpolar needle-leaved evergreen woodland (II.A.4.N.a.)
ALLIANCE	*Pinus ponderosa* Woodland Alliance

CLASSIFICATION CONFIDENCE LEVEL This association is a variation of the association *Pinus ponderosa / Quercus gambelii* Woodland. It is not designated as an association, but a variation of the association *Pinus ponderosa / Quercus gambelii* Woodland that has a strong confidence classification level.

USFS WETLAND SYSTEM Upland

RANGE
Walnut Canyon National Monument
Ponderosa Pine (Pinyon Pine - Utah Juniper) / Gambel Oak Woodland occurs in small patches in the non-canyon environments of Walnut Canyon and its environs as well as in the more mesic side canyons of Walnut Canyon. It was located from our relevé data to occur only on the south side of Walnut Canyon, specifically on and west of Anderson Mesa.

ENVIRONMENTAL DESCRIPTION
Walnut Canyon National Monument
The elevation of this association ranged from 2050-2150m (average 2110m). Topography varied from flat areas to hill slopes, ranging from 5-30% slope (average 20%).

MOST ABUNDANT SPECIES
Walnut Canyon National Monument

Stratum	Species
Tree canopy	*Pinus ponderosa, Pinus edulis, Juniperus osteosperma*
Tall Shrub	*Quercus gambelii*

ASSOCIATED SPECIES
Walnut Canyon National Monument
Amelanchier utahensis, Bouteloua gracilis, Poa fendleriana (all occur with >5% cover)

VEGETATION DESCRIPTION
Walnut Canyon National Monument
Ponderosa Pine (Pinyon Pine – Utah Juniper) / Gambel Oak Woodland total cover ranged from 65-76% (average 72%) with 52-65% absolute cover (average 58%) in the tree layer, 2-15% (average 9%) in the shrub layer, and 14-24% (average 17%) in the herbaceous layer. The total species diversity ranged from 20-30 (average 25) within the 4 relevés sampled.

The tree layer was co-dominated by *Pinus ponderosa* with 4-11% absolute cover (average 7%), *Pinus edulis* with 4-34% cover (average 19%), and *Juniperus osteosperma* with 7-18% cover (average 13%). The DBH for *Pinus ponderosa* was 5-26 in (12-67 cm) (average 11 in/28 cm), *Pinus edulis* was 4-11 in (11-29 cm) (average 6 in/16 cm), and *Juniperus osteosperma* was 5-40 in (12-102 cm) (average 11 in/28 cm). The shrub layer was dominated by *Quercus gambelii* with 9-27% cover (average 22%). The herbaceous layer was not dominated by a single herbaceous species.

CONSERVATION RANK G5

DATABASE CODE CEGL000870

MAP CLASSES
The association Ponderosa Pine (Pinyon Pine – Utah Juniper) / Gamble Oak Woodland is represented by the map class Ponderosa Pine – Pinyon Pine – Juniper / Gambel Oak Woodland (map code 13).

Ponderosa Pine – Pinyon Pine – Juniper / Gambel Oak Woodland was mapped as occurring mainly south of the canyon, only in small patches in the environs. It was mostly in the non-canyon environments and in side canyon drainages. The total area of Ponderosa Pine – Pinyon Pine – Juniper / Gambel Oak Woodland in the park environs is 366 ac (148 ha) within 28 polygons.

COMMENTS
Walnut Canyon National Monument
This association has a co-dominance of Ponderosa Pine, Pinyon Pine, and Utah Juniper. Previous classifications (Ponderosa Pine Series, Pinyon Pine Series, Juniper Woodlands) have defined vegetation with this co-dominance as occurring in Ponderosa Pine, Pinyon Pine, or Utah Juniper dominated types (Stuever and Hayden 1997b). However, our observations suggest that a new association should be defined based on the co-dominance of all three conifers occurring over a large area within Walnut Canyon NM and in its environs. Currently, this type is treated in the NVCS as the *Pinus edulis* phase of the *Pinus Ponderosa* / *Quercus gambelii* Woodland (CEGL000870) (see Stuever and Hayden 1997b). Hanks et al. 1983 treats this type as a *Quercus gambelii* phase of the *Pinus ponderosa / Festuca arizonica* habitat type and a *Pinus ponderosa / Bouteloua gracilis* habitat type.

REFERENCES
Stuever and Hayden 1997b

Acer negundo / Forestiera pubescens – Symphoricarpos rotundifolius Temporarily Flooded Shrubland (Local Assemblage)

MAP CLASS Canyon Floor Complex
COMMON NAME Box Elder / New Mexican Olive – Snowberry Temporarily Flooded Shrubland

CLASSIFICATION CONFIDENCE LEVEL Not Rated, Unique to Monument

USFS WETLAND SYSTEM Wetland

RANGE
Walnut Canyon National Monument
Box Elder / New Mexican Olive – Snowberry Temporarily Flooded Shrubland occurs as a part of a complex of vegetation associations along riparian corridors, specifically in Walnut Canyon and its side canyons. This assemblage was located from our relevé data at the lower elevations within the northeastern section of Walnut Canyon.

ENVIRONMENTAL DESCRIPTION
Walnut Canyon National Monument
The elevation of the assemblage ranged minimally from 6,201-6,234 ft (1,890-1,900 m). It only occurred on flat areas ranging from 0-3% slope.

MOST ABUNDANT SPECIES
Walnut Canyon National Monument

Stratum	Species
Tree canopy	*Acer negundo*
Shrub	*Forestiera pubescens, Symphoricarpos rotundifolius*

ASSOCIATED SPECIES
Walnut Canyon National Monument
Solidago canadensis, Rhus trilobata, Salix lasiolepis, Robinia neomexicana, Artemisia dracunculus (all occur with >5% cover)

VEGETATION DESCRIPTION
Walnut Canyon National Monument
Box Elder / New Mexican Olive – Snowberry Temporarily Flooded Shrubland total vegetation cover was 74 and 78%. The tree layer was 17 and 26% absolute cover, 50 and 65% in the shrub layer, and 5 and 12% in the herbaceous layer. Only two relevés were sampled and the total species diversity was 39 and 42 species.

The tree layer was dominated by *Acer negundo* with 8 and 17% absolute cover and with DBH measurements of 4 and 10 in (11 and 26 cm). The shrub layer was dominated by *Forestiera pubescens* with 11 and 15% absolute cover and *Symphoricarpos rotundifolius* with 9 and 10%. The herbaceous layer was sparse and not dominated by a single herbaceous species.

CONSERVATION RANK N/A (local assemblage)

DATABASE CODE N/A (local assemblage)

MAP CLASSES
Box Elder / New Mexican Olive – Snowberry Temporarily Flooded Shrubland is represented within the map class of Canyon Floor Complex (map code 10).

Due to this vegetation assemblage occurring within a narrow, linear riparian corridor, it was mapped together with the riparian associations as one map class, the Canyon Floor Complex. The following shrubland and woodland

associations were combined: *Acer negundo / Forestiera pubescens–Symphoricarpos rotundifolius* Temporarily Flooded Shrubland (local assemblage), *Pinus ponderosa / Quercus gambelii* Woodland, *Juniperus scopulorum* Woodland, *Pseudotsuga menziesii / Quercus gambelii* Forest, *Chamaebatiaria millefolium – Forestiera pubescens* Shrubland (local assemblage), and *Quercus gambelii / Robinia neomexicana / Symphoricarpos rotundifolius* Shrubland. The total area of Canyon Floor Complex within Walnut Canyon NM is 119 ac (48 ha) within 39 polygons and the total area in the park environs is 32 ac (13 ha) within 23 polygons.

COMMENTS

Walnut Canyon National Monument

Although this assemblage has only two relevés, its unique species composition and habit suggest that it may be a new community type. Observations and descriptions of additional occurrences are required to confirm it as a provisional association within the NVCS.

Chamaebatiaria millefolium – Forestiera pubescens Shrubland (Local Assemblage)

MAP CLASS Canyon Floor Complex
COMMON NAME Fernbush – New Mexican Olive Shrubland

CLASSIFICATION CONFIDENCE LEVEL Not Rated, Unique to Monument

USFS WETLAND SYSTEM Upland

RANGE
Walnut Canyon National Monument
Fernbush – New Mexican Olive Shrubland occurs as part of a complex of vegetation types along the canyon bottom of Walnut Canyon and its side canyons. This assemblage was described from one relevé in a mesic side canyon in the northeastern section of Walnut Canyon on a limestone wall.

ENVIRONMENTAL DESCRIPTION
Walnut Canyon National Monument
Only one relevé was sampled with this vegetation. It occurred on a limestone wall in a side canyon at an elevation of 6,463 ft (1,970 m) and with a moderately steep slope of 23%.

MOST ABUNDANT SPECIES
Walnut Canyon National Monument

Stratum	Species
Shrub	*Chamaebatiaria millefolium, Forestiera pubescens*

ASSOCIATED SPECIES
Walnut Canyon National Monument
Artemisia dracunculus, Bouteloua gracilis, Brickellia californica, Cercocarpus montanus, Eriogonum corymbosum var. *aureum, Gutierrezia sarothrae, Heterotheca villosa, Juniperus monosperma, Mahonia repens, Poa fendleriana* (all occur with >1% cover)

VEGETATION DESCRIPTION
Walnut Canyon National Monument
Fernbush – New Mexican Olive Shrubland total vegetation cover was 31%, with 2% absolute cover in the tree layer, 18% in the shrub layer, and 15% in the herbaceous layer. Only one relevé was sampled with total species diversity of 28 species.

The tree layer was sparse. The shrub layer was dominated by *Chamaebatiaria millefolium* with absolute cover of 12% and *Forestiera pubescens* with absolute cover of 5%. The herbaceous layer was not dominated by any single species.

CONSERVATION RANK N/A (local assemblage)

DATABASE CODE N/A (local assemblage)

MAP CLASSES
Fernbush – New Mexican Olive Shrubland is represented within map class Canyon Floor Complex (map code 10).

Due to this assemblage occurring within narrow linear riparian corridors, it was mapped together with other riparian associations as one map class, the Canyon Floor Complex. The following shrubland and woodland associations were combined: *Acer negundo / Forestiera pubescens–Symphoricarpos rotundifolius* Temporarily Flooded Shrubland (local assemblage), *Pinus ponderosa / Quercus gambelii* Woodland, *Juniperus scopulorum* Woodland, *Pseudotsuga menziesii / Quercus gambelii* Forest, *Chamaebatiaria millefolium – Forestiera pubescens* Shrubland (local assemblage), and *Quercus gambelii / Robinia neomexicana / Symphoricarpos rotundifolius* Shrubland. The

total area of Canyon Floor Complex within Walnut Canyon NM is 119 ac (48 ha) within 39 polygons and the total area in the park environs is 32 ac (13 ha) within 23 polygons.

COMMENTS

Walnut Canyon National Monument

Although this assemblage has only two relevés, a unique species composition and habit suggest that it may be a new community type. Observations and descriptions of additional occurrences are required to confirm it as a provisional association within the NVCS.

Chamaebatiaria millefolium - *(Mahonia fremontii)* - *Yucca baccata* Limestone Terrace Shrubland (Proposed)

MAP CLASS	Limestone Rim Complex
COMMON NAME	Fernbush – (Barberry) – Banana Yucca Limestone Terrace 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	Temperate cold-deciduous shrubland (III.B.2.N.a.)
ALLIANCE	*Chamaebatiaria millefolium* Shrubland Alliance

CLASSIFICATION CONFIDENCE LEVEL Weak

USFS WETLAND SYSTEM Upland

RANGE
Walnut Canyon National Monument
Fernbush – (Barberry) – Banana Yucca Limestone Terrace Shrubland occurs as part of a complex of vegetation associations along limestone canyon terrace walls of Walnut Canyon and its side canyons. This association was identified from our relevé data on the limestone terraces on the canyon walls on the north rim of Walnut Canyon in Walnut Canyon NM.

ENVIRONMENTAL DESCRIPTION
Walnut Canyon National Monument
The association occurred from 1950-2070m (average 2000). This association only occurred on limestone terraces with steep slopes ranging from 55-85% (average 65%).

MOST ABUNDANT SPECIES
Walnut Canyon National Monument

Stratum	Species
Shrub	*Chamaebatiaria millefolium, Mahonia fremontii, Yucca baccata*

ASSOCIATED SPECIES
Walnut Canyon National Monument
Cercocarpus montanus, Juniperus osteosperma, Juniperus scopulorum, Quercus gambelii (all occur with >5% cover)

VEGETATION DESCRIPTION
Walnut Canyon National Monument
Fernbush – (Barberry) – Banana Yucca Limestone Terrace Shrubland total vegetation cover ranges from 38-65% (average 51%), with 4-17% absolute cover (average 10%) in the tree layer, 14-45% (average 24%) in the shrub layer, and 12-25% (average 19%) in the herbaceous layer. The total species diversity ranged from 18-34 (average 24) within the 4 relevés sampled.

The tree layer is not characterized by one species: At least 5% cover of *Juniperus osteosperma, Juniperus scopulorum,* or *Quercus gambelii* occurred in at least one of the relevés measured. The shrub layer was co-dominated by *Chamaebatiaria millefolium* ranging from 1-7% absolute cover (average 5%), *Mahonia fremontii* ranging from 1-17% absolute cover (average 7%), and *Yucca baccata* ranging from 2-7% absolute cover (average 4%). The herbaceous layer was sparse and not dominated by a single herbaceous species.

CONSERVATION RANK G?

DATABASE CODE CEGL003494

MAP CLASSES
Fernbush – (Barberry) – Banana Yucca Limestone Terrace Shrubland is represented within map class Limestone Rim Complex (map code 9).

This association was mapped as part of a complex of associations on the limestone canyon walls, the Limestone Rim Complex. Due to difficulty in the photo-delineation of the steep limestone cliffs, the following shrubland and woodland associations were combined: *Chamaebatiaria millefolium* – (*Mahonia fremontii)* – *Yucca baccata* Limestone Terrace Shrubland [provisional], *Pinus edulis / Cercocarpus montanus* Woodland, *Pinus edulis – (Juniperus osteosperma) / Bouteloua gracilis* Woodland, and *Pinus edulis – (Juniperus osteosperma) / Purshia stansburiana* Woodland. The total area of the complex mapped within Walnut Canyon NM is 591 ac (239 ha) within 34 polygons and the total area in the park environs is 358 ac (145 ha) within 32 polygons.

COMMENTS
Walnut Canyon National Monument
Observations and descriptions of additional occurrences of this association are required to increase its classification confidence level as an association within the NVCS.

