USGS-NPS Vegetation Mapping Program

Wind Cave National Park, South Dakota

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April 30, 1999

TABLE OF CONTENTS

APPENDICES

LIST OF TABLES

LIST OF FIGURES

LIST OF CONTACTS

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EXECUTIVE SUMMARY

The USGS Biological Resources Division (USGS/BRD) under contract with the Inventory and Monitoring (I&M) Program of the National Park Service has initiated a multi-year project to produce vegetation maps for 235 national parks. As a contractor under this program, the Bureau of Reclamation's Remote Sensing and Geographic Information Group (RSGIG) with assistance from The Nature Conservancy (TNC) has mapped the vegetation occurring in and around Wind Cave National Park (near Hot Springs, South Dakota). Thirty-two vegetation map classes representing 28 plant community types and six Anderson Level II land-use classes were used for interpretation for approximately 139 square miles encompassing the Park and surrounding environs.

Vegetation map classes were determined through extensive field reconnaissance, data collection, and analysis in accordance with the National Vegetation Classification System (NVCS). The vegetation map was created initially by interpretation of 1997, 1:12,000 scale color infrared aerial photography (0.5 hectare minimum mapping unit). All vegetation and land-use information was then transferred to USGS digital orthophoto quarter-quads (DOQQ's) using a combination of on-screen digitizing and scanning techniques. Arc/Info™ (ESRI, Inc.) software was used throughout the project for digitizing, scanning, transforming, registering, and plotting the interpreted data. Overall map accuracy for the entire mapping effort was assessed initially at 73%. Final map products complied with national map accuracy standards, are described in this report, and occur on the accompanying compact disk (CD-ROM). They include the following:

- Vegetation Classification Descriptions and Key
- Land Use Classification System
- Representative Photos from Field Studies
- Vegetation Key
- Field Data (Digital Database)
- Digital and Hard Copy Vegetation Maps
- Accuracy Assessment
- Metadata
- Final Report

Wind Cave and other similar national park vegetation mapping databases can be accessed at the USGS/BRD website: http://biology.usgs.gov/npsveg.

INTRODUCTION

The Inventory and Monitoring (I&M) Program of the National Park Service (NPS) was created in 1991 to provide park managers with critical information on natural resources. A long-term goal of this program is to provide baseline inventories of the biological and geophysical resources for all natural resource parks. To address this need, the NPS entered a multi-year partnership with the United States Geological Survey's (USGS) Biological Resources Division (BRD) to map the vegetation resources of 235 national parks, monuments, and historic sites. Goals of the USGS-NPS Vegetation Mapping Program include the following:

- Provide support for NPS Resources Management
- Promote vegetation-related research for both NPS and USGS/BRD
- Provide support for NPS Planning and Compliance
- Add to the information base for NPS Interpretation
- Assist in NPS Operations

Efforts to make this program a reality have lead to various work contracts with other government and private agencies. Among those contracted was the United States Bureau of Reclamation's (BOR) Remote Sensing and Geographic Information Group (RSGIG) based at the Federal Center Denver, Colorado. The task of the RSGIG was to create a digital, spatial database representative of the vegetation occurring at Wind Cave National Park (WICA), South Dakota during 1997. The primary subcontractor for vegetation classification and characterization is The Nature Conservancy (TNC) (Minneapolis Satellite Offices Minneapolis, MN) and its affiliate the Wyoming Nature Conservancy (Lander, WY).

The specific objectives of this study included:

- Creation of vegetation and mapping classifications based on the National Vegetation Classification System (NVCS).

- Development of a spatial database for the vegetation of WICA using remote sensing and GIS techniques.

Production of digital and hard copy vegetation maps, assessed to be at least 80% accurate.

Vegetation mapping for WICA falls under the USGS-NPS Vegetation Mapping Program's general task of completing all the national parks within the Great Plains Ecosystem. Other parks in this region that have been mapped or are currently in progress include: Theodore Roosevelt National Park, Badlands National Park, Mt. Rushmore National Memorial, Agate Fossil Beds National Monument, Jewel Cave National Monument, Devil's Tower National Monument, Scott's Bluff National Monument, and Fort Laramie National Historic Site. Any available data pertaining to these and other USGS-NPS Vegetation Mapping projects can be accessed at the USGS/BRD's website: http://biology.usgs.gov/npsveg.

photo by D. Cogan

Figure 1. Bison on a western wheatgrass - Kentucky bluegrass grassland at Wind Cave National Park.

PROJECT AREA

Founded in 1903 as the seventh national park in the United States, Wind Cave National Park is best known for its extensive cave system and abundant wildlife. WICA personnel presently manage 81.76 miles of known passages in the Wind Cave complex along with 28,295 surface acres, predominately mixed-grass prairie and ponderosa pine forest. Two lightly used gravel roads and several trails cross the central and eastern parts of the Park.

Location and Regional Setting

WICA is situated on the southeastern edge of the Black Hills Region of South Dakota (Figure 2), about 7 miles north of Hot Springs, SD. The Park lies in Custer County between Custer State Park to the north and Black Hills National Forest to the west. U.S. Highway 385 and South Dakota Highway 87 are the Park's major roads; secondary roads within WICA include NPS 5 and 6 (Figure 3).

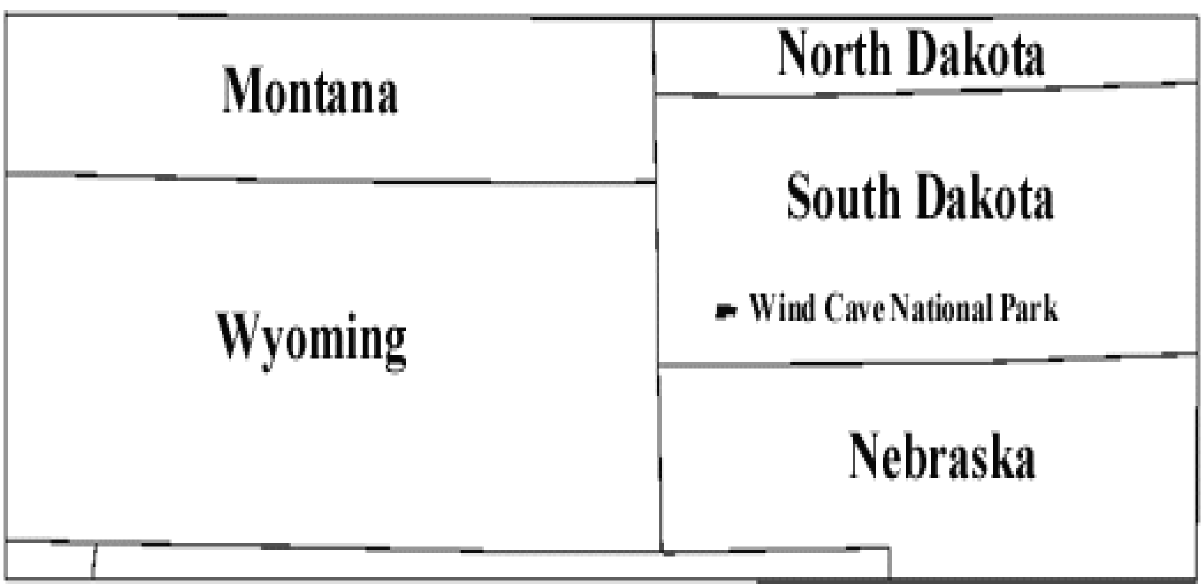


Figure 2. Location Map for Wind Cave National Park.

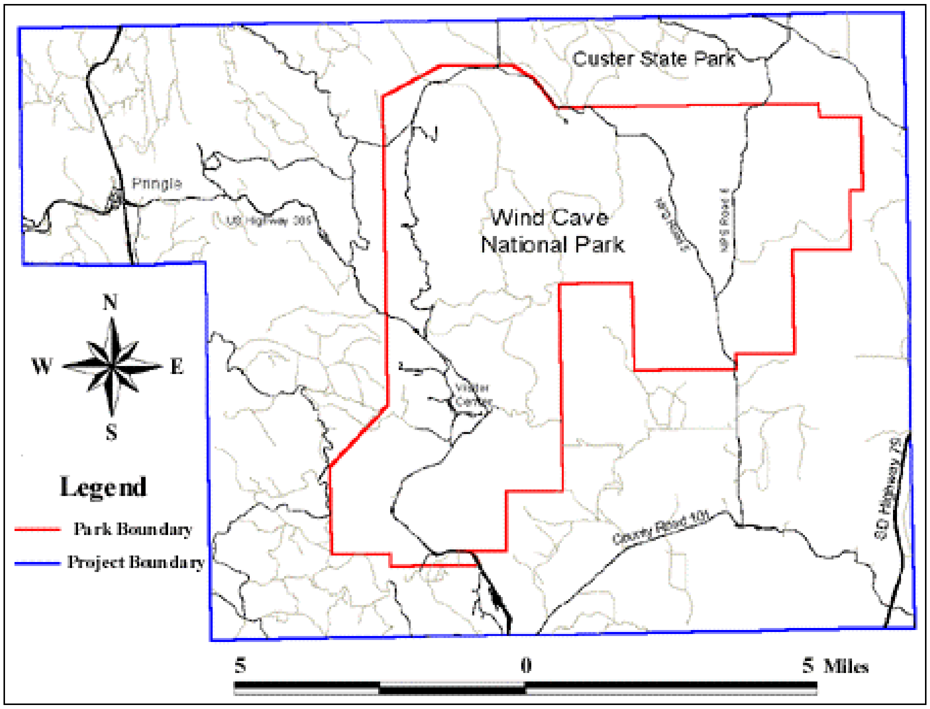


Figure 3. Wind Cave National Park and project mapping area.