Ericameria nauseosa - *Gutierrezia sarothrae* Shrubland (Local Assemblage)

MAP CLASS Snakeweed / Modified Grassland Complex
COMMON NAME Rabbitbrush – Snakeweed Shrubland

CLASSIFICATION CONFIDENCE LEVEL Not Rated, Unique to Monument

USFS WETLAND SYSTEM Upland

RANGE
Walnut Canyon National Monument
Rabbitbrush – Snakeweed Shrubland occurs within a complex of disturbed vegetation associations in the northeast section of the project boundary. *Ericameria nauseosa* and *Gutierrezia sarothrae* are both native species that often thrive in areas of disturbance. Only one relevé from this proposed association was identified on USDA-FS lands between the Walnut Canyon Park Road and Cosnino Road.

ENVIRONMENTAL DESCRIPTION
Walnut Canyon National Monument
Only one relevé of this assemblage was surveyed; it was found at an elevation of 6,562 ft (2,000 m) in a flat area.

MOST ABUNDANT SPECIES
Walnut Canyon National Monument

Stratum	Species
Shrub	*Ericameria nauseosa, Gutierrezia sarothrae*

ASSOCIATED SPECIES
Walnut Canyon National Monument
Amaranthus sp., *Aristida purpurea*, *Bouteloua gracilis*, *Bromus* sp., *Erodium cicutarium*, *Erigeron divergens*, *Machaeranthera gracilis*, *Portulaca oleracea*, *Verbascum thapsus* (all occur with >1% cover)

VEGETATION DESCRIPTION
Walnut Canyon National Monument
Only one relevé was sampled of the Rabbitbrush – Snakeweed Shrubland. Total vegetation cover was 57% with <1% in the tree layer, 26% in the shrub layer, and 23% in the herbaceous layer. The total species diversity was 22.

Gutierrezia sarothrae and *Ericameria nauseosa* dominated the shrub layer with both species having absolute cover of 12%. The herbaceous layer was not dominated by a single species, rather a conglomeration of many different species.

CONSERVATION RANK N/A (local assemblage)

DATABASE CODE N/A (local assemblage)

MAP CLASSES
Rabbitbrush – Snakeweed Shrubland is represented by map class Snakeweed / Modified Grassland Complex (map code 7).

This assemblage occurs in a mosaic of disturbed areas, mainly on chained areas in the project environs. Due to difficulty in the photo-delineation of the chained area mosaic, the following grassland and shrubland associations were mapped in this unit: *Gutierrezia sarothrae* Modified Dwarf-shrub Herbaceous Vegetation, *Bromus* (*tectorum, rubens*) Semi-natural Herbaceous Alliance, *Aristida purpurea* Herbaceous Vegetation, *Bouteloua eriopoda* Herbaceous Vegetation, and *Ericameria nauseosa – Gutierrezia sarothrae* Shrubland (local assemblage). The total area of this complex within Walnut Canyon NM is 101 ac (41 ha) within 10 polygons and the total area in the park environs is 2,417 ac (978 ha) within 28 polygons.

COMMENTS

Walnut Canyon National Monument

Alliances and associations characteristic of disturbed areas have not been well studied in the NVCS. Further study will allow for better classification of the vegetation classification of disturbed areas. Observations and descriptions of additional occurrences of *Ericameria nauseosa – Gutierrezia sarothrae* Shrubland are required to confirm it as a proposed association within the NVCS.

Quercus gambelii / Robinia neomexicana / Symphoricarpos rotundifolius Shrubland

MAP CLASS	Canyon Floor Complex
COMMON NAME	Gambel Oak - New Mexico Locust - Roundleaf Snowberry 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	Temperate cold-deciduous shrubland (III.B.2.N.a.)
ALLIANCE	*Quercus gambelii* Shrubland Alliance

CLASSIFICATION CONFIDENCE LEVEL Weak

USFS WETLAND SYSTEM Upland

RANGE

Walnut Canyon National Monument

Gambel Oak - New Mexico Locust - Roundleaf Snowberry Shrubland occurs from drier cooler slopes to areas with periodic flooding within Walnut Canyon NM and the surrounding USDA-FS lands. It was identified specifically from our relevé data in side drainages of Walnut Canyon, on the more mesic canyon rims of Walnut Canyon, and on the cooler canyon walls of Walnut Canyon.

Globally

This association is reported from central New Mexico and northern central Arizona along the Mogollon Rim.

ENVIRONMENTAL DESCRIPTION

Walnut Canyon National Monument

This association occurs at a wide range of elevations, from 4,957-6,857 ft (1,511-2,090 m) (average 5,774 ft/1,760 m). All of the relevés were found within side drainages or on steep north facing slopes ranging from 5-48% slope (average 19%).

Globally

This poorly known shrubland association is reported from the Sandía Mountains in north-central New Mexico and the Mogollon Rim in central Arizona. Elevation ranges from 4,950-10,000 ft (1,510-3,050 m). Sites include steep, exposed sites at higher elevations or north aspect midslopes and riparian areas in canyons at lower elevations. Slopes and aspects are variable. Substrates are generally coarser textured soils with a high percentage of mixed gravel, cobble and/or boulder sized rock. Litter cover is often over 10%.

MOST ABUNDANT SPECIES

Walnut Canyon National Monument

Stratum	Species
Tall Shrub	*Quercus gambelii, Robinia neomexicana, Symphoricarpos rotundifolius* var. *parishii*

Globally

Stratum	Species
Tall Shrub	*Quercus gambelii, Robinia neomexicana,*
Short Shrub	*Symphoricarpos rotundifolius, S. oreophilus,* or *S. palmeri*

ASSOCIATED SPECIES

Walnut Canyon National Monument

Amelanchier utahensis, Bromus sp., *Helianthus petiolaris, Poa fendleriana, Rhus trilobata, Vitis arizonica* (all occur with >5% cover)

Globally
Pinus edulis, Pinus ponderosa, Pseudotsuga menziesii, Juniperus scopulorum, J. osteosperma,, J. monosperma,, Acer negundo, Amelanchier utahensis, Chamaebatiaria millefolium, Forestiera pubescens, Rosa woodsii, Salix spp., *Achillea millefolium, Artemisia ludoviciana, Campanula rotundifolia, Hedeoma drummondii, Heterotheca villosa, Penstemon* spp.*, Poa fendleriana, Solidago velutina, Thalictrum fendleri*

VEGETATION DESCRIPTION
Walnut Canyon National Monument
Gambel Oak - New Mexico Locust - Roundleaf Snowberry Shrubland total vegetation cover ranged from 45-94% (average 72%) with 4-94% absolute cover (average 34%) in the tree layer, 20-75% (average 48%) in the shrub layer, and 7-50% (average 30%) in the herbaceous layer. The total species diversity ranged from 11-32 species (average 23) within the 4 relevés sampled.

The tree and shrub layer were dominated or co-dominated by *Quercus gambelii* with 4-80% absolute cover (average 26%) in the tree layer and 1-15% absolute cover (average 10%) in the shrub layer. DBH in the tree layer ranged from 4-10 in (11-26 cm) (average 6 in/15 cm). The shrub layer was also co-dominated by *Symphoricarpos rotundifolius* var. *parishii* with 7-46% absolute cover (average 18%). *Robinia neomexicana* often occurs in high cover within the shrub layer, but does not need to be present (0-22% absolute cover (average 12%)). The herbaceous layer contained a high diversity of herbaceous species including *Bromus* sp., *Helianthus petiolaris, Poa fendleriana,* and *Vitis arizonica;* however, no single species dominated this layer.

Globally
This association is characterized by a moderately dense to dense, deciduous tall shrub layer that is dominated by *Quercus gambelii* with *Robinia neomexicana* often co-dominating. Scattered conifer trees may be present including *Pinus edulis, Pinus ponderosa, Pseudotsuga menziesii, Juniperus scopulorum, J. osteosperma,,* or *J. monosperma.* Riparian stands may have occasional *Acer negundo* trees or *Salix* spp. shrubs. The short shrub layer is dominated by species of *Symphoricarpos* that vary depending on geography such as *S. rotundifolius, S. oreophilus,* or *S. palmeri*. Other shrubs may include *Amelanchier utahensis, Chamaebatiaria millefolium, Forestiera pubescens,* or *Rosa woodsii*. The herbaceous layer is generally sparse because of shading from dense shrub cover. Associates include *Achillea millefolium, Artemisia ludoviciana, Campanula rotundifolia, Hedeoma drummondii, Heterotheca villosa, Penstemon* spp.*, Poa fendleriana, Solidago velutina,* and *Thalictrum fendleri.*

CONSERVATION RANK GU

DATABASE CODE CEGL001116

MAP CLASSES
The association Gambel Oak - New Mexico Locust - Roundleaf Snowberry Shrubland is represented by map class Canyon Floor Complex (map code 10).

Canyon Floor Complex was mapped as occurring as small patches along the canyon bottom of Walnut Canyon. The Canyon Floor Complex consists of a tight mosaic of the following associations: *Acer negundo* / *Forestiera pubescens – Symphoricarpos rotundifolius* Temporarily Flooded Shrubland (local assemblage), *Quercus gambelii / Robinia neomexicana / Symphoricarpos rotundifolius* Shrubland, *Juniperus scopulorum* Woodland Alliance, *Pinus ponderosa / Quercus gambelii* Woodland, *Chamaebatiaria millefolium – Forestiera pubescens* Shrubland (local assemblage), and *Pseudotsuga menziesii / Quercus gambelii* Forest. The total area of Canyon Floor Complex within Walnut Canyon NM is 119 ac (48 ha) within 39 polygons and the total area in the park environs is 32 ac (13 ha) within 23 polygons.

COMMENTS
Walnut Canyon National Monument
This association is currently being reviewed by NatureServe to determine the differences between three similar vegetation associations: *Quercus gambelii / Robinia neomexicana / Symphoricarpos rotundifolius* Shrubland, *Quercus gambelii / Robinia neomexicana* Shrubland, and *Quercus gambelii / Symphoricarpos oreophilus* Shrubland. If there is revision of these associations, our current assignment may need to be reviewed.

Our relevé data also contained two taxonomically similar species, *Symphoricarpos rotundifolius* var. *parishii* and *Symphoricarpos oreophilus.* Both of these species are know to occur in the canyon bottom of Walnut Canyon (Joyce 1974). Although both of these species are know to occur, we believe that they are taxonomically similar and were combined for the analysis. *Symphoricarpos rotundifolius* is the most common of the species to occur in Walnut Canyon and this allowed us to maintain the nomenclature previously identified in the *Quercus gambelii / Robinia neomexicana / Symphoricarpos rotundifolius* Shrubland association description.

Globally
This poorly known plant association is reported both as chaparral from Sandía Mountains in New Mexico and riparian vegetation canyons in northern Arizona. It is similar to stands of *Quercus gambelii / Robinia neomexicana* Shrubland (CEGL001115) described from the Mazatzal Mountains in central Arizona (Warren and Treadwell 1980) and stands of *Quercus gambelii / Symphoricarpos oreophilus* Shrubland (CEGL001117) described from White Sands Missile Range in New Mexico (Muldavin et al. 2000). These related stands are all dominated by *Quercus gambelii* with *Symphoricarpos* spp. and *Robinia neomexicana* potentially present. Further review is needed to better understand this association and its relationship to the other associations.

DYNAMICS
Globally
Seems to occur on sites at higher elevation that are too dry for conifer trees to dominate, and on relatively mesic sites at lower elevation.

REFERENCES
Bourgeron and Engelking 1994, Driscoll et. al. 1984, Muldavin et. al. 2000, Warren and Treadwell 1980, Watson 1912, Western Ecology Working Group of NatureServe

Gutierrezia sarothrae Modified Dwarf-shrubland [Provisional]

MAP CLASS	Snakeweed / Modified Grassland Complex
COMMON NAME	Snakeweed Modified Dwarf-Shrub Herbaceous Vegetation
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.)
FORMATION	Cespitose cold-deciduous dwarf-shrubland (V.A.8.N.a.)
ALLIANCE	*Gutierrezia sarothrae* Dwarf-Shrubland

CLASSIFICATION CONFIDENCE LEVEL Weak

USFS WETLAND SYSTEM Upland

RANGE
Walnut Canyon National Monument
Snakeweed Modified Dwarf-Shrub Herbaceous Vegetation is a common vegetation association in the northeast section of the project boundary. This association was identified from our relevé data in the northeastern section of the project boundary on USDA-FS lands that were previously chained. These areas previously supported *Juniperus monosperma*, which were chained to increase the forage potential of the site for grazing (USDA Forest Service Rangelands 2004). This association was also identified south of Walnut Canyon on Forest Service lands in the southeastern section of the project boundary.

ENVIRONMENTAL DESCRIPTION
Walnut Canyon National Monument
This association occurred from 1970-2110m (average 2020m). Topography varied from flat areas to hills, 0-12% slope (average 7%).

MOST ABUNDANT SPECIES
Walnut Canyon National Monument

Stratum	Species
Shrub	*Gutierrezia sarothrae*

ASSOCIATED SPECIES
Walnut Canyon National Monument
Bouteloua gracilis, Chamaebatiaria millefolium, Marrubium vulgare, Pascopyrum smithii, Pinus edulis, Portulaca oleracea, Purshia stansburiana (all occur with >5% cover)

VEGETATION DESCRIPTION
Walnut Canyon National Monument
Snakeweed Modified Dwarf-Shrub Herbaceous Vegetation total vegetation cover ranged from 38-68% (average 46%) with 0-18% absolute cover (average 6%) in the tree layer, 13-26% (average 19%) in the shrub layer, and 9-29% (average 23%) in the herbaceous layer. The total species diversity ranged from 14-41 (average 23) within the 6 relevés sampled.

The tree layer was sparse with occasional *Pinus edulis* and *Juniperus osteosperma*. The shrub layer was dominated by *Gutierrezia sarothrae* ranging from 3-17% cover (average 10%). The herbaceous layer was dominated by annual and perennial weedy species such as *Portulaca oleracea, Pascopyrum smithii*, and *Marrubium vulgare* and also supported remnant native grasses such as *Bouteloua gracilis*.

CONSERVATION RANK G?

DATABASE CODE to be determined

MAP CLASSES
The association Snakeweed Modified Dwarf-Shrub Herbaceous Vegetation is represented by the map class Snakeweed / Modified Grassland Complex (map code 7).

The chained areas are a mosaic of grasslands and shrublands that have been mapped as a single map class, Snakeweed / Modified Grassland Complex. It consists of the following vegetation types which occurred in a tight mosaic in the landscape: *Gutierrezia sarothrae* Modified Dwarf-shrubland [provisional], *Bromus* (*tectorum, rubens*) Semi-natural Herbaceous Alliance, *Aristida purpurea* Herbaceous Vegetation, *Bouteloua eriopoda* Herbaceous Vegetation, and *Ericameria nauseosa – Gutierrezia sarothrae* Shrubland (local assemblage). The total area of this complex within Walnut Canyon NM is 101 ac (41 ha) within 10 polygons and the total area in the park environs is 2,417 ac (978 ha) within 28 polygons.

COMMENTS
Walnut Canyon National Monument
Disturbed alliances and associations have not been well defined in the NVCS; therefore, further study will allow for better classification of the alliances and associations.

Ericameria nauseosa / Bouteloua gracilis Shrub Herbaceous Vegetation

MAP CLASS	Rabbitbrush / Blue Grama Shrub Herbaceous Vegetation
COMMON NAME	Rabbitbrush / Blue Grama 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 a sparse microphyllous shrub layer (V.A.7.N.j.)
ALLIANCE	*Ericameria nauseosa* Shrub Herbaceous Alliance

CLASSIFICATION CONFIDENCE LEVEL Weak

USFS WETLAND SYSTEM Upland

RANGE
Walnut Canyon National Monument
Rabbitbrush / Blue Grama Shrub Herbaceous Vegetation is a common vegetation association in eastern section of the project boundary. This association was identified from our relevé data to occur in the northeastern section of the project boundary near the chained areas as well as in small patches in the southeastern section of the project boundary east of Cherry Canyon.

ENVIRONMENTAL DESCRIPTION
Walnut Canyon National Monument
The elevation at which this association was surveyed ranged from 1935-2010m (average 1980m). Topography varied from flat areas to slight inclines of 0-13% slope (average 4%).

MOST ABUNDANT SPECIES
Walnut Canyon National Monument

Stratum	Species
Shrub	*Ericameria nauseosa*
Herbaceous	*Bouteloua gracilis*

ASSOCIATED SPECIES
Walnut Canyon National Monument
Aristida purpurea, Artemisia dracunculus, Chamaebatiaria millefolium, Gutierrezia sarothrae, Juniperus osteosperma, Linaria genistifolia, Pinus edulis, Tetradymia canescens (all occur with >1% cover)

VEGETATION DESCRIPTION
Walnut Canyon National Monument
Rabbitbrush / Blue Grama Shrub Herbaceous Vegetation total vegetation cover ranged from 52-62% (average 57%) with 1-9% absolute cover (average 3%) in the tree layer, 18-32% (average 25%) in the shrub layer, and 28-40% (average 32%) in the herbaceous layer. The total species diversity ranged from 14-35 (average 24) within the 7 relevés sampled.

The tree layer was sparse with occasional *Pinus edulis* and *Juniperus osteosperma*. The shrub layer was dominated by *Ericameria nauseosa* ranging in cover from 9-22% (average 17%). *Gutierrezia sarothrae* occurred in all relevés, often with low cover (1-13%, average 5%). The herbaceous layer was dominated by *Bouteloua gracilis* with absolute cover ranging from 20-30% (average 26%).

CONSERVATION RANK G?

DATABASE CODE CEGL003495

MAP CLASSES
The association Rabbitbrush / Blue Grama Shrub Herbaceous Vegetation is represented by map class Rabbitbrush / Blue Grama Shrub Herbaceous Vegetation (map code 8).

This association was mapped on Forest Service lands and at Walnut Canyon NM on the north rim in areas that were previously chained and on the south rim at lower elevations adjacent to Pinyon Pine – Utah Juniper / Blue Grama Woodland map class. The total area of Rabbitbrush / Blue Grama Shrub Herbaceous Vegetation within Walnut Canyon NM is 37 ac (15 ha) within 13 polygons and the total area in the park environs is 418 ac (169 ha) within 56 polygons.

REFERENCES
Francis 1986, Western Ecology Working Group of NatureServe

Aristida purpurea Herbaceous Vegetation

MAP CLASS	Snakeweed / Modified Grassland Complex
COMMON NAME	Purple Three-Awn 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.d)
ALLIANCE	*Aristida purpurea* Herbaceous Alliance

CLASSIFICATION CONFIDENCE LEVEL Weak

USFS WETLAND SYSTEM Upland

RANGE
Walnut Canyon National Monument
Purple Three-Awn Herbaceous Vegetation occurs as a part of a complex of disturbed vegetation associations in the northeast section of the project boundary. *Aristida purpurea* is an effective colonizer of disturbed areas and occurs within the mosaic of disturbed associations in the project environs. Only one relevé was assigned to this association and it occurred on the chained areas were *Juniperus monosperma* was removed to increase the forage potential of the site for grazing (USDA Forest Service Rangelands 2004). This area also has natural disturbance resulting from a large prairie dog colony.

ENVIRONMENTAL DESCRIPTION
Walnut Canyon National Monument
Only one relevé in this association; it was at 1970m in a flat area.

MOST ABUNDANT SPECIES
Walnut Canyon National Monument

Stratum	Species
Herbaceous	*Aristida purpurea*

ASSOCIATED SPECIES
Walnut Canyon National Monument
Artemisia dracunculus, Bouteloua gracilis, Ericameria nauseosa, Senecio spartioides, Sphaeralcea sp., *Verbascum thapsus* (all occur with >1% cover)

VEGETATION DESCRIPTION
Walnut Canyon National Monument
Purple Three-Awn Herbaceous Vegetation total vegetation cover was 63%, with 8% absolute cover in the shrub layer and 55% in the herbaceous layer. Only one relevé was sampled with total species diversity of 21 species.

The shrub layer was dominated by *Ericameria nauseosa* with absolute cover of 6%. The herbaceous layer was dominated by *Aristida purpurea* with absolute cover of 42%.

CONSERVATION RANK G?

DATABASE CODE CEGL005800

MAP CLASSES
Purple Three-Awn Herbaceous Vegetation is represented by the map class Snakeweed / Modified Grassland Complex (map code 7).

Snakeweed / Modified Grassland Complex was mapped mainly in the northeastern section of the project boundary in highly disturbed environments. Due to the difficulty in photo-delineation of the chained area mosaic, the following grassland and shrubland associations were mapped together: *Gutierrezia sarothrae* Modified Dwarf-shrubland [provisional], *Bromus* (*tectorum, rubens*) Semi-natural Herbaceous Alliance, *Aristida purpurea* Herbaceous Vegetation, *Bouteloua eriopoda* Herbaceous Vegetation, and *Ericameria nauseosa – Gutierrezia sarothrae* Shrubland (local assemblage). The total area of this complex within Walnut Canyon NM is 101 ac (41 ha) within 10 polygons and the total area in the park environs is 2,417 ac (978 ha) within 28 polygons.

COMMENTS

Walnut Canyon National Monument

Disturbed alliances and associations have not been defined in the NVCS; therefore, further study will allow for better classification of the alliances and associations.

Globally

A provisional alliance has been described from disturbed sites in the eastern plains of Colorado.

REFERENCES

Western Ecology Working Group of NatureServe

Bouteloua eriopoda Semi-desert Herbaceous Vegetation

MAP CLASS	Snakeweed / Modified Grassland Complex
COMMON NAME	Black Grama Semi-desert 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 Weak

USFS WETLAND SYSTEM Upland

RANGE

Walnut Canyon National Monument

Black Grama Semi-desert Herbaceous Vegetation occurs as part of a complex of disturbed vegetation associations in the northeast section of the project boundary. Only one relevé of this association was sampled and it occurred as a remnant patch of native grass within the mosaic of disturbed associations on chained areas in the project environs. Here *Juniperus monosperma* was chained to increase the forage potential of the site for grazing (USDA Forest Service Rangelands 2004).

Globally

This association occurs in south-central New Mexico and northern Arizona in the Chihuahuan Desert and Colorado Plateau.

ENVIRONMENTAL DESCRIPTION

Walnut Canyon National Monument

Only one relevé of this association was surveyed; it was at 6,463 ft (1,970 m) in a flat area.

Globally

This grassland occurs on semi-arid plains and bajadas in the Chihuahuan Desert and Colorado Plateau. Elevation ranges from 4,920-6,475 ft (1,500-1,975 m). Sites are flat to gentle lower slopes. Soils are non-calcareous sandy loams.

MOST ABUNDANT SPECIES

Walnut Canyon National Monument

Stratum	Species
Herbaceous	*Bouteloua eriopoda*

Globally

Stratum	Species
Herbaceous	*Bouteloua eriopoda, Allionia incarnata*

ASSOCIATED SPECIES

Walnut Canyon National Monument

Gutierrezia sarothrae, Robinia neomexicana, Senecio flaccidus (all occur with >5% cover)

Globally

Ephedra trifurca, Gutierrezia sarothrae, Robinia neomexicana, Aristida purpurea, Bouteloua curtipendula, Muhlenbergia porteri, Allionia incarnata, Datura wrightii, Opuntia phaeacantha, Senecio flaccidus, Solanum elaeagnifolium

VEGETATION DESCRIPTION

Walnut Canyon National Monument

Black Grama Semi-desert Herbaceous Vegetation total vegetation cover was 54%, with 18% absolute cover in the shrub layer and 40% in the herbaceous layer. Only one relevé was sampled with total species diversity of 10 species.

The shrub layer was dominated by *Robinia neomexicana* with absolute cover of 7%. The herbaceous layer was dominated by *Bouteloua eriopoda* with absolute cover of 38%.

Globally

This association is characterized by a moderately dense herbaceous layer dominated by the perennial shortgrass *Bouteloua eriopoda*, sometimes forming nearly pure stands. Shrubs or dwarf-shrubs may be present in low cover such as *Ephedra trifurca, Gutierrezia sarothrae,* or *Robinia neomexicana.* Common associates include *Aristida purpurea, Bouteloua curtipendula, Muhlenbergia porteri, Allionia incarnata, Datura wrightii, Eriogonum* spp, *Opuntia phaeacantha, Senecio flaccidus,* and *Solanum elaeagnifolium.*

CONSERVATION RANK G2Q

DATABASE CODE CEGL001752

MAP CLASSES

Black Grama Semi-desert Herbaceous Vegetation is represented by the map class Snakeweed / Modified Grassland Complex (map code 7).

The mosaic of grassland and shrubland associations has been lumped as a map class, the Snakeweed / Modified Grassland Complex. The following grassland and shrubland associations were combined in this map class: *Gutierrezia sarothrae* Modified Dwarf-shrubland [provisional], *Bromus* (*tectorum, rubens*) Semi-natural Herbaceous Alliance, *Aristida purpurea* Herbaceous Vegetation, *Bouteloua eriopoda* Herbaceous Vegetation, and *Ericameria nauseosa - Gutierrezia sarothrae* Shrubland (local assemblage). The total area of this complex within Walnut Canyon NM is 101 ac (41 ha) within 10 polygons and the total area in the park environs is 2,417 ac (978 ha) within 28 polygons.

COMMENTS

Walnut Canyon National Monument

Bouteloua eriopoda was originally the dominant forage grass in numerous areas in the southwest (USDA 1988). However, *Bouteloua eriopoda* does not withstand heavy grazing regimes and may die out in extensive drought periods (USDA 1998). The small remnant patch of *Bouteloua eriopoda* in the project boundary may be representative of larger stands that once dominated these grasslands.

Globally

This association is not well known, based only on 6 relevés on the Jornada Experimental Range in south-central New Mexico and 1 relevé from Walnut Canyon National Monument in northern Arizona. More survey and classification work is needed to better define this type. This association needs to be compared with *Ephedra trifurca / Bouteloua eriopoda* Shrub Herbaceous Vegetation (CEGL001732) described by Muldavin et al. 2000.

DYNAMICS

Globally

The abundance of *Bouteloua eriopoda*-dominated grasslands has declined significantly in the last 50 years (Buffington and Herbel 1965, Gardner 1950, Hennessy et al. 1983, Herbel et al. 1972, Nelson 1934). These grasslands have been replaced largely by shrublands dominated by *Prosopis glandulosa* in Trans Pecos, southern New Mexico and southeastern Arizona. Studies on the Jornada Experimental Range suggest that combinations of drought, overgrazing by livestock, wind and water erosion, seed dispersal by livestock, fire suppression, shifting dunes, and changes in the seasonal distribution of precipitation have caused this recent, dramatic shift in vegetation physiognomy (Buffington and Herbel 1965, Gibbens et al. 1983, Herbel et al. 1972, Hennessy et al. 1983, Humphrey 1974, McLaughlin and Bowers 1982, McPherson 1995, Schlesinger et al. 1990). *Prosopis* spp. and other shrubs have extensive root systems that allow them to exploit deep soil water that is unavailable to shallower rooted

grasses and cacti (Burgess 1995). This strategy works well, except on sites that have well-developed argillic or calcic soil horizons that limit infiltration and storage of winter moisture in the deeper soil layers (McAuliffe 1995). McAuliffe (1995) found *Prosopis* spp. invasion on these sites to be limited to a few, small individuals. This has implications in plant geography and grassland revegetation work in the southwestern United States.

REFERENCES

Bourgeron and Engelking 1994, Buffington and Herbel 1965, Burgess 1995, Driscoll et al. 1984, Gardner 1950, Gibbens et al. 1983, Hennessy et al. 1983, Herbel et al. 1972, Humphrey 1974, McLaughlin and Bowers 1982, McAuliffe 1995, McPherson 1995, Nelson 1934, Schlesinger et al. 1990, Stein and Ludwig 1979

Bouteloua gracilis Herbaceous Vegetation

MAP CLASS	Blue Grama - Mountain Muhly Grassland Group
COMMON NAME	Blue Grama 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 gracilis* Herbaceous Alliance

CLASSIFICATION CONFIDENCE LEVEL Weak

USFS WETLAND SYSTEM Upland

RANGE

Walnut Canyon National Monument

Blue Grama Herbaceous Vegetation occurs mostly as small isolated patches throughout the project boundary in a mosaic with Ponderosa Pine (Pinyon Pine – Utah Juniper) / Blue Grama Woodland, Ponderosa Pine / Blue Grama Woodland, Pinyon-Utah Juniper / Blue Grama Woodland, Rabbitbrush / Blue Grama Herbaceous Vegetation, and Snakeweed / Modified Grassland Complex map classes. Only one relevé was assigned to this association and was identified from the northeastern section of the project boundary within an area of high disturbance.

Globally

This plant association occurs in Arizona, New Mexico and Wyoming.

ENVIRONMENTAL DESCRIPTION

Walnut Canyon National Monument

Only one relevé of this association was surveyed; it was at 6,759 ft (2,060 m) with a gentle slope (8%).

Globally

This plant association is reported from in Arizona, New Mexico and Wyoming. Elevation ranges from 6,000-7,200 ft (1,830-2,200 m). Sites are flat to gently sloping and include plains, plateaus and montane meadows. Substrates are variable and range from coarse-textured soils derived from sand, gravel or cinder to silty clay loam prairie soils.

MOST ABUNDANT SPECIES

Walnut Canyon National Monument

Stratum	Species
Herbaceous	*Bouteloua gracilis*

Globally

Stratum	Species
Herbaceous	*Bouteloua gracilis*

ASSOCIATED SPECIES

Walnut Canyon National Monument

Ericameria nauseosa, Hymenoxys richardsonii, Juniperus deppeana, Muhlenbergia montana, Pinus ponderosa (all occur with >1% cover)

Globally

Bouteloua curtipendula, Elymus elymoides, Muhlenbergia montana, Muhlenbergia richardsonis, Muhlenbergia torreyi, Pascopyrum smithii, Pleuraphis jamesii, Sporobolus cryptandrus, Bromus tectorum, Artemisia caruthii, Artemisia dracunculus

VEGETATION DESCRIPTION

Walnut Canyon National Monument

Blue Grama Herbaceous Vegetation total vegetation cover was 32%, with 11% absolute cover in the tree layer, 1% in the shrub layer, and 25% in the herbaceous layer. Only one relevé was sampled with total species diversity of 32 species.