Climate

Wind Cave National Park lies in the southern Black Hills, which typically records warm summers and relatively mild winters. Average temperatures recorded for Custer, SD (about 11 miles northwest of the Park) range from 23o F in the winter to 62o F in the summer (Ensz 1990). Temperatures in the spring and fall seasons can vary dramatically and change abruptly within short time periods. Throughout the year, humidity averages around 50% during mid-afternoons and winds are usually less than 13 mph. The Park usually experiences about 115 frost-free days a year (Smith 1978).

Precipitation for the southern Black Hills is usually heaviest in late spring and early summer. Local observations by WICA personnel report the last ten years as wetter than normal, largely based on the rise of the water table within the cave complex during this time period. Monthly precipitation records from Hot Springs and Custer show an increase in 1997 monthly averages compared to the last 50-year averages (1997-1947) (Appendices 1-2). Precipitation values recorded at WICA are limited to the last 8 years, and show no real increase from year to year (Appendix 3). Average seasonal accumulation of snowfall for Custer is about 45 inches (Ensz 1990).

Geology and Topography

The basic geology of the Black Hills can be traced to various uplifting events that resulted in an approximate 125-mile by 60-mile elliptical dome reaching up to 7,242 feet above sea level. Over time, sedimentary rock cover has been weathered by erosion, leaving more resistant crystalline rocks as caps, ridges, pinnacles and outcrops. As seen from an aerial perspective, the Black Hills consist of concentric rings of progressively younger rocks moving out from central high elevations. This concentric pattern can be separated into five major geomorphic regions: 1) the Central Crystalline Area (CCA), 2) the Limestone Plateau, 3) Minnelusa Foothills, 4) the Red Valley, and 5) the Cretaceous or "Dakota" Hogback (Froiland 1990). Interspersed within these formations are deposits of sediment (alluvium) left by various depositional events (Figure 4). Directly to the east of the Park, the Black Hills blend into the rolling prairie lands of the Central Great Plains Region.

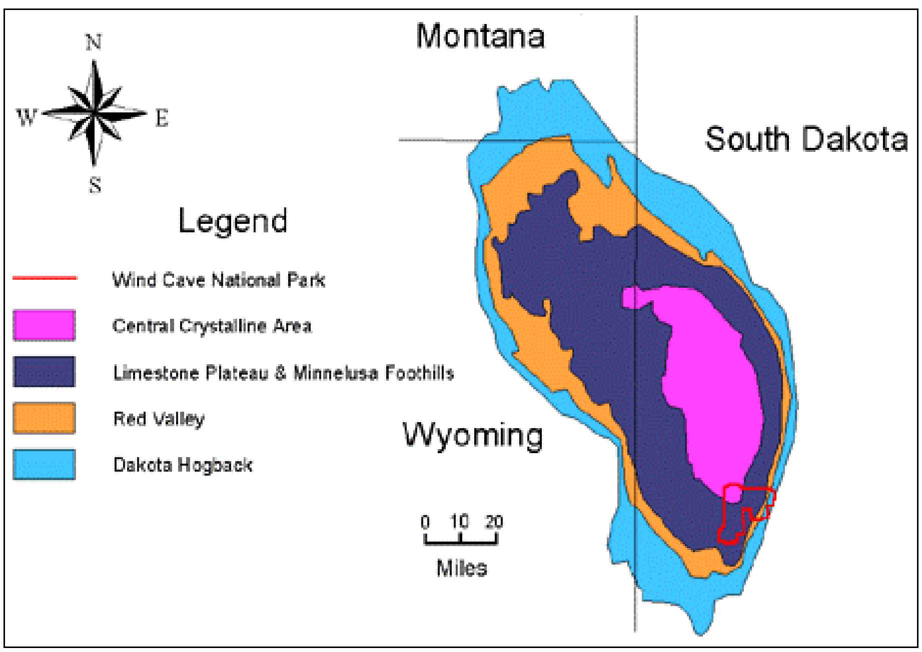


Figure 4. An overview map of the Black Hills showing general geomorphic regions.

All of the major geomorphic subdivisions of the Black Hills are represented at WICA and its immediate surroundings (Froiland 1990). The Central Crystalline Area, made up of granitic and metamorphic rocks, occurs in the highest, westernmost part of the Park (4,525 - 5,000 feet elevation). Dramatic topographic relief and rugged slopes characterize this area. East of this zone is an area underlain by limestones and sandstones, corresponding to the Limestone Plateau and Minnelusa Foothills regions (4,500 feet elevation). In the project area, the Limestone Plateau is not well developed due to steep dips of the rock strata (Pahasapa limestone). The Minnelusa Foothills zone is more extensive including outcrops and narrow limestone-rimmed drainages such as Limestone and Curley Canyons (Figure 5). Elevations drop through the Minnelusa Foothills to the Red Valley in the eastern part of the Park. Here, the underlying red, iron-rich Spearfish formation is intermittently exposed as red badlands or "redbeds" intermingled with gypsum outcrops (3,610 to 3,770 feet elevation) (Figures 7 and 8). The outermost geomorphic subdivision is the Dakota Hogback, or Hogback Rim, which is represented in the project area by Boland Ridge near the east Park boundary (Figure 8). Boland Ridge stands up to 400 ft. above the Red Valley (4,101feet elevation) and is underlain by steeply tilted sandstones. The eastern side of the Dakota Hogback is gently sloping, while the western slope is generally steeper and more rugged. The Dakota Hogback represents an interface between the Black Hills and the Central Great Plains. Finally, broad flat benches capped with old alluvial deposits occur in the northern and central parts of the study area. Good examples of these benches are located in northeast WICA between NPS Roads 5 and 6.

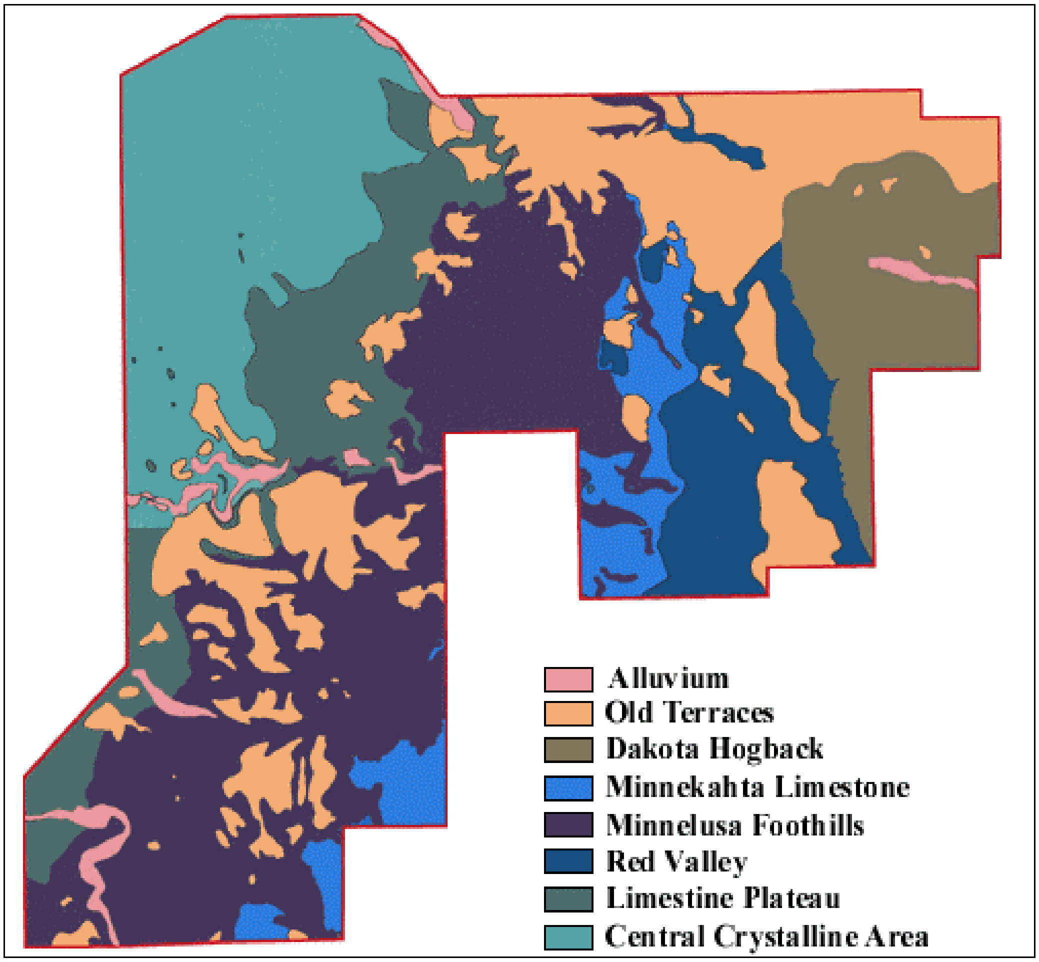


Figure 5. Map of Wind Cave National Park showing general geomorphic regions.

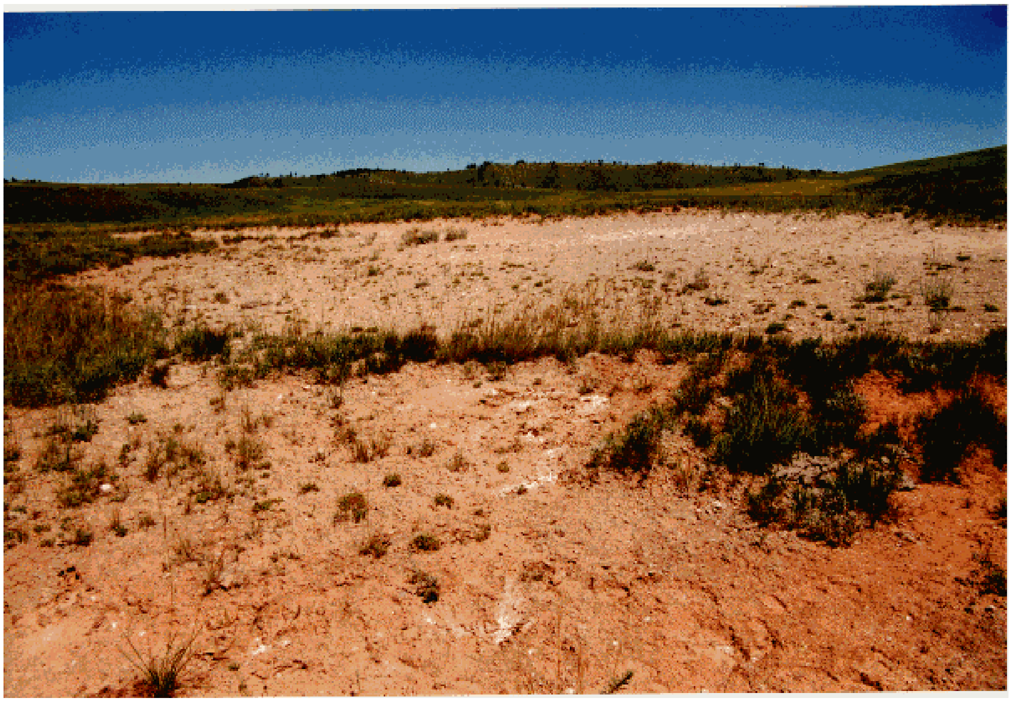


photo by D. Cogan

Figure 6. A sparsely vegetated redbed in the Red Valley region of WICA.

photo by D. Cogan

Figure 7. The Red Valley region of Wind Cave National Park with the Dakota Hogback (Boland Ridge) in the background.

Major drainages in WICA generally trend east and southeast. The more important are Beaver, Spring and Highland Creeks, sections of which flow all or most of the year. Many of the smaller drainages are dry, flowing only during precipitation events. Active springs are occasional and found at scattered locations. Other standing water is rare. In most years, an ephemeral pond forms on Bison Flats in the south portion of the Park, drying out through the summer. A few other very small ponds with limited aquatic vegetation are found at scattered locations.

Soils

Major soil associations occurring at WICA are either derived directly from the underlying parent material or were deposited as alluvium by erosion events. These soils relate to specific geologic landforms, topographic relief, climate, and the corresponding natural vegetation (Ensz 1990). Table 1 contains the major soil associations present, separated by their corresponding geologic formations. Each soil association consists of a variety of major and minor soil units that are sometimes combined to form complexes. Appendix 4 contains all the soil units and their descriptions found at WICA.

photo by D. Cogan

Figure 8. Limestone rock outcrops at Wind Cave National Park

Table 1. Major geomorphic region, soil association, soil names, and descriptions for the WICA mapping project (summarized from Ensz 1990 and Neilsen 1996).

Geomorphic Region	Soil Asscociation	Soil Name	Description	Location	Dominant Species
Central Crystalline Area	Buska-Mocmont-Rock Outcrop				
		Buska	Gray loam	Broad ridges and slopes	Ponderosa pine
		Mocmont	Gray/brown gravelly loam	Ridges & Mt. slopes	Ponderosa pine
		Rock Outcrop	Granite and schist	Peaks and dikes	Thin ponderosa pine
	Pactola-Rock Outcrop-Virkula				
		Pactola	Gray channery loam	Upper side slopes	Ponderosa pine
		Rock Outcrop	Hard metamorphic rock	Peaks, ledges, and dikes	Thin ponderosa pine
		Virkula soils	Gray/brown loam	Mid and low slopes	Ponderosa pine
	Heely-Cordeston				
		Heely	Gray/brown channery loam	High areas	Various native grasses
		Cordeston	Gray loam	Toe slopes and swales	Shrubs and deciduous trees
Limestone Plateau & Minnelusa Foothills	Vanocker-Sawdust-Paunsaugunt				
		Vanocker	Brown channery loam	N and E facing slopes	Ponderosa pine
		Sawdust	Gray/brown calcareous channery loam	S and W facing slopes	Ponderosa pine
		Paunsaugunt	Brown calcareous gravelly loam	Ridges	Ponderosa pine
		Rock Outcrop	Limestone and sandstone	Ridges and ledges	Thin ponderosa pine

Table 1. Continued

Geomorphic Region	Soil Asscociation	Soil Name	Description	Location	Dominant Species
Red Valley	Nevee-Gypnevee-Rekop				
		Nevee	Red/yellow calcareous silt loam	Mid and low regions	Various native grasses
		Gypnevee	Red/brown calcareous silt loam	Mid and low regions	Various native grasses & thin ponderosa pine
		Rekop	Red/brown calcareous loam	High regions	Various native grasses
		Rock Outcrops	Red/white gypsum and gypsiferous siltstone	High regions	Sparsley vegetated
Dakota Hogback	Canyon-Rockoa-Rock Outcrop				
		Canyon	Brown calcareous loam	S and W facing slopes	Various native grasses
		Rockoa	Gray/brown cobbly fine sandy loam	N and E facing slopes	Ponderosa pine
		Rock-Outcrop	Sandstone, limestone, or shale	Ledges and high regions	Sparsely vegetated
Prairie	Samsil-Pierre Association				
		Samsil	Brown clay	Shoulder and upper back slopes (shallow)	Western wheatgrass and juniper
		Pierre	Gray/brown clay	Back slopes (deep)	Western wheatgrass

Wildlife

WICA supports numerous species including many of the historical animals native to the Black Hills. Some of the larger mammals are actively managed (or have been managed historically) by Park personnel to ensure the overall health of the Park. These include bison (Bison bison), elk (Cervus canadensis), pronghorn antelope (Antilocapra americana), mule deer (Odocoileus hemionus) and black-tailed prairie dog (Cynomys ludovicianus) (Figure 9). Domesticated cattle and sheep have not been present at WICA since 1946 (Coppock et al. 1983).

photo by D. Cogan

Figure 9. A typical black-tailed prairie dog burrow.

Vegetation

WICA's vegetation can be divided into two major types, ponderosa pine forest and mixed grass prairie. Ponderosa pine forest comprises almost 30% of the Park and typically grows in the higher elevations; it is the dominant tree and is occasionally observed with birch, aspen, and white spruce. Fire suppression, timber management, and increased precipitation have likely led to an expansion of ponderosa pine cover in parts of the Black Hills. In some areas, this has resulted in dense stands of even-aged pines and rapid encroachment of young trees into grassland areas.

Other major vegetation types at WICA and its surrounding area include hardwood drainages dominated by boxelder, green ash and elm with occasional stands of other hardwoods, mountain mahogany shrublands, several shrubby draw types, riparian/wet meadow vegetation, and prairie dog towns. The higher western part of the study area generally has more tree cover. Much of the eastern part is prairie, with stands of pine woodland on Boland Ridge along the eastern boundary. Mountain mahogany shrubland is well developed in the Minnelusa Foothills zone in the central part of WICA.

Fire History

Throughout the history of WICA, the vegetation has been altered by fire events of various sizes and intensities. This has resulted in large prairie and forested tracts being in different stages of re-growth. Prairie grasses recover relatively quickly from fire making burned prairie sites more difficult to distinguish from non-burned prairie. Forest fires are typically more dramatic, leaving behind charred ponderosa pine trees (both standing and fallen) and blackened soil and rocks for many years (Figure 10). Recent and intense forest fires usually show greater effects; an example is the controlled fire set along Beaver and Cold Spring Creeks in May 1997.

photo by D. Cogan

Figure 10. Evidence of a historic forest fire that occurred just north of Wind Cave National Park, showing charred ponderosa pine stumps and fallen debris.

MATERIALS AND METHODS

The organization of this project followed the protocols outlined in Field Methods for Vegetation Mapping, Standardized National Vegetation Classification System (NVCS), and Accuracy Assessment Procedures (The Nature Conservancy 1994). The basic steps included:

1. **Planning and Scoping**
2. **Preliminary Data Collection and Review of Existing Information**
3. **Aerial Photography Acquisition**
4. **Gradsect Design**
5. **Field Survey**
6. **Vegetation Classification and Characterization**
7. **Vegetation Map Preparation**
8. **Accuracy Assessment**

1. Planning and Scoping

This project incorporated the combined expertise and oversight of several organizations. Oversight and programmatic considerations were managed by the Center for Biological Informatics (CBI) of the USGS/BRD. NPS and WICA personnel provided additional guidance on specific Park needs. The technical mapping portion was contracted to the BOR RSGIG in Denver, CO. TNC was sub-contracted to collect, analyze, and write-up the requisite plant association data and conduct fieldwork to support the accuracy assessment (AA). The specific technical responsibilities and deliverables for the mapping portion included the following:

BOR Responsibilities and Deliverables:

- Interpret aerial photographs;
- Transfer interpreted information to a digital spatial database and produce hard copy (paper) vegetation maps;

- Create digital vegetation coverages including relevant attribute information;
- Produce Arc/Info export file of vegetation plot, observation point, and accuracy assessment locations;
- Provide an annotated list of representative field site photographs/slides;
- Create a spreadsheet and contingency table comparing the mapped classes with the AA classes in order to determine map accuracy;
- Provide any ancillary digital files developed during the mapping process;
- Document and record digital FGDC compliant metadata files (*.html) for all created spatial data;
- Final report and CD-ROM describing procedures used in preparing all products;

TNC Responsibilities and Deliverables:

- Develop a preliminary vegetation classification for the study area from secondary sources;
- Design a sampling strategy;
- Collect observation points to refine the preliminary classification and familiarize investigators with community characteristics and their range of variation;
- Select and sample representative stands for all community types;
- Prepare final classification, community descriptions, and key to community types;
- Field test final classification, descriptions, and key during accuracy assessment;
- Collect accuracy assessment points;

Scoping Meeting:

A scoping meeting was held at the WICA visitor center with all interested parties during Spring 1997. The purpose of this meeting was to determine the project mapping extent, discuss logistics, and develop a sampling approach. At this time, various project boundaries around the Park were presented. It was decided that the mapping environs would include the town of Pringle, SD in the northwest corner and extend to the intersection of SD Highway 79 and County Road 101 in the southeast (Figure 2). This mapping boundary effectively covered two large expanses of Beaver Creek, an important riparian corridor and waterway through the Park. In order to sample in the environs, WICA personnel agreed to contact, and try to obtain permission from, all private landowners south and east of the Park. Following the data sampling protocols for large parks outlined in the Field Methods for Vegetation Mapping (TNC 1994), it was decided that a gradient-oriented transect or gradsect sampling approach (Austin and Heyligers 1989, Gillison & Brewer 1985) would be used at WICA.