The tree layer consisted of *Juniperus deppeana* (average DBH 9 in/22 cm) and *Pinus ponderosa* (average DBH 11 in/29 cm). The shrub layer was sparse. The herbaceous layer was dominated by *Bouteloua gracilis* with absolute cover of 20%.

Globally

This association is characterized by moderate to dense (25-80% cover) herbaceous layer that is strongely dominated by the warm season, perennial shortgrass, *Bouteloua gracilis*. Associated grasses are *Bouteloua curtipendula, Elymus elymoides, Muhlenbergia montana, M. richardsonis, M. torreyi, Pascopyrum smithii, Pleuraphis jamesii (= Hilaria jamesii), Sporobolus cryptandrus* and the introduced annual grass *Bromus tectorum.* Forb cover is sparse. Associated forb species include *Artemisia caruthii* and *Artemisia dracunculus.* Scattered *Ericameria nauseosa* shrubs and an occasional *Juniper* spp., *Pinus edulis,* or *P. ponderosa* (in montane stands) tree may be present.

CONSERVATION RANK G4Q

DATABASE CODE CEGL001760

MAP CLASSES

Blue Grama Herbaceous Vegetation is represented by Blue Grama - Mountain Muhly Grassland Group (map code 4).

Due to the inability to distinguish the differences in herbaceous species from aerial photography, the areas with high cover of *Bouteloua gracilis* (*Bouteloua gracilis* Herbaceous Vegetation) and *Muhlenbergia montana* (*Muhlenbergia montana* Herbaceous Vegetation) were combined into the Blue Grama - Mountain Muhly Grassland Group. Small patches of Blue Grama - Mountain Muhly Grassland Group were mapped throughout the project boundary. The total area of this group within Walnut Canyon NM is 10 ac (4 ha) within 12 polygons and the total area in the park environs is 217 ac (88 ha) within 72 polygons.

COMMENTS

Walnut Canyon National Monument

These small isolated patches of grassland may be relics of pre-settlement conditions where this grass occurred in large parks rather than isolated patches. These patches of grassland do not have high shrub cover and are hence a grassland rather than shrub herbaceous or steppe.

Globally

This is a low confidence association. There are many other associations in the *Bouteloua gracilis* Herbaceous Alliance (A.1282).

DYNAMICS

Globally

Bouteloua gracilis is an extremely drought- and grazing-tolerant shortgrass species. It is one of the most widely distributed grasses in the interior western U.S., and is present in many different grassland, shrubland and woodland communities. It evolved with grazing by large herbivores and generally forms a short sod. However, in some stands ungrazed plants develop the upright physiognomy of a bunchgrass.

REFERENCES

Bourgeron and Engelking 1994, Bradley et. al. 1992, Driscoll et. al. 1984, Dwyer and Peiper 1967, Fisser 1970, Fisser et. al. 1965, Hansen et. al. 2003, Madany and West 1980, Pieper 1968, Western Ecology Working Group of Nature Serve

Bromus (*tectorum, rubens*) Semi-natural Herbaceous Alliance

MAP CLASS	Snakeweed / Modified Grassland Complex
COMMON NAME	Cheatgrass Herbaceous Semi-natural Alliance
SYNONYM	Cheatgrass Annual Grassland
PHYSIOGNOMIC CLASS	Herbaceous Vegetation (V)
PHYSIOGNOMIC SUBCLASS	Annual graminoid or forb vegetation (V.D.)
PHYSIOGNOMIC GROUP	Temperate or subpolar annual grasslands or forb vegetation (V.D.2.)
PHYSIOGNOMIC SUBGROUP	Natural/Semi-natural (V.D.2.N.)
FORMATION	Short temperate annual grassland (V.D.2.N.d)
ALLIANCE	*Bromus tectorum* Semi-natural Herbaceous Alliance

CLASSIFICATION CONFIDENCE LEVEL Moderate

USFS WETLAND SYSTEM Upland

RANGE

Walnut Canyon National Monument

Cheatgrass Semi-Natural Herbaceous Vegetation occurs as a part of a complex of disturbed vegetation associations in the northeast section of the project boundary. This association was only identified from one relevé on disturbed USDA-FS lands in the northeastern section of the project environs. *Juniperus monosperma* was chained in this area to increase the forage potential of the site for grazing (USDA Forest Serve Rangelands 2004).

Globally

This alliance-level herbaceous vegetation type is found throughout much of western North America from the western Great Plains to intermountain and southwestern U.S.

ENVIRONMENTAL DESCRIPTION

Walnut Canyon National Monument

Only one relevé was surveyed of this association and it occurred at an elevation of 6,529 ft (1,990m) in a flat area.

Globally

This alliance-level herbaceous vegetation type is found throughout much of western North America from the western Great Plains to intermountain and southwestern U.S. Elevation ranges from sea level to 7,218 ft (2,200 m). Stands occur after disturbance of a natural shrub- or grass-dominated community resulting in the replacement of the natural vegetation by non-native, annual grass species of *Bromus*. At Wind Cave National Park in South Dakota, weedy non-native graminoid vegetation occurs on recently disturbed areas, most commonly along roads. Small stands also occur in prairie dog towns (H. Marriott pers. comm. 1999). In the Great Basin, *Bromus tectorum* grasslands has invaded large areas of burned-over sagebrush steppe. *Bromus tectorum* increases the fire frequency of steppe communities, which eventually eliminates sagebrush (FEIS 2001).

MOST ABUNDANT SPECIES

Walnut Canyon National Monument

Stratum	Species
Shrub	*Gutierrezia sarothrae*
Herbaceous	*Bromus tectorum, Bromus rubens*

Globally

Stratum	Species
Shrub	*Gutierrezia sarothrae*
Herbaceous	*Bromus tectorum, Bromus rubens*

ASSOCIATED SPECIES

Walnut Canyon National Monument

Amaranthus sp., *Convolvulus arvensis, Elymus elymoides, Erigeron divergens, Hymenoxys richardsonii, Linaria genistifolia, Packera multilobata, Sphaeralcea* sp. (all occur with >1% cover)

Globally

Bromus carinatus, Bromus hordeaceus, Bromus madritensis, Bromus japonicus, Bromus rigidus, Bromus rubens

VEGETATION DESCRIPTION

Walnut Canyon National Monument

Bromus (tectorum, rubens) Semi-natural Herbaceous Alliance total vegetation cover was 44% with 1% in the tree layer, 20% in the shrub layer, and 23% in the herbaceous layer. Only one relevé was sampled with total species diversity of 26.

The tree layer was sparse. The shrub layer was dominated by *Gutierrezia sarothrae* with absolute cover of 7%. The herbaceous layer was dominated by the invasive annual grasses *Bromus tectorum* and *Bromus rubens* with absolute cover of 12%.

Globally

This alliance-level vegetation type is characterized by a sparse to dense short annual graminoid layer that is typically dominated by *Bromus tectorum* with over 80-90% of the total vegetation cover. Other Eurasian introduced annual species of *Bromus* which may alternatively dominate or codominate are *Bromus carinatus, Bromus hordeaceus, Bromus madritensis, Bromus japonicus, Bromus rigidus*, or *Bromus rubens*. Although there may be remnant species of the former native vegetation, the high cover of annual bromes makes it difficult to determine what natural community was formerly present. At Wind Cave National Park in South Dakota, this weedy non-native graminoid vegetation is usually dominated by several perennial and annual brome grasses, including *Bromus inermis, Bromus japonicus*, and cheatgrass *Bromus tectorum*. Cover is variable (H. Marriott pers. comm. 1999).

CONSERVATION RANK GW

DATABASE CODE CEGL003019

MAP CLASSES

Cheatgrass Semi-Natural Herbaceous Vegetation is represented by map class Snakeweed / Modified Grassland Complex (map code 7).

Snakeweed / Modified Grassland Complex was mapped as part of a mosaic within the chained areas in the project environs, dominated by the exotic invasives *Bromus tectorum* and *Bromus rubens*. The following vegetation types were mapped as one class: *Gutierrezia sarothrae* Modified Dwarf-shrubland [provisional], *Bromus* (*tectorum, rubens*) Semi-natural Herbaceous Alliance, *Aristida purpurea* Herbaceous Vegetation, *Bouteloua eriopoda* Herbaceous Vegetation, and *Ericameria nauseosa – Gutierrezia sarothrae* Shrubland (local assemblage). The total area of this complex within Walnut Canyon NM is 101 ac (41 ha) within 10 polygons and the total area in the park environs is 2,417 ac (978 ha) within 28 polygons.

COMMENTS

Walnut Canyon National Monument

Disturbed alliances and associations have not been well defined in the NVCS; therefore, further study will allow for better classification of the alliances and associations.

Globally

This alliance also includes grasslands dominated or codominated by other Eurasian introduced annual *Bromus* species, but is distinct from the annual *Bromus* communities found along the Pacific Coast with Mediterranean or maritime climates because it does not have the introduced annual oatgrass (*Avena barbata* and *Avena fatua*), or other species typical of the California annual grassland (Sawyer and Keeler-Wolf 1995).

DYNAMICS

Globally

Bromus tectorum is an annual grass and is able to complete its lifecycle in the spring before drying out mid-summer. Its fine structure makes it extremely flammable when dry, and it will increase the fire frequency of a site (FEIS 2001). Frequent fires favor *Bromus tectorum* because they eliminate competing perennial vegetation, but do not kill all the *Bromus tectorum* seeds, which survive in the unburned organic material (FEIS 2001). This altered ecological process has promoted the spread of *Bromus tectorum* and other exotic annual bromes at the expense of sagebrush shrublands in large parts of the western U.S. (Daubenmire 1975, Young and Evans 1973, 1978).

This type is most common where disturbances have eliminated or largely set back the native vegetation. Where the brome grasses are invading native vegetation, the types may still be tracked as native types, since the native species may still persist. A recent study (Karl et al. 1999) found that despite strong seed and seedling production by the exotic brome grasses (*Bromus japonicus*, *Bromus tectorum*), the large amount of herbaceous biomass produced by the two vegetatively propagating native grasses, *Bouteloua gracilis* and *Pascopyrum smithii* suggests that these native grasses may well maintain their ecological importance in the stands.

In Nevada, Beatley (1976) found dense stands of the introduced winter annual grass *Bromus tectorum* growing in disturbed *Artemisia* shrublands. *Bromus rubens* is more common in lower elevation sites, and *Bromus tectorum* is most common in higher elevation sagebrush and pinyon-juniper communities.

REFERENCES

Beatley 1976, Daubenmire 1975, FEIS 2001, Karl et al. 1999, Sawyer and Keeler-Wolf 1995, Thompson 2001, Von Loh 2000, Young and Evans 1973, Young and Evans 1978

Muhlenbergia montana Herbaceous Vegetation

MAP CLASS	Blue Grama – Mountain Muhly Grassland Group
COMMON NAME	Mountain Muhly 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.d.)
ALLIANCE	*Muhlenbergia montana* Herbaceous Vegetation

CLASSIFICATION CONFIDENCE LEVEL Moderate

USFS WETLAND SYSTEM Upland

RANGE

Walnut Canyon National Monument

Mountain Muhly Herbaceous Vegetation occurs mostly as small isolated patches throughout the project boundary within Ponderosa Pine / Blue Grama Woodland map class. This association was found from our relevé data on USDA-FS and State Lands, specifically northwest of Walnut Canyon and near Anderson Mesa.

Globally

This plant association forms meadows in the mountains and foothills of Colorado, Arizona and Utah.

ENVIRONMENTAL DESCRIPTION

Walnut Canyon National Monument

Only two relevés were assigned to this alliance, with elevation ranging from 6,857-6,890 ft (2,090-2,100 m). Both relevés were recorded on moderate slopes of (11-14%).

Globally

This plant association has been described from meadows in the mountains, plateaus and foothills of Colorado, Arizona and Utah. Elevation ranges from 7,540-9,200 ft (2,300-2,800 m). Sites are typically xeric forest openings or parks in the Ponderosa Pine zone with southern aspects on moderately steep slopes and ridgetops. Occasionally the stands occupy rolling parklands or volcanic cinder fields. The xeric nature of sites appears to be an important environmental factor. Substrates are shallow to moderately deep, rocky, sand to sandy loam textured soils sometimes with a distinct clay horizon. Parent materials are primarily colluvium derived from granite and gneiss or cinder. Bare soil, exposed gravels, and small rocks account for as much as 50% of the ground surface area.

MOST ABUNDANT SPECIES

Walnut Canyon National Monument

Stratum	Species
Herbaceous	*Muhlenbergia montana*

Globally

Stratum	Species
Herbaceous	*Muhlenbergia montana*

ASSOCIATED SPECIES

Walnut Canyon National Monument

Bouteloua gracilis, Eriogonum racemosum, Festuca arizonica, Heterotheca villosa, Juniperus osteosperma, Lupinus sp., *Pinus ponderosa, Quercus gambelii, Robinia neomexicana* (all occur with >1% cover)

Globally

Allium geyeri, Antennaria rosea, Arenaria fendleri, Artemisia frigida, Blepharoneuron tricholepis, Bouteloua curtipendula, Bouteloua gracilis, Carex duriuscula, Danthonia parryi, Elymus albicans, Eriogonum

umbellatum,Festuca brachyphylla, Harbouria trachypleura, Hesperostipa comata, Heterotheca villosa, Koeleria macrantha, Mertensia lanceolata,Muhlenbergia filiculmis, Opuntia polyacantha, Pascopyrum smithii, Penstemon secundiflorus, Phlox diffusa, Poa secunda, Schizachyrium scoparium, Trisetum spicatum

VEGETATION DESCRIPTION

Walnut Canyon National Monument

Only two relevés were assigned to the Mountain Muhly Herbaceous Vegetation with total vegetation cover of 42 and 48%, with 9 and 17% absolute cover in the tree layer, 2 and 7% absolute cover in the shrub layer, and 25 and 32% absolute cover in the herbaceous layer. The species diversity in the two relevés was 25 and 26 species.

In both relevés the tree layer consisted of a sparse *Pinus ponderosa* cover (4 and 9% absolute cover) and DBH ranged from 6-11 in (14-29 cm) (average 9 in/24 cm). The shrub layer was sparse and not dominated by a single species. *Muhlenbergia montana* was the dominant herbaceous species with 12 and 22% absolute cover. *Bouteloua gracilis* occurred in both relevés with generally lower cover (5-14%) than *Muhlenbergia montana*.