2. Preliminary Data Collection and Review of Existing Information

To minimize duplication of previous work and to aid in the overall mapping project, existing maps and reports were obtained from various sources. The staff at WICA provided digital and hard copy background material for geology, fire history, prairie dog town locations, Canada thistle locations, elk exclosure locations, and rare tree and shrub locations (Smith 1978) for WICA. Soil surveys were obtained for Custer and Pennington Counties. Digital elevation models (DEM's), digital line graphics (DLG's), and digital raster graphics (DRG's) were obtained from the USGS. The DEM's were further manipulated to create slope and aspect maps.

A preliminary list of community types thought to have a high likelihood of being in the mapping area was used to develop the preliminary vegetation classification. This preliminary list contained vegetation associations and alliances generated for the Park in May of 1996 from the Midwest portion of the NVCS (Faber-Langendoen *et al*. 1996). Modifications were made to the list through a literature review of WICA and Black Hills vegetation and by contacting knowledgeable experts.

3. Aerial Photography Acquisition

Horizons, Incorporated of Rapid City, South Dakota acquired the aerial photography for WICA; thirteen flight lines were used to cover the entire project area (Figure 11). Flight lines 1-4 were flown on June 22, 5-8 flown on June 27, and 9-13 flown on June 26, 1997. A total of 220 color-infrared (CIR) photographs were taken at 1:12,000 (1"=1,000') scale and printed on 9"x9" stock. Overlap for these photos were approximately 50-60% and sidelap between flight lines was approximately 20-30%.

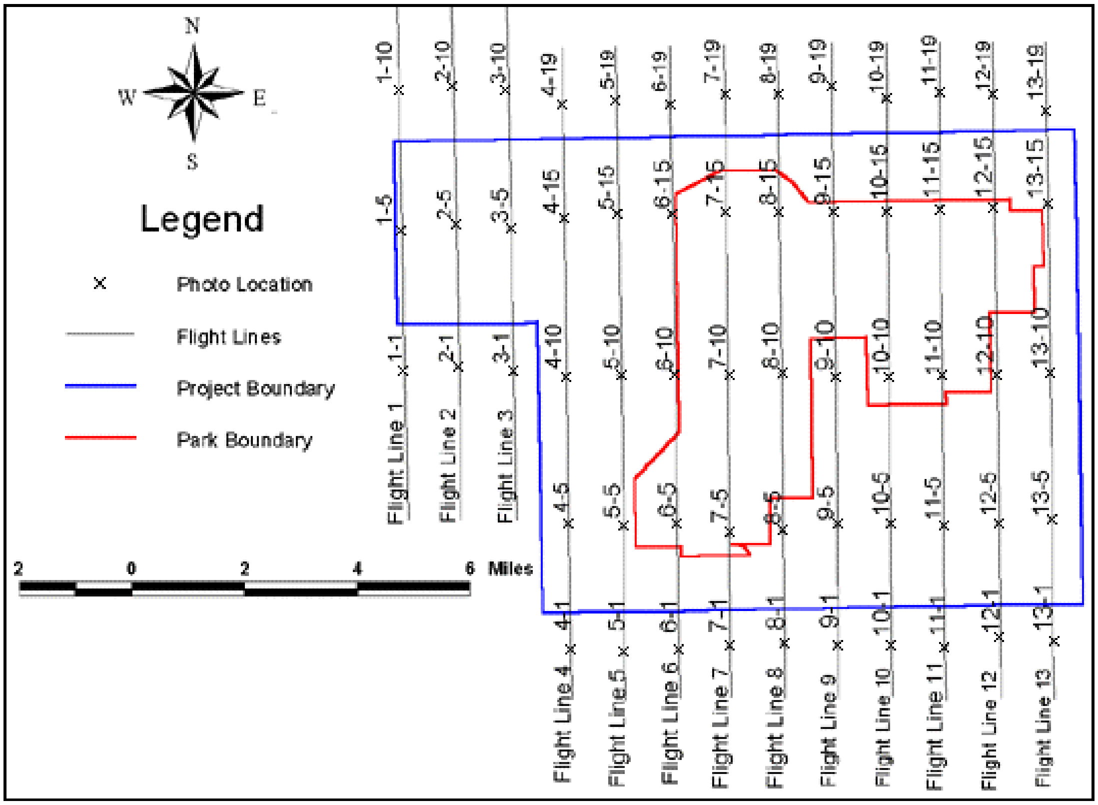


Figure 11. Flight line map for the Wind Cave National Park vegetation mapping program flown in June 1997.

4. Gradsect Design

The WICA study area was sufficiently large to require a gradsect approach to vegetation sampling. Gradsects were used to concentrate the sampling effort into smaller areas representing the full range of vegetation variability. This was achieved using the following assumptions: 1) certain site characteristics or combination of characteristics dictate the presence and growth of plant communities, 2) these characteristics tend to repeat themselves across a landscape, and 3) the concentration of sampling efforts across small heterogeneous areas provides an accurate representation of the vegetation diversity for a much larger region (Austin & Heyligers 1989).

Gradsects for WICA were designed at a meeting of BOR and TNC staff held in the RSGIG offices in Denver prior to the 1997 field season. Aerial photography was manually overlaid and compared with soils, geologic, and topographic maps. Composite maps were also used showing the relative variability of different environmental factors. Gradsects were placed on a majority of the stratigraphic units, elevations, major soil types, and several major drainages within the study area. Accessibility and land ownership influenced placement of the gradsects. Locations and design were also slightly modified based on prior knowledge of WICA's vegetation. The resulting gradsects included roughly 20% of the overall study area, and were considered highly likely to include the full range of plant communities found in the area (Figure 12).

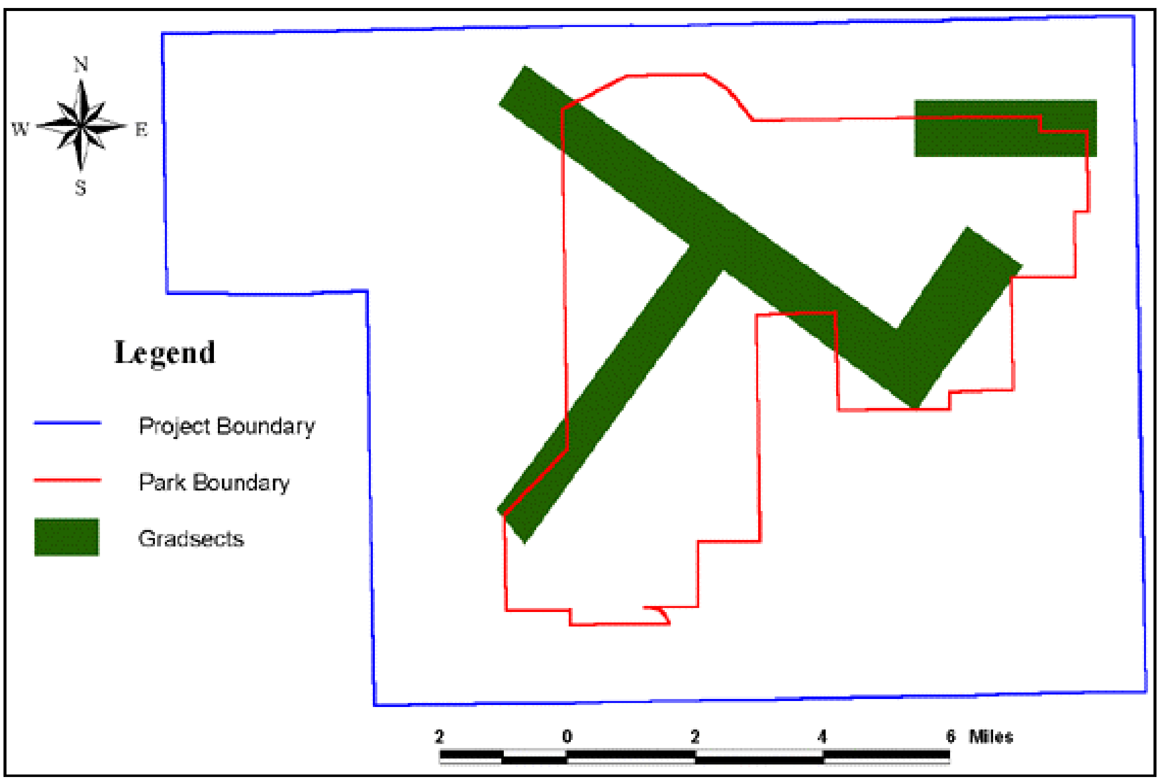


Figure 12. Map of the gradsect locations for Wind Cave National Park.

5. Field Survey

Field surveys began in the first week of July 1997 after aerial photography was acquired. The first step was reconnaissance using observation points, which allowed investigators to visit many areas. Observation points were used to become quickly familiar with community characteristics, community ranges of variation, and to field check the preliminary classification. Observation point sampling included basic information on habitat and vegetation structure and composition. Specific information recorded included UTM X-Y coordinates, dominant species cover data, and brief environmental characteristics (Appendix 5). Limitations of observation point data included no measurement or delineation of the sampling area and cover was only estimated for the common species in each stratum.