Globally

This association is characterized by a moderately dense herbaceous layer that is typically dominated by the warm-season, perennial bunchgrass *Muhlenbergia montana*, but may be codominated by *Blepharoneuron tricholepis* or *Trisetum spicatum (= Trisetum montanum)* (in New Mexico). Other associated graminoids include *Bouteloua curtipendula, Bouteloua gracilis, Carex duriuscula (= Carex eleocharis), Danthonia parryi, Elymus albicans (= Elymus lanceolatus* ssp. *albicans), Festuca brachyphylla, Hesperostipa comata, Koeleria macrantha, Muhlenbergia filiculmis, Pascopyrum smithii, Poa secunda*, and *Schizachyrium scoparium*. The typically sparse forb layer often consists of *Allium geyeri, Antennaria rosea, Arenaria fendleri, Eriogonum umbellatum, Harbouria trachypleura, Heterotheca villosa, Mertensia lanceolata, Opuntia polyacantha, Penstemon secundiflorus* and *Phlox diffusa.* Except for the abundant dwarf-shrub *Artemisia frigida*, scattered *Ericameria nauseosa* shrub or occasional *Pinus ponderosa* trees, woody species are very sparse or absent. Occasional *Pinus ponderosa* trees may be present. The exotic grasses *Poa pratensis* and *Bromus tectorum* are common in some of these stands. Diagnostic of this grassland association is the dominance of *Muhlenbergia montana* in the herbaceous layer and low cover of *Festuca arizonica*.

CONSERVATION RANK G3G4

DATABASE CODE CEGL001646

MAP CLASSES

Mountain Muhly Herbaceous Vegetation is represented by map class Blue Grama - Mountain Muhly Grassland Group (map code 4).

Due to the inability to distinguish the differences in herbaceous species from aerial photography, *Bouteloua gracilis* Herbaceous Vegetation and *Muhlenbergia montana* Herbaceous Vegetation were combined into the map class Blue Grama - Mountain Muhly Grassland Group. The total area of this group within Walnut Canyon NM is 10 ac (4 ha) within 12 polygons and the total area in the park environs is 217 ac (88 ha) within 72 polygons.

COMMENTS

Walnut Canyon National Monument

These small isolated patches of grassland may be relics of pre-settlement conditions where this grass occurred in large parks rather than isolated patches. These patches of grassland do not have high shrub cover and are hence a grassland rather than shrub herbaceous or steppe.

Although both Mountain Muhly Herbaceous Vegetation and Blue Grama Herbaceous Vegetation have a co-dominance of *Bouteloua gracilis* and *Muhlenbergia montana, Muhlenbergia montana* takes precedence in these mixed community types. If *Bouteloua gracilis* has higher cover than *Muhlenbergia montana* then this association is classified as Blue Grama Herbaceous Vegetation; however, if *Muhlenbergia montana* has equal or higher cover than *Bouteloua gracilis* than the vegetation is classified as Mountain Muhly Herbaceous Vegetation.

DYNAMICS

Globally

Muhlenbergia montana often grows in association with montane conifer forests, especially ones dominated by *Pinus ponderosa* and has developed a tolerance for relatively frequent fire regimes. Although *Muhlenbergia montana* resprouts after burning, it may take a few years to recover to pre-burn density (Fischer and Bradley 1987) These grasslands may be considered seral or an edaphic climax depending if there are environmental factors, such as aridity, that are preventing establishment of trees. Historically, much of the area where this association occurs was heavily grazed by livestock, primarily sheep and cattle (Shepherd 1975). Season of use is important in stands with both *Hesperostipa comata* and *Muhlenbergia montana*; fall grazing will favor *Hesperostipa comata* over the later blooming *Muhlenbergia montana* (Clary 1978). The reverse is true if grazing is always limited to summer. Overgrazing will reduce or eliminate *Hesperostipa comata*, *Muhlenbergia montana* and the other palatable species, leaving the more grazing-tolerant *Bouteloua gracilis* and less palatable plants such as *Hymenoxys*, *Artemisia* and *Chrysothamnus* species to dominate the site Clary (1978).

REFERENCES

Bourgeron and Engelking 1994, Clary 1978, Driscoll et. al. 1984, Fischer and Bradley 1987, Hansen et al. 2003, ,Johnston 1987, Loveless 1963, Loveless 1967, McIntosh 1923, Merkle 1962, Ramaley 1915, Ramaley 1916a, Ramaley 1916b, Reid 1974, Shanks 1977, Shepherd 1975, Terwilliger et. al. 1979, U.S. Forest Service 1983b, Western Ecology Working Group of NatureServe

Pascopyrum smithii Herbaceous Vegetation

MAP CLASS	Introduced Western Wheatgrass Grassland
COMMON NAME	Western Wheatgrass 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 sod temperate or subpolar grassland (V.A.5.N.c.)
ALLIANCE	*Pascopyrum smithii* Herbaceous Alliance

CLASSIFICATION CONFIDENCE LEVEL Weak

USFS WETLAND SYSTEM Upland

Walnut Canyon National Monument
This association was only described during the photointerpretation process. No field data was collected on the specifics of this vegetation type.

CONSERVATION RANK G3G5Q

DATABASE CODE CEGL001577

MAP CLASSES
This map class was mapped as occurring in small linear polygons in the northeastern section of the project area, inside or adjacent to the map class Snakeweed / Modified Grassland Complex. The total area of this group within Walnut Canyon NM is 1 ac (0.4 ha) within 1 polygon and the total area in the park environs is 15 ac (6 ha) within 11 polygons.

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APPENDIX F

F. Walnut Canyon 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
Aceraceae	*Acer negundo* L.	boxelder
Agavaceae	*Agave parryi* Engelm.	Parry's agave
	Yucca angustissima Engelm. ex Trel.	narrowleaf yucca
	Yucca baccata Torr.	banana yucca
Amaranthaceae	*Amaranthus biltoides* S. Wats.	mat amaranth
Anacardiaceae	*Rhus trilobata* Nutt.	skunkbush sumac
	Toxicodendron radicans (L.) Kuntze	eastern poison ivy
Apiaceae	*Pseudocymopterus montanus* (Gray) Coult. & Rose	alpine false springparsley
Apocynaceae	*Apocynum cannabinum* L.	Indianhemp
Asclepiadaceae	*Asclepias asperula* (Dcne.) Woods.	spider milkweed
	Asclepias subverticillata (Gray) Vail	horsetail milkweed
	Asclepias sp. L.[1]	milkweed
Asteraceae	*Achillea millefolium* L.	common yarrow
	Ambrosia acanthicarpa Hooke.	flatspine burr ragweed
	Ambrosia artemisiifolia L.	annual ragweed
	Ambrosia tomentosa Nutt.	skeletonleaf burr ragweed
	Antennaria marginata Greene	whitemargin pussytoes
	Antennaria parviflolia Nutt.	small-leaf pussytoes
	Artemisia campestris ssp. *pacifica* (Nutt.) Hall & Clements	field sagewort
	Artemisia carruthii Wood ex Carruth.	Carruth's sagewort
	Artemisia dracunculus ssp. *dracunculus* L.	tarragon
	Artemisia frigida Willd.	prairie sagewort
	Artemisia ludoviciana Nutt.	white sagebrush
	Aster sp. L.	aster
	Bahia dissecta (Gray) Britt.	ragleaf bahia
	Brickellia californica (Torr. & Gray) Gray	California brickellbush
	Brickellia grandiflora (Hook.) Nutt.	tasselflower brickellbush
	Brickellia sp. Ell.	brickellbush
	Chaetopappa ericoides (Torr.) Nesom	rose heath
	Chrysothamnus depressus Nutt.	longflower rabbitbrush
	Chrysothamnus sp. Nutt.	rabbitbrush
	Cirsium arizonicum (Gray) Petrak	Arizona thistle
	Cirsium calcareum (M.E. Jones) Woot. & Standl.	Cainville thistle
	Cirsium wheeleri (Gray.) Petrak	Wheeler's thistle
	Cirsium sp. P. Mill.	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 formosissimus Greene	beautiful fleabane
	Gaillardia pinnatifida Torr.	red dome blanketflower
	Grindelia nuda Wood var. *aphanactis* (Rydb.) Nesom	curlytop gumweed
	Gutierrezia sarothrae (Pursh) Britt. & Rusby	broom snakeweed

[1] Genera that do not include specific epithets are unique unidentified species.

Family	Scientific Name	Common Name
	Helianthus petiolaris Nutt.	prairie sunflower
	Heliomeris longifolia var. *annua* (M.E. Jones) Yates	longleaf false goldeneye
	Heliomeris multiflora var. *multiflora* Nutt.	showy goldeneye
	Heterotheca villosa (Pursh) Shinners	hairy false goldenaster
	Hymenopappus filifolius var. *lugens* (Greene) Jepson	Idaho hymenopappus
	Hymenoxys bigelovii (Gray) Parker	Bigelow's rubberweed
	Hymenoxys richardsonii (Hook.) Cockerell	pingue rubberweed
	Lactuca serriola L.	prickly lettuce
	Machaeranthera canescens ssp. *canescens* var. *canescens* (Pursh) Gray	hoary tansyaster
	Machaeranthera gracilis (Nutt.) Shinners	slender goldenweed
	Machaeranthera grindelioides var. *grindelioides* (Nutt.) Shinners	rayless tansyaster
	Packera multilobata (Torr. & Gray ex Gray) W.A. Weber & A. Löve	lobeleaf groundsel
	Packera neomexicana var. *neomexicana* (Gray) W.A. Weber & A. Löve	New Mexico groundsel
	Parthenium incanum Kunth.	mariola
	Psilostrophe sparsiflora (Gray) A. Nels.	greenstem paperflower
	Senecio flaccidus var. *flaccidus* Less.	threadleaf ragwort
	Senecio spartioides Torr. & Gray	broomlike ragwort
	Senecio sp. L.	ragwort
	Solidago canadensis L.	Canada goldenrod
	Solidago velutina DC.	threenerve goldenrod
	Stephanomeria sp. Nutt.	wirelettuce
	Symphyotrichum falcatum var. *crassulum* (Rydb.) Nesom	white prarie aster
	Tetradymia canescens DC.	spineless horsebrush
	Tetraneuris acaulis var. *acaulis* (Pursh) Greene	stemless four-nerve daisy
	Tragopogon dubius Scop.	yellow salsify
Berberidaceae	*Mahonia fremontii* (Torr.) Fedde	Fremont's mahonia
	Mahonia haematocarpa (Woot.) Fedde	red barberry
	Mahonia repens (Lindl.) G. Don	creeping barberry
Boraginaceae	*Cryptantha cinerea* var. *jamesii* Cronq.	James' cryptantha
	Lappula occidentalis (S. Wats.) Greene	flatspine stickseed
	Lithospermum multiflorum Torr. ex Gray	manyflowered stoneseed
	Macromeria viridiflora DC.	giant-trumpets
Brassicaceae	*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
	Draba asprella Greene	rough draba
	Lesquerella intermedia (S. Wats.) Heller	mid bladderpod
Cactaceae	*Echinocereus* sp. Engelm.	hedgehog cactus
	Echinocereus triglocidiatus Engelm.	kingcup cactus
	Mammillaria sp. Haw	globe cactus
	Opuntia phaeacantha Engelm.	tulip pricklypear
	Opuntia sp. P. Mill.	pricklypear
Cannabaceae	*Humulus lupulus* var. *lupuloides* E. Small	common hop
Caprifoliaceae	*Lonicera arizonica* Rehd.	Arizona honeysuckle

Family	Scientific Name	Common Name
	Sambucus nigra ssp. Cerulea (Raf.) R. Bolli	European black elderberry
	Symphoricarpos rotundifolius var. *parishii* (Rydb.) Dempster	Parish's snowberry
	Symphoricarpus oreophilus Gray	mountain snowberry
Caryophyllaceae	*Arenaria eastwoodiae* Rydb.	Eastwood's sandwort
	Arenaria lanuginosa (Michx.) Rohrb.	spreading sandwort
Chenopodiaceae	*Atriplex canescens* (Pursh) Nutt.	fourwing saltbush
	Chenopodium berlandieri Moq.	pitseed goosefoot
	Chenopodium fremontii S. Wats.	Fremont's goosefoot
	Chenopodium graveolens Willd.	fetid goosefoot
	Krascheninnikovia lanata (Pursh) Guldenstaedt	winterfat
	Salsola tragus L.	prickly Russian thistle
Convolvulaceae	*Convolvulus arvensis* L.	field bindweed
Cornaceae	*Cornus sericea* ssp. *sericea* L.	redosier dogwood
Crassulaceae	*Sedum cockerellii* Britt.	Cockerell's stonecrop
Cupressaceae	*Juniperus deppeana* Steud.	alligator juniper
	Juniperus monosperma (Engelm.) Sarg.	oneseed juniper
	Juniperus osteosperma (Torr.) Little	Utah juniper
	Juniperus scopulorum Sarg.	Rocky Mountain juniper
	Juniperus sp. L.	juniper
Cyperaceae	*Carex foenea* var. *foenea* Willd.	dryspike sedge
	Carex sp.	sedge
Ephederaceae	*Ephedra viridis* Coville	mormon tea
Euphorbiaceae	*Chamaesyce fendleri* (Torr. & Gray) Small	Fendler's sandmat
	Euphorbia brachycera Engelm.	horned spurge
	Euphorbia sp. L.	spurge
Fabaceae	*Astragalus humistratus* Gray	groundcover milkvetch
	Astragalus lentiginosus Dougl. ex Hook.	freckled milkvetch
	Astragalus sp. L.	milkvetch
	Lotus wrightii (Gray) Greene	Wright's deervetch
	Lupinus argenteus Pursh	silvery lupine
	Lupinus sp. L.	lupine
	Medicago sativa L.	alfalfa
	Melilotus officinalis (L.) Lam.	yellow sweetclover
	Mimosa sp. L.	sensitive plant
	Oxytropis lambertii Pursh	purple locoweed
	Phaseolus angustissimus Gray	slimleaf bean
	Psoralidium tenuiflorum (Pursh) Rydb.	slimflower scurfpea
	Robinia neomexicana Gray	New Mexico locust
	Vicia americana Muhl. Ex Willd.	American vetch
Fagaceae	*Quercus gambelii* Nutt.	Gambel oak
Geraniaceae	*Erodium cicutarium* (L.) L'Her. ex Ait	redstem stork's bill
	Geranium caespitosum James	pineywoods geranium
	Geranium caespitosum var. *eremophilum* (Woot. & Standl.) W.C Martin & C.R. Hutchins	purple cluster geranium
	Geranium sp. L.	geranium
Grossulariaceae	*Ribes cereum* Dougl.	wax currant