Data from 134 observation points were collected from the beginning of field survey through the second week of September 1997. Points were recorded mainly within gradsects, and were chosen to sample the range of habitat and vegetation variability observed on aerial photography, on preliminary maps, and in the field (Figure 13).

After completion of observation point survey, investigators chose representative stands of plant communities for more intensive sampling. Sample sites were identified in the field within gradsects using standard Relevè methodology (Mueller-Dombois 1974). Detailed sampling plots were subjectively placed in vegetation that was representative of an area, relatively homogeneous, and which covered more than 1/2 ha (the minimum mapping unit). Thus, ecotones and small patches of vegetation were avoided. Forest and woodland communities were sampled with 20 x 20 meter plots while shrubland and herbaceous communities were sampled with 10 x 10 meter plots. Collected data included habitat characteristics (e.g. slope, aspect, elevation, and soil characteristics), vegetation composition and structure, and other site features such as wildlife or human disturbance (Appendix 6).

To characterize vegetation structure, all species found within a plot were noted and foliar cover for each species by strata was estimated using a modified Daubenmire (1959) classification. Since cover was estimated independently for both species and strata, total coverage for some of the plots was greater than 100%. In forests and woodlands, dbh (diameter at breast height) was measured for all trees greater than 10 cm dbh. Various environmental data were also collected for each plot to characterize the abiotic conditions under which the sampled vegetation occurred. The UTM coordinates and elevation of all plots where logged using a hand-held Precision Light-weight Global Positioning System (GPS) Receiver (PLGR) unit. 35mm slides were taken for each plot and representatives are included in this report (Appendix 16).

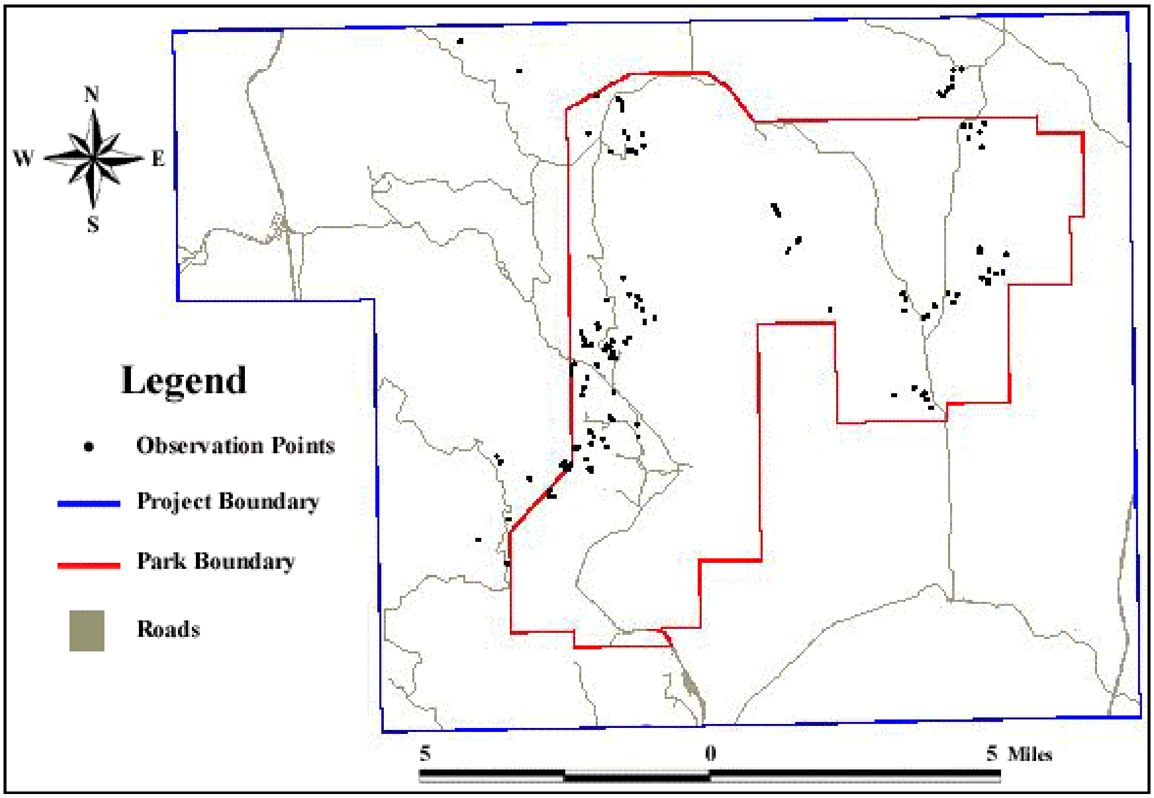


Figure 13. Map of the observation points collected during summer 1997.

Data were collected on 65 plots during the 1997 field season extending into early September and four additional plots were sampled in 1998 (Figure 14). Three plots were sampled for each plant community found in the study area, as long as three stands were available. For several uncommon plant communities, only one or two plots were sampled. All sampled data were eventually entered into TNC's "PLOTS" database program.

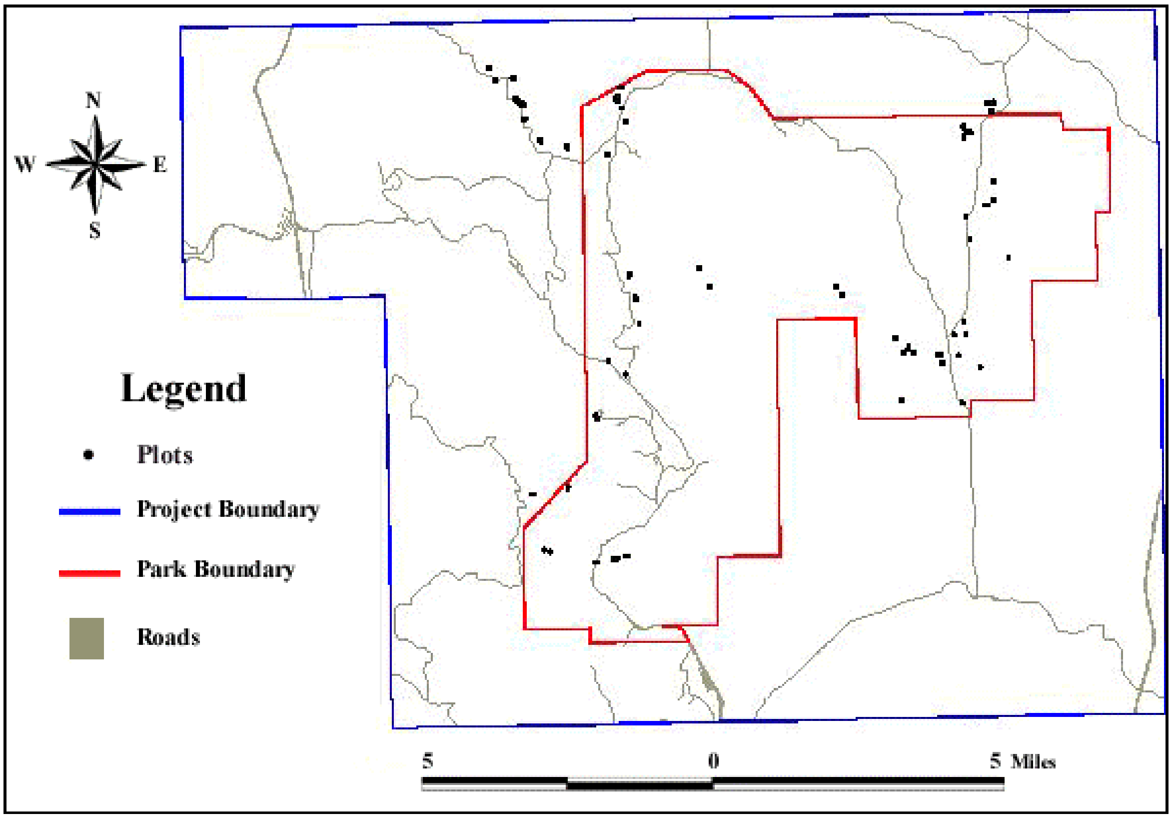


Figure 14. Map of the plot locations sampled during summer 1997.

6. Vegetation Classification and Characterization

The procedure for classifying vegetation followed guidelines set forth in the Vegetation Classification Standard (FGDC 1997) which was developed from the Standardized National Vegetation Classification System (NVCS) (TNC 1994). This national system contains seven classification levels with the two finest (lowest) being the alliance and association (community) levels. Associations are separated from alliances through the use of floristic composition and are named by the most dominant and/or indicator species. If two or more dominant species occur in the same stratum a dash symbol is used. If the species occur in different strata then a slash is used. Parentheses are used in instances when the diagnostic species are not consistently present in the vegetation unit.

Classification for the WICA study area involved placing all observation point data and plot data into groups based on vegetation structure and composition. From here, extensive floristic knowledge of the field team allowed most of the sampled community types to be qualitatively evaluated and subjectively assigned to an existing NVCS class. In a few instances, new NVCS classes were discerned and prepared from evaluations of the floristic data. Additional analyses were performed using the plot data combined with other similar Black Hills data (including other local National Parks) to provide a better regional perspective on vegetation types. These were quantitatively analyzed using ordination techniques (Detrended Correspondence Analysis "DCA"and Non-Metric Multidimensional Scales "NMS"), a clustering algorithm, Unweighted Pair-Group Method Using Arithmetic Means (UPGMA), and Two-Way Indicator Species Analysis (TWINSPAN). Since, in a number of cases, there were only a few sample plots per vegetation type, the above analyses could not be solely relied upon for classification. However, the results of the numerical analyses were compared to the subjective classification in order to detect any discrepancies between the two. All analyses were completed using PC-ORD (McCune and Mefford 1997).