Family	Scientific Name	Common Name
Hydrophyllaceae	*Phacelia egena* (Greene ex Brand) Greene ex J.T. Howell	Kaweah River phacelia
Iridaceae	*Iris missouriensis* Nutt.	Rocky Mountain iris
Juglandaceae	*Juglans major* (Torr.) Heller	Arizona walnut
Lamiaceae	*Hedeoma hyssopifolia* Gray	aromatic false pennyroyal
	Hedeoma nana ssp. *macrocalyx* W.S. Stewart	dwarf false pennyroyal
	Hedeoma sp. Pers.	false pennyroyal
	Marrubium vulgare L.	horehound
	Monarda fistulosa ssp. *fistulosa* var. *menthifolia* (Graham) Fern.	wild bergamot
	Monardella odoratissima Benth.	mountain monardella
Liliaceae	*Disporum trachycarpum* (S. Wats.)Benth. & Hook. f.	roughfruit fairybells
	Maianthemum racemosum (L.) Link	feathery false lily of the vally
	Maianthemum stellatum (L.) Link	starry false lily of the vally
	Zigadenus elegans Pursh	mountain deathcamas
Linaceae	*Linum lewisii* Pursh	prairie flax
	Linum neomexicanum Greene.	New Mexico yellow flax
	Linum sp. L.	flax
Malvaceae	*Malva neglecta* Wallr.	common mallow
	Sphaeralcea fendleri Gray	Fendler's globemallow
	Sphaeralcea parvifolia A. Nels.	smallflower globemallow
	Sphaeralcea sp. St.-Hil.	globemallow
Nyctaginaceae	*Mirabilis bigelovii* Gray	wishbone-bush
	Mirabilis decipiens (Standl.) Standl.	broadleaf four o'clock
	Mirabilis linearis (Pursh) Heimerl	narrowleaf 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 sp. L.	evening-primrose
Pinaceae	*Pinus edulis* Engelm.	twoneedle pinyon
	Pinus ponderosa P. & C. Lawson	ponderosa pine
	Pseudotsuga menziesii (Mirbel) Franco	Douglas-fir
Plantaginaceae	*Plantago lanceolata* L.	narrowleaf plantain
	Plantago patagonica Jacq.	woolly plantain
Poaceae	*Agropyron desertorum* (Fisch. Ex Link) J.A. Schultes	desert wheatgrass
	Aristida divaricata Humb. & Bonpl. ex Willd.	poverty threeawn
	Aristida purpurea Nutt. var. *longiseta* (Steud.) Vasey	Fendler’s threeawn
	Aristida purpurea var. *fendleriana* (Steud.) Vasey	Fendler's threeawn
	Aristida sp. L.	threeawn
	Bouteloua curtipendula (Michx.) Torr.	sideoats grama
	Bouteloua eriopoda (Torr.) Torr.	black 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
	Dactylis glomerata L.	orchardgrass
	Elymus elymoides ssp. *elymoides* (Raf.) Swezey	squirreltail

Family	Scientific Name	Common Name
	Elymus sp. L.	wildrye
	Eragrostis lehmanniana Nees	Lehmann lovegrass
	Festuca arizonica Vasey	Arizona fescue
	Monroa squarrosa (Nutt.) Torr.	false buffalograss
	Muhlenbergia montana (Nutt.) A.S. Hitchc.	mountain muhly
	Muhlenbergia rigens (Benth.) A.S. Hitchc.	deergrass
	Pascopyrun smithii (Rydb.) A. Love	western wheatgrass
	Poa fendleriana (Steud.) Vasey	muttongrass
	Poa secunda J. Presl	Sandberg bluegrass
	Schizachyrium scoparium ssp. *scoparium* (Michx.) Nash	little bluestem
	Sporobolus cryptandrus (Torr.) Gray	sand dropseed
	Sporobolus sp. Br.	alkali sacaton
Polemoniaceae	*Ipomopsis aggregata* ssp. *aggregata* (Pursh) V. Grant	scarlet gilia
	Ipomopsis arizonica (Greene) Wherry	Arizona ipomopsis
	Ipomopsis multiflora (Nutt.) V. Grant	manyflowered ipomopsis
Polygonaceae	*Eriogonum alatum* Torr.	winged buckwheat
	Eriogonum corymbosum var. *aureum* (M.E. Jones) Reveal	crispleaf buckwheat
	Eriogonum divaricatum Hook.	divergent buckwheat
	Eriogonum jamesii Benth.	James' buckwheat
	Eriogonum jonesii S. Stewart	Jones' buckwheat
	Eriogonum microthecum Nutt.	slender buckwheat
	Eriogonum racemosum Nutt.	redroot buckwheat
	Eriogonum umbellatum var. *cognatum* (Greene) Reveal	sulphur-flower buckwheat
	Eriogonum sp. Mitchx.	buckwheat
	Polygonum aviculare L.	prostrate knotweed
Polypodiaceae	*Cheilanthes feei* T. Moore	slender lipfern
Portulacaceae	*Portulaca oleracea* L.	little hogweed
Ranunculaceae	*Clematis lingusticifolia* Nutt.	western white clematis
	Thalictrum fendleri Engelm. ex Gray	Fendler's meadow-rue
Rosaceae	*Agrimonia gryposepala* Wallr.	tall hairy agrimony
	Amelanchier utahensis Koehne	Utah serviceberry
	Cercocarpus montanus Raf.	alderleaf mountain mahogany
	Chamaebatiaria millefolium (Torr.) Maxim	fernbush
	Fallugia paradoxa (D. Don) Endl. ex Torr.	Apache plume
	Petrophytum caespitosum (Nutt.) Rydb.	mat rockspirea
	Prunus virginiana L.	chokecherry
	Purshia mexicana (D. Don) Henrickson	Mexican cliffrose
	Purshia stansburiania (Torr) Henrickson	Stansbury cliffrose
	Rosa woodsii var. *ultramontana* (S. Wats.) Jepson	Woods' rose
Rubiaceae	*Galium stellatum* Kellogg	bedstraw
	Galium wrightii Gray	Wright's bedstraw
	Galium sp. L.	starry bedstraw
Rutaceae	*Ptelea trioliata* ssp. *angustifolia* (Benth.) V. Bailey	common hoptree
Salicaceae	*Salix laevigata* Bebb.	red willow
	Salix lasiolepis Benth.	arroyo willow
Saxifragaceae	*Heuchera parviflora* Bartl.	littleleaf alumroot

Family	Scientific Name	Common Name
	Heuchera rubescens var. *versicolor* (Greene) M.G. Stewart	pink alumroot
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 jamesii Benth.	James' beardtongue
	Penstemon linarioides Gray	toadflax penstemon
	Penstemon linarioides ssp. *compactifolius* Keck	toadflax beardtongue
	Penstemon rostriflorus Kellogg	Bridge penstemon
	Penstemon sp. Schmidel	penstemon
	Penstemon thompsoniae (Gray) Rydb.	Thompson's beardtongue
	Verbascum thapsus L.	common mullein
Solanaceae	*Datura wrightii* Regel	sacred thorn-apple
	Lycium pallidum Miers	pale desert-thorn
	Physalis hederifolia var. *fendleri* (Gray) Cronq.	Fendler's groundcherry
Valerianaceae	*Valeriana arizonica* Gray	Arizona valerian
	Valeriana edulis Nutt. ex Torr. & Gray	tobacco root
Verbenaceae	*Verbena bracteata* Lag. & Rodr.	bigbract verbena
Viscaceae	*Phoradendron juniperinum* Engelm.	juniper mistletoe
Vitacaceae	*Parthenocissus quinquefolia* (L.) Planch.	Virginia creeper
	Parthenocissus vitacea (Knerr) A.S. Hitchc.	woodbine
	Vitis arizonica Engelm.	canyon grape

APPENDIX G

G. Visual Guide and Descriptions of the Walnut Canyon National Monument Map classes

Introduction

This document is a guide to the photointerpretation of vegetation map classes for Walnut Canyon National Monument. Its purpose is to provide a ground photo image for each map class, provide visual examples of each map code with aerial photographs and delineated overlays, and provide descriptions for the visual examples.

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.

How this Guide is Organized

This guide describes and illustrates every vegetation map class used in the Walnut Canyon 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 code in yellow. 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 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.

The map classes are arranged 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 page number for that map code.

Aerial Photographs

Merrick, & Company of Aurora, Colorado flew the aerial photographs for WACA on October 8, 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 CIR 9 x 9-in photos is 1:12,000 (approximately 1 in = 1,000 ft, 1 cm = 102 m). Two sets of contact prints were produced and used for stereoscopic interpretation. A total of 44 frames taken over six 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.

Texture is also important to the photointerpreter. For trees, texture is influenced by type and orientation of leaves, crown size and shape, and branch structure. An uneven canopy will appear lumpy, an even canopy smooth. Similarly, trees having small crowns will appear a finer texture than trees that have large crowns. Depending on the tree species, the texture can be rough or smooth, fine, lacy, billowy, compact, or any number of other descriptors. These are imprecise terms, but nonetheless provide important visual cues to the imagery. In contrast, herbaceous vegetation, including wetland and upland communities, generally tend to lack texture (Hershey and Befort 1995).

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 (Hershey and Befort 1995). For accurate mapping at WACA, ground verification by both the photointerpreter and the project ecologists was very important for successful interpretation of types with confusing or similar signatures.

Literature Cited:

Hershey, Rachel Riemann; Befort, William A. 1995. Aerial photo guide to New England forest cover types. General Technical Report NE-195. Radnor, PA: USDA, Forest Service, Northeastern Forest Experiment Station. 70 p.

Alphabetical Index To the Vegetation Map Codes

Map Class Name	Unit #
Sparsely Vegetated Coconino Sandstone	1
Sparsely Vegetated Kaibab Limestone	2
Sparsely Vegetated Intermittent Drainage Channel	3
Blue Grama-Mountain Muhly Grassland Group	4
Introduced Western Wheatgrass Grassland	5
Common Horehound – Prairie Dog Town	6
Snakeweed/Modified Grassland Complex	7
Rabbitbrush/Blue Grama Shrub Herbaceous Vegetation	8
Limestone Rim Complex	9
Canyon Floor Complex	10
Pinyon Pine-Utah Juniper/Blue Grama Woodland	11
Ponderosa Pine-Pinyon Pine-Juniper/Blue Grama Woodland	12
Ponderosa Pine-Pinyon Pine-Juniper/Gambel Oak Woodland	13
Ponderosa Pine/Gambel Oak Woodland	14
Ponderosa Pine Mixed Graminoid Woodland Complex	15
Douglas-fir/Gambel Oak Forest	16

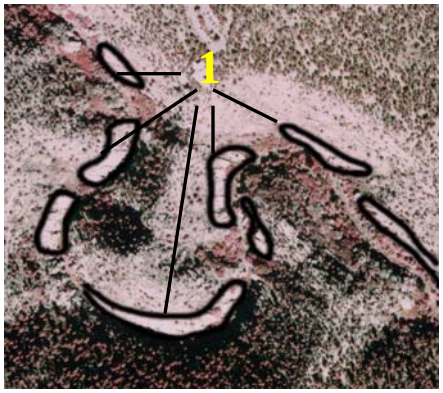
Alphabetical Index To the Anderson Land Use Map Codes

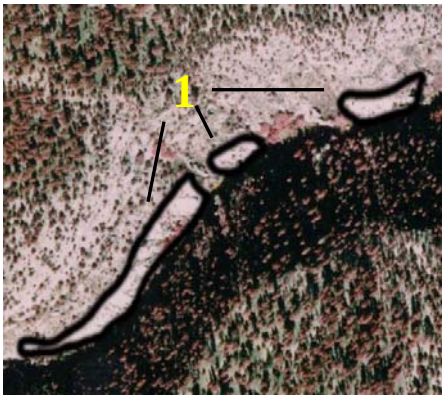
Map Class Name	Unit #
Rural Residential	17
Ranch Developments	18
NPS Facilities	19
Utility Corridors	20
Transportation Routes	21
Pastures	22
Reservoirs	23
Stock Tanks and Dams	24

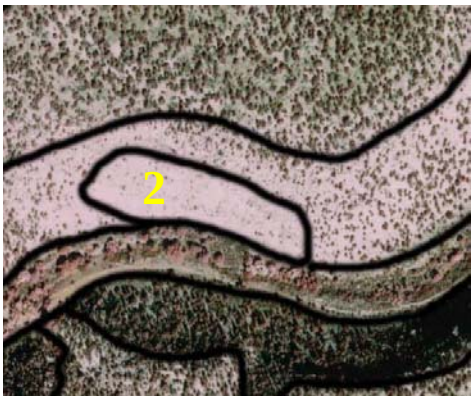
Sparsely Vegetated Coconino Sandstone (1) and Sparsely Vegetated Kaibab Limestone (2)

Location: Outcrops of Coconino sandstone and Kaibab limestone are exposed on the walls of Walnut Canyon. Kaibab limestone lies above the Coconino sandstone and appears higher on the canyon walls, while Coconino sandstone crops out only at the bottom of the canyon.

Photosignature: Both rock types appear white on the aerial photos and are distinguished primarily on the basis of relative position and texture. The ledgy stratigraphy of the limestone gives it a striated appearance in the photos, whereas the sandstone appears as narrow uniform bands.







Sparsely Vegetated Intermittent Drainage Channel (3)

Location: Floor of Walnut Canyon.

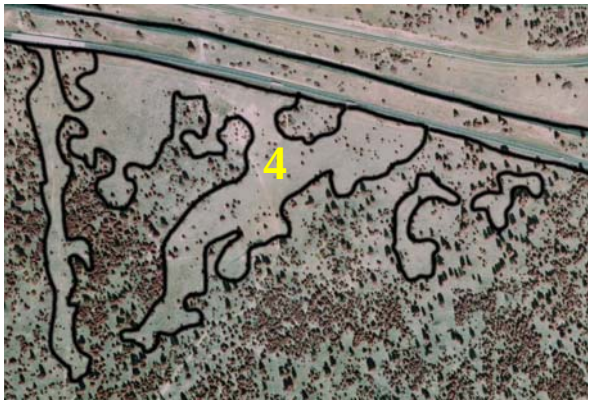
Photosignature: White due to unvegetated sands and gravels in the intermittent stream channel.

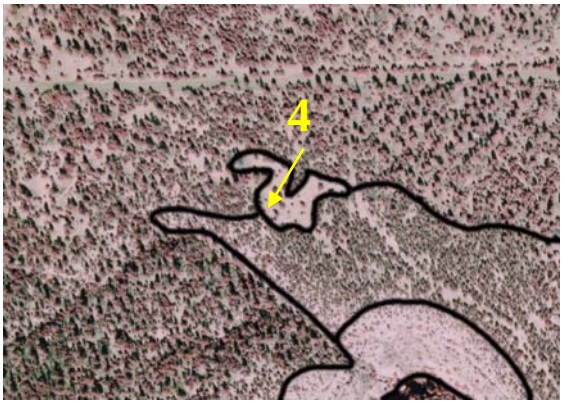
Figure: See figure on page G-21.

Blue Grama-Mountain Muhly Grassland Group (4)

Location: This mixed grassland occupies swales and openings among stands of ponderosa pine. Occurrences are scattered throughout the west half of the mapping area, both north and south of Walnut Canyon.

Photosignature: Smooth-textured, uniform pale green to whitish-gray. Small trees within the grasslands appear as dark red specks.

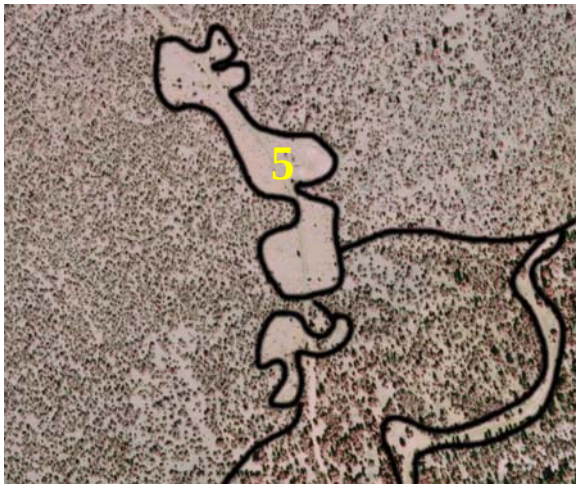




Introduced Western Wheatgrass Herbaceous Vegetation (5)

Location: This type occurs in clearings and meadows where it was planted following clear cutting or chaining of the original woodland vegetation. It was mapped on the basis of field observations.

Photosignature: Western wheatgrass meadows are gray to pale green and have an exceptionally smooth texture resulting from the rhizomatous growth form of the grass.

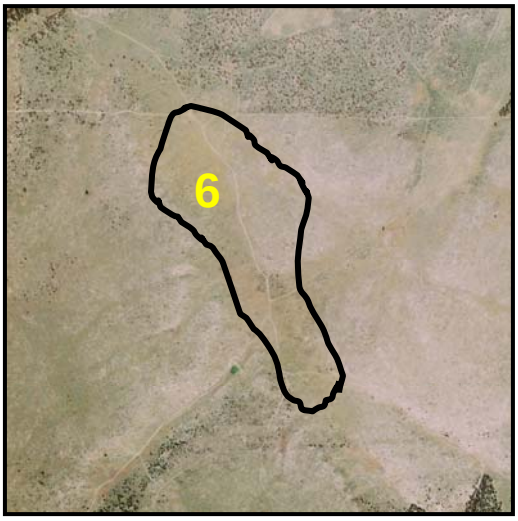


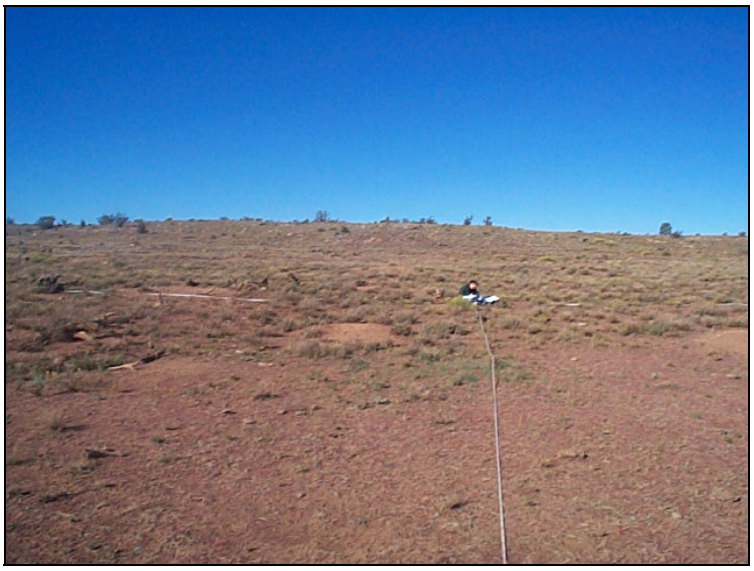
No ground photographs are available for this map class.

Common Horehound – Prairie Dog Town (6)

Location: This type is isolated to one relatively large polygon in the northeast quadrant of the project area. This map class is completely contained in the environs portion of the project.

Photosignature: This map unit is characterized by the disturbance created by prairie dog activity. Prairie dog impact is witnessed by the combination of the stippled, white holes representing their burrows and the smearing of yellow and orange colors resulting from the annual weedy vegetation growing on the site. The vegetation signature for this prairie dog town is caused by an abundance of common horehound.

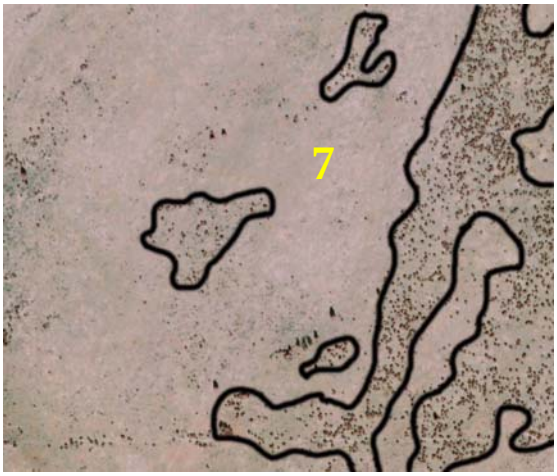


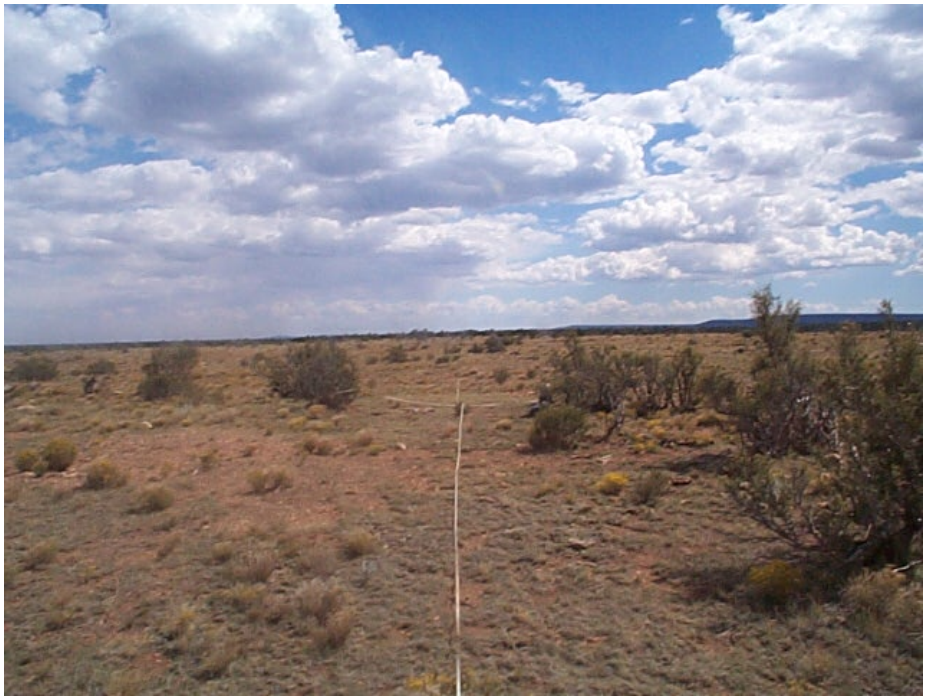


Snakeweed/Modified Grassland Complex (7)

Location: This type occurs in a large, nearly uninterrupted block in the northeastern part of the mapping area. It lies in an area between the Monument access road on the west, US Highway 40 on the north, and Walnut Canyon on the south and east.

Photosignature: This type is an aggregation of several disturbed and introduced grassland and shrubland types, so the signature is varied throughout its extent. The basic color is pale gray-green to pale green, with patches of white, darker green and pink representing the different vegetation types. Small juniper and pinyon trees are scattered throughout the type and appear as brown to reddish specks. Occasionally, linear striations that represent lines of chaining or plowing and planting are apparent.

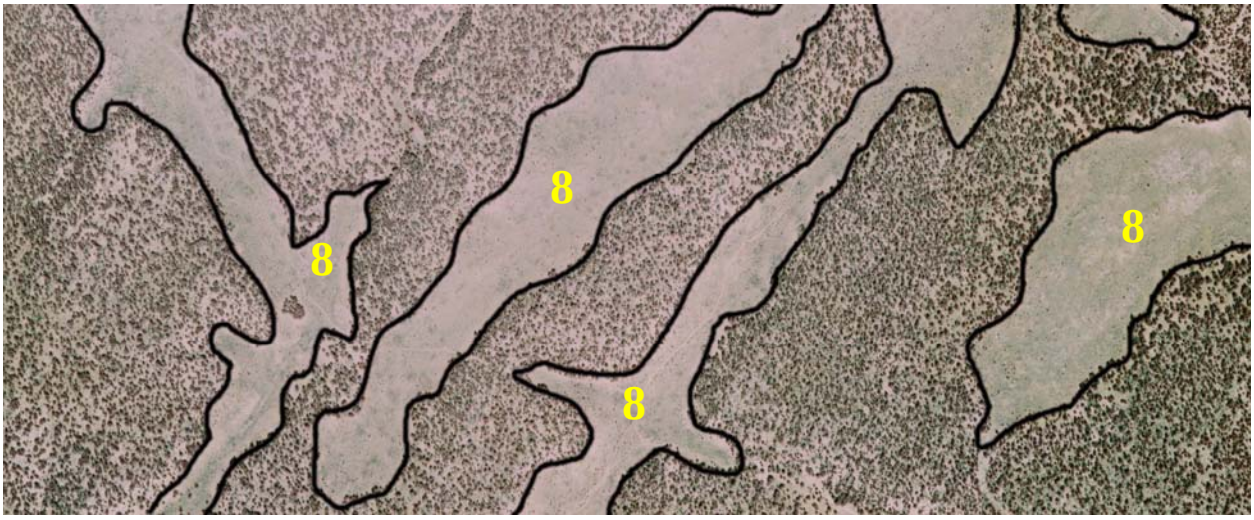




Rabbitbrush / Blue Grama Shrub Herbaceous Vegetation (8)

Location: Broad drainages and parks on the eastern side of the project area. The best examples are southeast of Walnut Canyon.

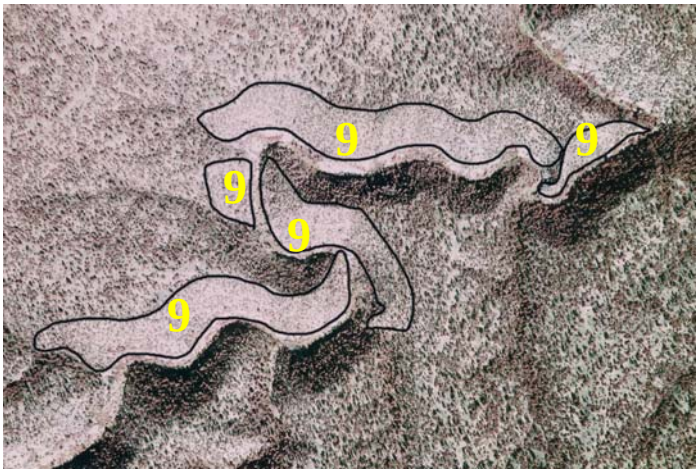
Photosignature: Predominantly smooth-textured and greenish-gray in color, although dense stands of rabbitbrush are indicated by a gritty texture.



Limestone Rim Complex (9)

Location: This complex of woodland, shrubland, and sparse plant associations occurs on south, east, and west-facing canyon slopes in Walnut Canyon. It also occurs on north-facing slopes in the lower part of Walnut Canyon where the canyon is wider and the walls are less steep.

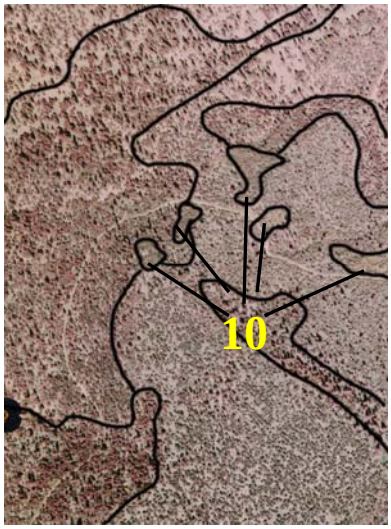
Photosignature: The basic color of the signature is white, modified by the type of vegetation present. Sparse vegetation tints the signature slightly gray to light green with a mottled texture. Denser shrublands and areas where pinyon pines and junipers grow are more speckled in appearance; the speckles are gray and brownish green.

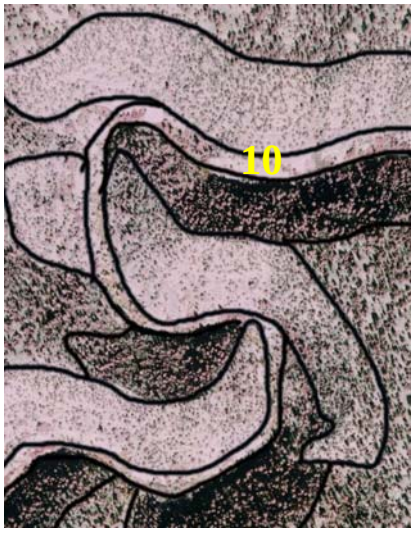


Canyon Floor Complex (10)

Location: This mosaic of deciduous types occupies the bottom of Walnut and Cherry Canyons on terraces above the former active channel. A few stands also occur in sheltered upland areas south of Walnut Canyon.

Photosignature: Because this map class includes several plant associations, the signature is a complicated one. Gambel oak stands have an even, pebbly texture and are dark red to orange red in color. Box elder and cottonwood trees tend to occur in smaller clumps or as scattered individuals, and the crowns are generally a brighter red. Clones of shrubs such as snowberry, chokecherry and wild privet appear as smoother red patches. The deciduous woodlands and shrublands are separated by an area of mixed forblands and grasslands, which appear pale gray on the photos.

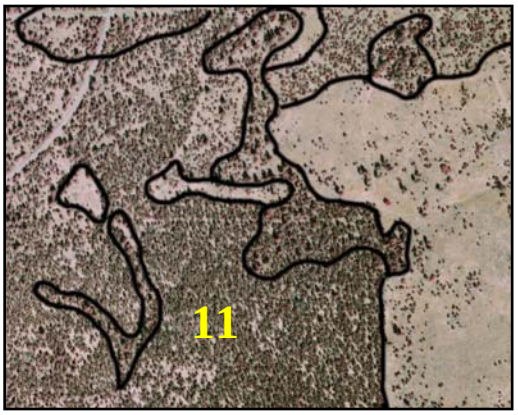


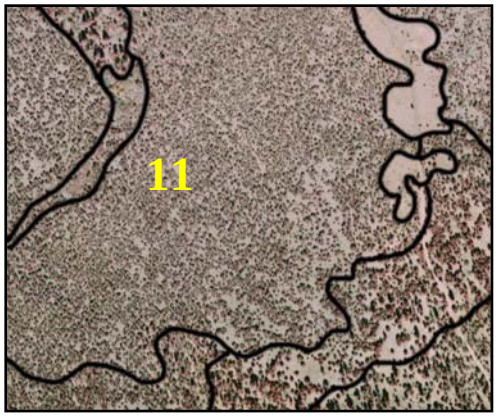


Pinyon Pine - Utah Juniper / Blue Grama Woodland (11)

Location: This type occupies large areas throughout the mapping area. It occurs east of the Monument access road, north of the canyon, and south of the canyon on a basalt covered slope of Anderson Mesa.