A synoptic vegetation key for WICA was prepared during the 1998 field season (Appendix 8). The key was tested during the Accuracy Assessment process, resulting in only minor modifications. A synoptic key leading to community type descriptions was chosen rather than a dichotomous key based on previous keys developed for other NPS sites in the Black Hills. It was felt that these dichotomous keys did not fully address the natural range of variability occurring in each of the plant communities. This was due in part, to the very brief descriptions required at branch points in dichotomous keys, potentially leading the user to the incorrect type. The WICA synoptic key allows the user to quickly browse relevant vegetation types within each major vegetation group and make an accurate decision based on comprehensive descriptions.

7. Vegetation Map Preparation

Map Units

Final WICA map units used for photo-interpretation were based on the NVCS, Anderson (1976) Level II classification system, and special requests by WICA personnel. The preliminary NVCS classification was used to determine relationships between signatures on aerial photos and vegetation associations on the ground. In most instances, one NVCS association corresponded to one map unit. However, due to various limitations in the aerial photography, certain individual NVCS had to be merged into a larger map unit (i.e. complex). Anderson Level II classes were used to classify land-use types including semi-natural and cultural types (i.e. roads, facilities, and agricultural fields). Finally, some small vegetation types recognized by the Park but not included in the NVCS were mapped. In these situations, the vegetation had an unique photo signature and could be easily interpreted from the aerial photography.

Aerial Photograph Interpretation

All aerial photographs for WICA were covered with translucent mylar overlays. Fiducial points (corner and side marks), flight line, and photograph numbers were transferred from each photo onto its corresponding overlay. The center portion of each aerial photograph was systematically delineated to minimize the effects of edge distortion. Aerial photos and their overlays were then back-lit on a light table and visually scanned for photographic signatures using magnification and stereo. The actual interpretation of the photographs involved three basic steps. First, all of the photos were initially interpreted into broad classes based solely on standard photo-interpretation signature characteristics. These included: tone, texture, color, pattern, topographic position, size, and shadow. Second, field note overlays and plot and observation point locations were used to refine the preliminary delineation into the appropriate map units. Finally, in order to ensure completeness and accuracy, another independent researcher reviewed all of the interpreted photos for consistency and recommended changes where necessary.

Additional references aided in aerial photo interpretation. These included: the Soil Surveys of Custer and Pennington Counties, Black Hills and Prairie Parts, SD (Ensz 1990 and Nielsen 1996), USGS geology maps, and prairie dog town maps (provided by WICA). Specific guidelines written for prairie dog colony mapping were used in this study to improve the interpretation of prairie dog town edges at WICA (Appendix 11).

Map Validation

Before the accuracy assessment, a verification or map validation trip was taken in August 1998 to refine and assess the initial mapping effort. This trip included collecting additional observation points and ground-truthing aerial photographs using landmarks and GPS waypoints. Map classes were modified to reflect any inadequacies in the initial photointerpretation.

Digital Transfer

An ArcInfo(tm) (ESRI) GIS database was designed for WICA using the National Park GIS Database Design, Layout, and Procedures created by the BOR (Appendix 12). This was created through Arc Macro Language (AML) scripts that helped automate the transfer process and ensure that all spatial and attribute data was consistent and stored properly. Actual transfer of information from the interpreted aerial photographs to a digital, geo-referenced format involved two techniques, scanning (for the vegetation classes) and on-screen digitizing (for the land-use classes). Both techniques required the use of 14 digital black-and-white orthophoto quarter quadrangles (DOQQ's) covering the study area (Appendix 13); supplied by the USGS.

The scanning technique used for WICA involved a multi-step process whereby mylar overlays, with the interpreted line work, were scanned into digital form. The essential principle behind this process was to match the scale and position of features on the photographs with the scale and position of the same features on the DOQQ. This was accomplished by readjusting the scale of the photography, shifting the origin of the photo, rotating the axes, and bending/warping (rubber-sheeting) the photo between known control points (tic marks) and origin and destination points (links). The actual manipulation was conducted by computer program routines until the adjustment was considered a good fit by the technician. Any remaining land-use classes that were not already scanned were quickly transferred through on-screen digitizing. This process entered the interpreted line work from the photos into the GIS database by manually drawing digital lines over the DOQQ (using the mouse with the DOQQ on the computer screen as a background image). Finally, the digitized line work transferred by both methods was connected, and polygon attribute information was added to produce a completed digital coverage.

Transferred information was used to create vegetation polygon coverages and ancillary linear coverages in ArcInfo(tm) for each WICA DOQQ. Attribute information including vegetation map unit, location, and aerial photo number was subsequently entered for all polygons. All spatial data for WICA and the processes used are described in the WICA Metadata (Appendix 15).

8. Accuracy Assessment

The accuracy assessment (AA) for the WICA vegetation map consisted of preliminary planning and discussion, logistical planning, fieldwork, analysis of fieldwork, and computation of final results. Preliminary planning involved BOR (responsible for developing the GIS spatial database) and TNC (responsible for collecting the field AA data) personnel. After considerable discussion, a modified accuracy assessment procedure was determined using the protocols outlined in the Accuracy Assessment Procedures (TNC 1994).

The following guidelines for this procedure were adopted at this time:

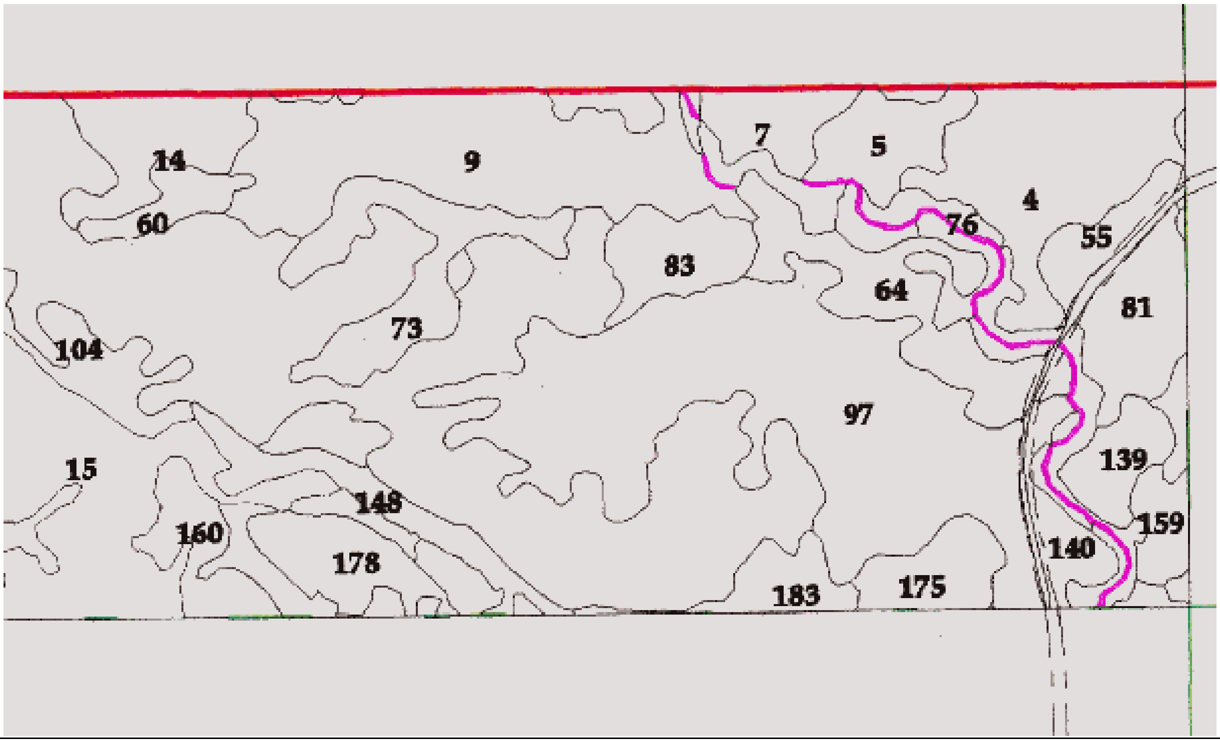
- Observations of vegetation classes were to be ground-based.
- Ground sampling techniques were to be similar to the Observation Points collected during initial classification.
- The number of samples per class would vary depending on abundance and size of classified polygons.

Logistical planning for the AA revolved around coordination of work schedules and division of work areas within the Park. WICA personnel were briefed on the AA process and invited to assist with data collection. The actual assessment was started as soon as preliminary vegetation maps had been prepared and delineated polygons were available. Assessment was done within Park boundaries and data points were not limited to the gradsects, but rather they were located based on relative ease of access and time constraints. Selecting random AA sampling sites beforehand was deemed unnecessary due to familiarity of the researchers with the vegetation distribution at WICA.

Field staff were provided with two sets of preliminary vegetation maps by the BOR. The first included labeled, colored polygons, which was used to select areas and polygons for sampling (i.e. to ensure a sufficient number of sampling points per type). In the second set, polygons were not colored, and were labeled only with unique identifiers or polygon identification numbers (poly id#'s). A key listing UTM coordinates for the centrum of each polygon accompanied this set of maps (Figure 13). Polygons and survey routes were chosen before going into the field, using the colored, labeled maps. The UTM coordinates for those polygons were recorded, and this list was taken into the field. In the field, investigators entered UTM coordinates into GPS PLGR units, and navigated to assessment points, assisted at times by the uncolored vegetation maps. The final point chosen for assessment was selected to be as representative as possible of the vegetation in the immediate area, and well away from stand boundaries.

AA data, including limited habitat and vegetation data, was recorded on field forms to document the classification decision made by the investigator (Appendix 7). This form was modified and expanded from previous forms to include fields for additional community types found within 50 meters of the actual assessment point. Modifications were made to help accommodate several types of difficult situations, such as AA points located in small inclusions, heterogeneous polygons/stands, and GPS PLGR inaccuracies.