Photosignature: The older stands (mostly south of the canyon) have an evenly pebbly texture resulting from the even spacing of tree crowns. North of the canyon in the disturbed area the trees are in mixed aged stands with an uneven pebbly appearance. In both cases the tree crowns are grayish brown tinged with red.





Ponderosa Pine - Pinyon Pine - Juniper / Blue Grama Woodland (12)

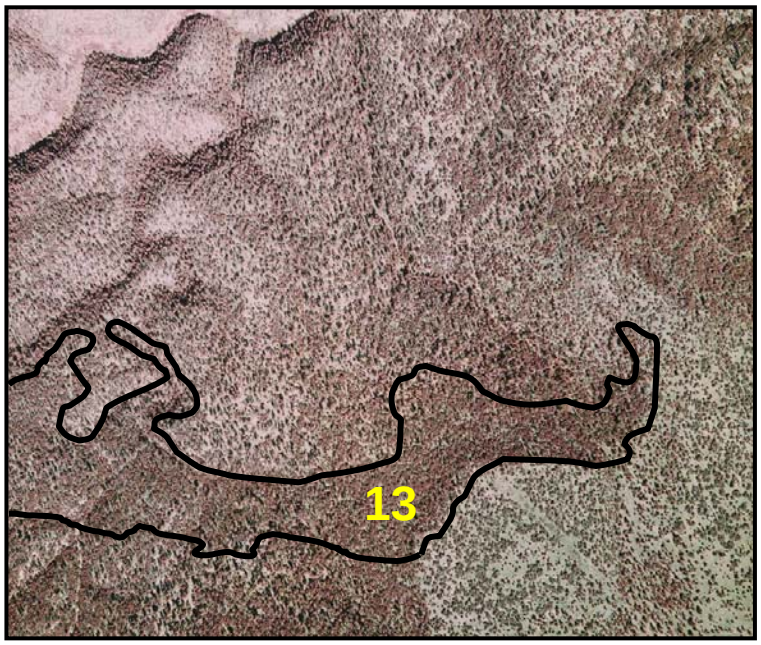
Location: This map unit is widespread throughout the mapping area and is abundant on the west side of the project area, decreasing gradually to the east. This type occurs on primarily uplands both north and south of Walnut Canyon.

Photosignature: Ponderosa pines appear as red specks, while pinyon and juniper trees appear as brown specks. Taller ponderosas have black shadows. The stands are generally open, so the overall appearance is that of coarse sandpaper; red and brown specks in a pale gray matrix. The complete absence or dramatic reduction of Gambel oak stands (appearing as brick red clumps) distinguishes this type from Map Unit 13.

Ponderosa Pine - Pinyon Pine - Juniper / Gambel Oak Woodland (13)

Location: This map unit is located primarily south of Walnut Canyon in the southwest corner of the project area. A few pockets of this type also occur along the western project boundary. This type is very similar to Map Class 12 but has a larger component of Gambel oak.

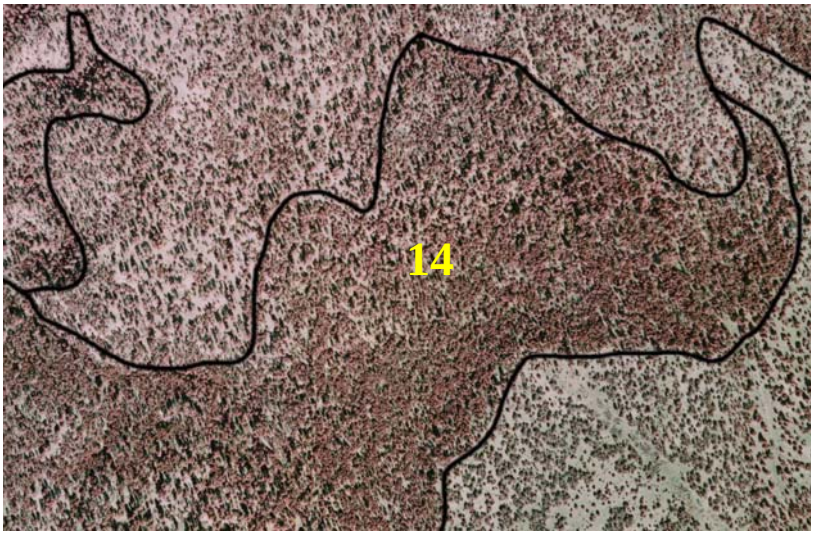
Photosignature: The photosignature for this type is similar to Map Unit 12 with the ponderosa pines appearing as red specks, pinyon and juniper trees as brown specks, and the taller ponderosas having black shadows. However, this type is usually significantly denser with dark, brick red clumps of Gambel oak filling the understory space. This results in a loss of the blue-green background color typical of Map Unit 12. Map Unit 13 also differs from Map Unit 15, Ponderosa Pine / Gambel Oak Woodland, by the presence of pinyon and juniper trees.



Ponderosa Pine / Gambel Oak Woodland (14)

Location: This type occurs primarily south of Walnut Canyon and from just east of Cherry Canyon, west to the project area boundary.

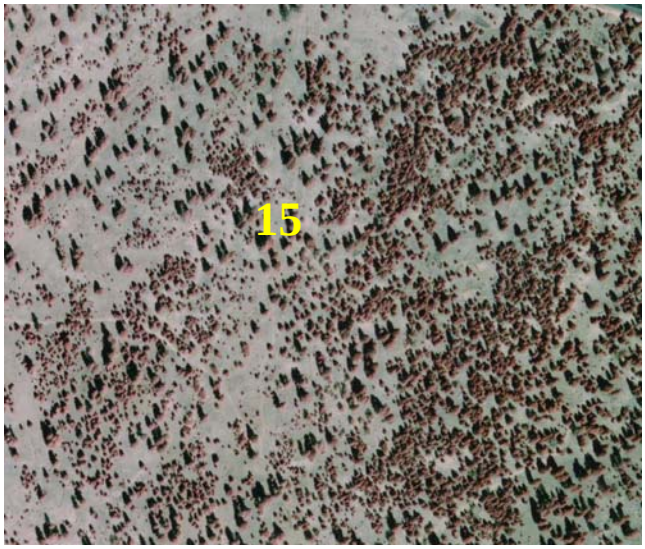
Photosignature: The signature is very similar to that of Map Code 16, but the crowns of Gambel oak trees/shrubs are visible as red-gold to dark-red, rough-textured specks and patches among the dark-red ponderosa pine crowns.



Ponderosa Pine Mixed Graminoid Woodland Complex (15)

Location: This type is best developed north of Walnut Canyon and west of the Monument access road. Smaller examples of this type also occur on the west side of the project area south of the canyon.

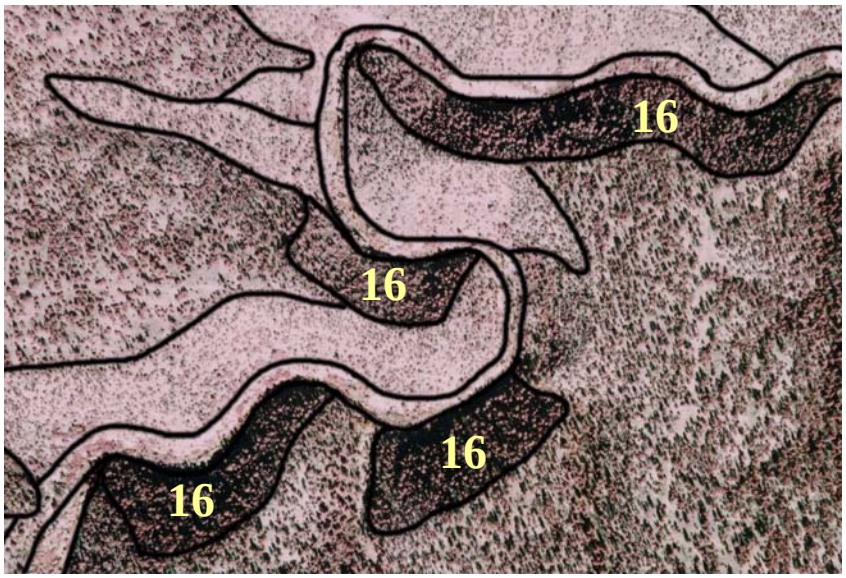
Photosignature: The texture is uneven, with pines of all sizes occurring in open to dense stands. Taller pines have black shadows, and all pines have red crowns. The grassy openings among the trees are gray green to pale green in color and have a smooth texture.



Douglas-fir / Gambel Oak Forest (16)

Location: This forest type occurs on north-facing canyon walls below the rim of Walnut Canyon.

Photosignature: Douglas-fir forests are uneven and rough in texture, and dark brown tinged with red in color.



Rural Residential (17)

Location: West and north edges of the project area.

Photosignature: Rectangular shapes for houses, landscaping, and outbuildings. Roofs, lawns, access roads, etc. appear in a variety of colors.

Figure: On page G-21.

Ranch Developments (18)

Location: Isolated buildings and corrals on private lands, often near pastures (22).

Photosignature: Similar to rural residential (17).

Figure: On page G-21.

NPS Facilities (19)

Location: Monument facilities, located at the end of the main park road. Includes buildings, a water tower and sewage treatment ponds.

Photosignature: Individual structures are easily identifiable. The fact that they are park facilities was confirmed in the field.

Figure: On page G-21.

Utility Corridors (20)

Location: A telephone line cuts east-west through the central part of the project area.

Photosignature: This type was field verified. It consists of a narrow belt of smooth, gray-green color.

Figure: On page G-21.

Transportation Routes (21)

Location: Transportation roads, including improved county roads and unimproved tracks, occur throughout the project area.

Photosignature: White for gravel and dirt roads, black for paved roads. Texture is smooth for all roads.

Figure: On opposite page.

Pastures (22)

Location: North center edge and the west edge of the mapping area, on private lands.

Photosignature: Smooth-textured, light grayish-green for dormant grasslands. Straight edges indicate fence lines or the boundary of pasture plantings.

Figure: On opposite page.

Reservoirs (23)

Location: The historic reservoir site on private land in the bottom of Walnut Canyon.

Photosignature: Whitish-gray reflecting bare ground; smooth gray texture indicating annual herbaceous vegetation. The dam structure is evident.

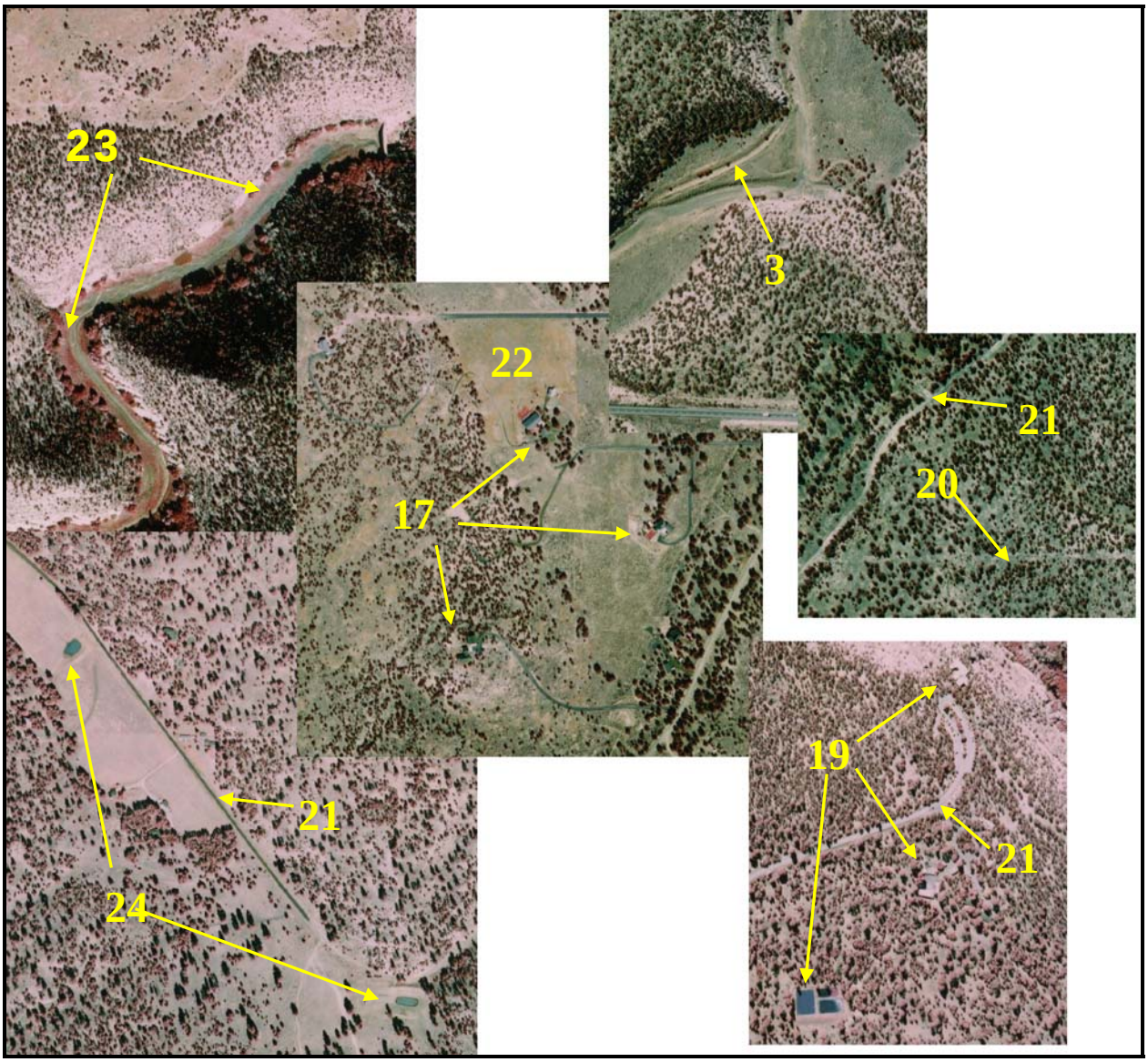
Figure: On opposite page.

Stock Tanks and Dams (24)

Location: Scattered throughout the project area outside the Monument boundary.

Photosignature: Usually a dark blue-green spot surrounded by a curved shape in white, gray or orange, depending on the color of the substrate the tank was dug in.

Figure: On opposite page.



Examples of aerial photosignatures for Anderson Land Use map classes at Walnut Canyon as they appear on the aerial photographs. Map code numbers are in yellow.