All AA data were collected from late September through the first week of December 1998. The weather at this time was unusually warm and vegetation identifiable, although by November it had become rather difficult to estimate shrub cover due to loss of foliage. Total data collected



Wind Cave National Park: Mt. Coolidge quadrangle (se quarter)

X-Y Coordinates for Mt. Coolidge (se quarter) Vegetation Polygons
UTM ZONE 13, Datum NAD83

Poly ID#	Veg Code	X-Coord	Y-Coord	Poly ID#	Veg Code	X-Coord	Y-Coord
4	16	630,944	4,831,898	83	15	630,607	4,831,833
5	15	630,797	4,831,948	97	35	630,781	4,831,693
7	16	630,686	4,831,958	104	15	630,029	4,831,747
9	35	630,406	4,831,929	139	16	631,036	4,831,652
14	15	630,114	4,831,928	140	16	630,987	4,831,568
15	16	630,032	4,831,634	148	2	630,318	4,831,606
55	15	631,008	4,831,825	159	15	631,073	4,831,592
60	33	630,098	4,831,868	160	15	630,147	4,831,574
64	16	630,811	4,831,812	175	16	630,843	4,831,529
73	15	630,344	4,831,771	178	15	630,298	4,831,548
76	35	630,879	4,831,874	183	15	630,722	4,831,521
81	15	631,048	4,831,797				

Figure 15. Portion of a preliminary WICA vegetation map and key used for Accuracy Assessment.

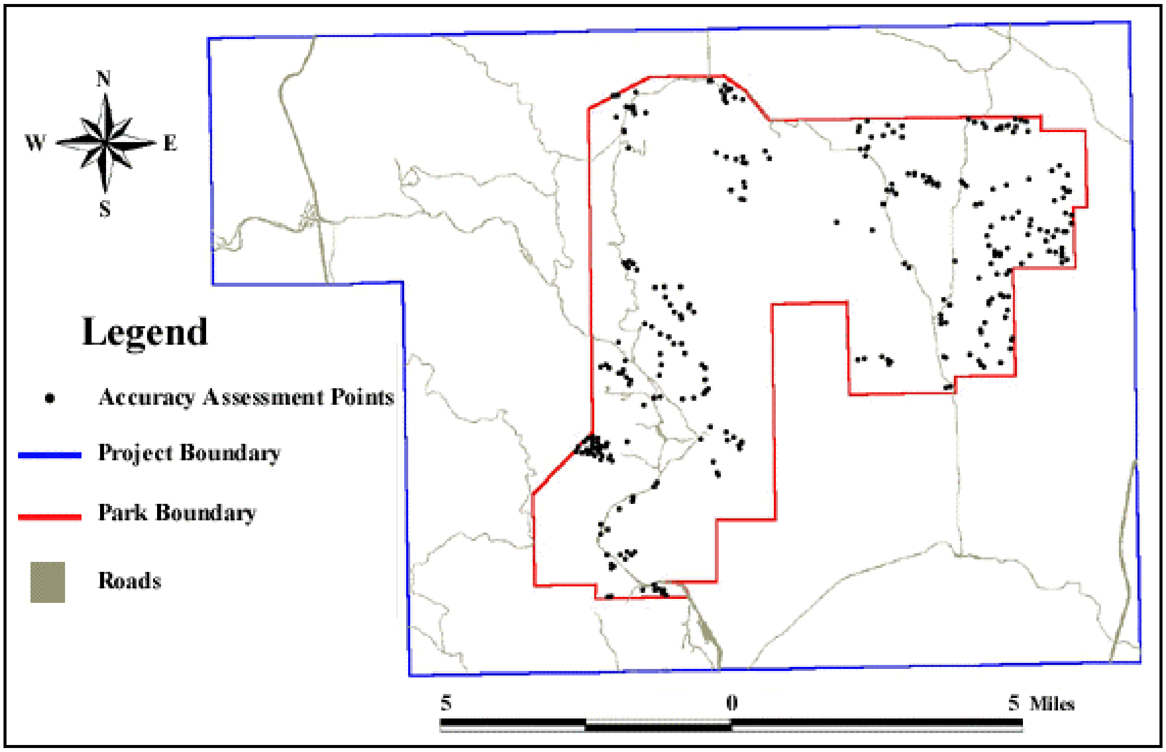


Figure 16. Map of the accuracy assessment locations sampled during summer and fall 1998.

came to 295 points (Figure 16), with more points collected within extensive types. AA points were not collected for several map units since they were either too small, on inaccessible private land, or the only known occurrence was already described by a plot or observation point.

Accuracy assessment of the WICA project area was conducted in February 1999. This involved the plotting of all accuracy data points onto semi-clear vellum and overlaying these on final vegetation maps. AA point numbers plotted alongside each point allowed for comparison with accuracy assessment data forms. A contingency table was set up to record the reference data (collected field data) versus the sample data (vegetation map) for each map unit.

Errors of commission (i.e. user's errors) for each class were calculated by dividing the number of correctly classified samples by the total number of samples that were classified as belonging to that map class. Errors of omission (i.e. producer's errors) for each class were calculated by dividing the number of samples that were classified correctly by the total number of reference samples in that class. Confidence intervals for each map class were calculated using one of the following methods depending on the normality and size of the data:

- For large sample sizes (n > 30), a normal distribution was assumed when

  1) np (5 and n (1-p) (5, and
  2) 0.2 <p>0.8
     where n = sample size and p = (number of correct samples / total number of samples)
     (Zar 1984 and Hay 1979).

- For normally distributed map classes the confidence intervals were calculated using the equations provided by Snedecor and Cochran (1967) in the Accuracy Assessment Procedures (TNC 1994).

- When the normal approximation was not valid (as determined from the above criteria), equations obtained from Zar (1984) were used to determine the lower and upper confidence intervals.

- For map classes containing small numbers of accuracy assessment points (n (30), calculated tables of probabilities based on the underlying binomial distribution (Natrella 1963) were referenced for the upper and lower confidence limits.

Overall total accuracy for WICA was calculated across all sampled map classes by dividing the number of correctly classified accuracy points by the total number of accuracy points. Confidence intervals for overall total accuracy were calculated using the equation for normally distributed data (see above). A Kappa Index (Foody 1992) was used to help account for any correct classification due to chance.

RESULTS

Vegetation Classfication and Characterization

The classification of vegetation for the WICA study area includes 28 community types comprised of eight forest and woodland types, five shrubland types, ten herbaceous types and five sparse vegetation types. The final classification is presented in Tables 2 and 3. A field key and detailed type descriptions are included in Appendices 8 and 9. Many of the plant community types sampled are typical of the ponderosa pine / prairie transition zone of the lower elevations of the Black Hills and are well represented in the WICA study area. In fact, WICA has been recognized as an exemplary site for Black Hills vegetation due to diversity, vegetation condition, stand size and the relative intactness of the landscape including the presence of many natural or simulated ecological processes (Marriott *et al*. Black Hills Community Inventory, in prep.).

In the study area, ponderosa pine forests and woodlands are most extensive in areas of higher elevation in the western part. The most mesophytic of these types is ponderosa pine / chokecherry forest, best developed on northerly aspects and on lower slopes near drainage bottoms. Ponderosa pine / sunsedge (Figure 17), ponderosa pine / western wheatgrass and ponderosa pine / little bluestem woodlands occur on a variety of slopes and aspects. The ponderosa pine / little bluestem community is often the most extensive type on drier sites. Boland Ridge (in the eastern part of the study area) also includes extensive pine cover, with the more xerophytic community types well represented. Sizeable stands of ponderosa pine / common juniper woodland are found only in the westernmost part of the study area, with only one stand inside Park boundaries. This type is very common in higher elevations of the Black Hills to the west and north.

Deciduous forests and woodlands generally are restricted to floodplains, drainage bottoms and toeslopes, with a few scattered trees found elsewhere. The boxelder/chokecherry type is the most common overall, occurring in drainages scattered throughout the Park. Other trees, such as American elm, were locally abundant. Two floodplain types, plains cottonwood / western snowberry woodland and green ash - American elm / western snowberry forest, are

Table 2. Vegetation classification for WICA. Types are grouped into physiognomic classes. Elcodes are included in the first column.

NVCS Association	Common Name
Hardwood Forests and Woodlands	
CEGL000628 *Acer negundo / Prunus virginiana* Forest	BOX ELDER/CHOKECHERRY FOREST
CEGL002082 *Fraxinus pennsylvanica - Ulmus americana / Symphoricarpos occidentalis* Forest	ASH - ELM/WOLFBERRY FOREST
CEGL000660 *Populus deltoides / Symphoricarpos occidentalis* Woodland	COTTONWOOD/WOLFBERRY - WESTERN ROSE FLOODPLAIN
Coniferous Forests and Woodlands	
CEGL000849 *Pinus ponderosa / Carex inops* ssp. *Heliophila* Woodland	PONDEROSA PINE/SEDGE WOODLAND
CEGL000188 *Pinus ponderosa / Pascopyrum smithii* Woodland	PONDEROSA PINE/WESTERN WHEATGRASS WOODLAND
CEGL000201 *Pinus ponderosa / Schizachyrium scoparium* Woodland	PONDEROSA PINE/LITTLE BLUESTEM WOODLAND
CEGL000859 *Pinus ponderosa / Juniperus communis* Woodland	PONDEROSA PINE/COMMON JUNIPER WOODLAND
CEGL000192 *Pinus ponderosa / Prunus virginiana* Forest	PONDEROSA PINE/CHOKECHERRY FOREST
Shrublands	
CEGL001086 *Cercocarpus montanus / Bouteloua curtipendula* Shrubland	MOUNTAIN MAHOGANY/SIDE-OATS GRAMA SHRUBLAND
CEGL001394 *Juniperus horizontalis / Schizachyrium scoparium* Dwarf-shrubland	CREEPING JUNIPER/LITTLE BLUESTEM DWARF-SHRUBLAND
CEGL001108 *Prunus virginiana* Shrubland	CHOKECHERRY SHRUBLAND
CEGL001131 *Symphoricarpos occidentalis* Shrubland [Provisional]	WOLFBERRY SHRUBLAND
CEGL001173 *Salix bebbiana* Shrubland	BEAKED WILLOW SCRUB

Table 2. (continued)

Herbaceous Vegetation, upland		
CEGL001681	*Schizachyrium scoparium – Bouteloua (curtipendula gracilis) - Carex filifolia* Herbaceous Vegetation	NORTHERN GREAT PLAINS LITTLE BLUESTEM PRAIRIE
CEGL002037	*Stipa comata - Bouteloua gracilis - Carex filifolia* Herbaceous Vegetation	NEEDLE-AND-THREAD - BLUE GRAMA MIXEDGRASS PRAIRIE
CEGL001583	*Pascopyrum smithii - Nassella viridula* Herbaceous Vegetation	WESTERN WHEATGRASS - GREEN NEEDLEGRASS MIXEDGRASS PRAIRIE
CEGL002205	*Andropogon gerardii - Schizachyrium scoparium* Northern Plains Hillslope Herbaceous Vegetation	NORTHERN PLAINS BIG BLUESTEM PRAIRIE
CEGL003081	*Poa pratensis* Herbaceous Vegetation	KENTUCKY BLUEGRASS HERBACEOUS VEGETATION
not yet coded	*Aristida purpurea – Dyssodia papposa* Herbaceous Vegetation	Purple Three-awn - Fetid Marigold Herbaceous Vegetation PRAIRIE DOG TOWN GRASSLAND COMPLEX
not yet coded	Introduced Weedy Graminoid Herbaceous Vegetation	
Herbaceous Vegetation, riparian/wet meadow		
CEGL001833	*Eleocharis palustris* Herbaceous Vegetation	CREEPING SPIKERUSH WET MEADOW
CEGL001477	*Spartina pectinata - Carex* spp. Herbaceous Vegetation	PRAIRIE CORDGRASS - SEDGE WET MEADOW
CEGL005263	Western Great Plains Streamside Vegetation	WESTERN GREAT PLAINS STREAMSIDE VEGETATION
Sparse Vegetation		
CEGL002055	*Pinus ponderosa* Limestone Cliff Sparse Vegetation	PONDEROSA PINE LIMESTONE CLIFF
CEGL002295	Black Hills Rock Outcrop Sparse Vegetation	BLACK HILLS ROCK OUTCROP
CEGL002294	Shale Barren Slope Sparse Vegetation	SHALE BARREN SLOPES
CEGL005261	Redbeds (Silt/sandstone) Sparse Vegetation	REDBEDS

Table 3. Vegetation classification for WICA. Types are arranged by ecological groups following the Black Hills Community Inventory (Marriott *et al.* in prep.). Elcodes are included in the first column.

NVCS Association	Common Name
Dry Coniferous Forests and Woodland	
CEGL000849 *Pinus ponderosa / Carex inops* ssp. *heliophila* Woodland	PONDEROSA PINE/SEDGE WOODLAND
CEGL000188 *Pinus ponderosa / Pascopyrum smithii* Woodland	PONDEROSA PINE/WESTERN WHEATGRASS WOODLAND
CEGL000201 *Pinus ponderosa / Schizachyrium scoparium* Woodland	PONDEROSA PINE/LITTLE BLUESTEM WOODLAND
Mesic Coniferous Forests and Woodlands	
CEGL000859 *Pinus ponderosa / Juniperus communis* Woodland	PONDEROSA PINE/COMMON JUNIPER WOODLAND
CEGL000192 *Pinus ponderosa / Prunus virginiana* Forest	PONDEROSA PINE/CHOKECHERRY FOREST
Dry Plains Shrublands	
CEGL001086 *Cercocarpus montanus / Bouteloua curtipendula* Shrubland	MOUNTAIN MAHOGANY/SIDE-OATS GRAMA SHRUBLAND
CEGL001394 *Juniperus horizontalis / Schizachyrium scoparium* Dwarf-shrubland	CREEPING JUNIPER/LITTLE BLUESTEM DWARF-SHRUBLAND
Mesic Plains Shrublands	
CEGL001108 *Prunus virginiana* Shrubland	CHOKECHERRY SHRUBLAND
Dry Mixedgrass Prairies	
CEGL001681 *Schizachyrium scoparium – Bouteloua (curtipendula, gracilis) - Carex filifolia* Herbaceous Vegetation	NORTHERN GREAT PLAINS LITTLE BLUESTEM PRAIRIE
CEGL002037 *Stipa comata - Bouteloua gracilis - Carex filifolia* Herbaceous Vegetation	NEEDLE-AND-THREAD – BLUE GRAMA MIXEDGRASS PRAIRIE

Table 3. (continued)

Mesic Mixedgrass Prairies		
CEGL001583	*Pascopyrum smithii - Nassella viridula* Herbaceous Vegetation	WESTERN WHEATGRASS - GREEN NEEDLEGRASS MIXEDGRASS PRAIRIE
CEGL002205	*Andropogon gerardii - Schizachyrium scoparium* Northern Plains Hillslope Herbaceous Vegetation	NORTHERN PLAINS BIG BLUESTEM PRAIRIE
CEGL003081	*Poa pratensis* Herbaceous Vegetation	KENTUCKY BLUEGRASS HERBACEOUS VEGETATION
Prairie Dog Town Grassland Complex		
not yet coded	*Aristida purpurea – Dyssodia papposa* Herbaceous Vegetation	Purple Three-awn - Fetid Marigold Herbaceous Vegetation PRAIRIE DOG TOWN GRASSLAND COMPLEX
Introduced Weedy Graminoid Herbaceous Vegetation		
not yet coded	Introduced Weedy Graminoid Herbaceous Vegetation	
Black Hills Sparse Vegetation		
CEGL002055	*Pinus ponderosa* Limestone Cliff Sparse Vegetation	PONDEROSA PINE LIMESTONE CLIFF
CEGL002295	Black Hills Rock Outcrop Sparse Vegetation	BLACK HILLS ROCK OUTCROP
CEGL002294	Shale Barren Slope Sparse Vegetation	SHALE BARREN SLOPES
CEGL005261	Redbeds (Silt/sandstone) Sparse Vegetation	REDBEDS
not yet coded	Recent Burn Sparse Vegetation	
Plains Riparian Forests and Shrublands		
CEGL000628	*Acer negundo / Prunus virginiana* Forest	BOX ELDER/CHOKECHERRY FOREST
CEGL002082	*Fraxinus pennsylvanica - Ulmus americana / Symphoricarpos occidentalis* Forest	ASH - ELM/WOLFBERRY FOREST
CEGL000660	*Populus deltoides / Symphoricarpos occidentalis* Woodland	COTTONWOOD/WOLFBERRY - WESTERN ROSE FLOODPLAIN
CEGL001131	*Symphoricarpos occidentalis* Shrubland [Provisional]	WOLFBERRY SHRUBLAND

Table 3. (continued)

High Elevation Riparian Forests and Shrublands	
CEGL001173 *Salix bebbiana* Shrubland	BEAKED WILLOW SCRUB
Riparian/Wet Meadow Herbaceous Vegetation	
CEGL001833 *Eleocharis palustris* Herbaceous Vegetation	CREEPING SPIKERUSH WET MEADOW
CEGL001477 *Spartina pectinata* - *Carex* spp. Herbaceous Vegetation	PRAIRIE CORDGRASS - SEDGE WET MEADOW
CEGL005263 Western Great Plains Streamside Vegetation	WESTERN GREAT PLAINS STREAMSIDE VEGETATION

photo by H. Marriott

Figure 17. Ponderosa pine with a mixed graminoid understory dominated by sun sedge.

present but are primarily located on private lands in the southeast and were not accessible for survey. However, data was collected for a very small cottonwood stand in the northeast portion of the Park. Aspen and paper birch forests were surveyed in the northwest part of the study area on US Forest Service lands, but only scattered small patches and individual trees are found within the Park boundaries.

Four shrubland types are recognized for the study area. Extensive mountain mahogany / side-oats grama shrublands occur in areas underlain by the Minnekahta limestone in the central part of WICA and small scattered stands are found elsewhere. Western snowberry shrubland occurs in drainage bottoms and draws. It is a common type in draws of grasslands in the eastern part of the Park. The chokecherry shrubland is also frequently found in these draws, although often on slightly more mesic sites, such as the head of the draw or around rock outcrops. The two types may blend extensively in these situations. Three-leaved sumac is often present or actually dominates many of the chokecherry stands and is also found as scattered patches on grassy slopes. Leadplant stands occurred in several grassland types, typically on slopes. Some of the best examples were found on uppermost slopes just below the summits of the broad benches in the northeast portion of the Park. Leadplant is not classified as a separate vegetation type (it was treated as a shrubby phase of several mixedgrass prairie types), but large stands above the minimum mapping unit were mapped.

One high-elevation riparian shrubland type occurs in the study area. A stand of beaked or Bebb's willow shrubland was sampled along a stream in the northwestern part of the project area, outside of the Park. This represents by far the most common riparian shrub type of higher elevations in the Black Hills (Marriott *et al*. Black Hills Community Inventory, in prep.).

Seven upland herbaceous vegetation types were included in the classification. The most mesophytic is the big bluestem - little bluestem herbaceous vegetation. This type is highly variable depending on the season's moisture. It typically occurs as large stands on steep rocky (cobbly) slopes of the broad benches in the northeast part of the Park and on rocky slopes on Boland Ridge. The cobbly talus may actually serve as a local aquifer allowing the big bluestem to thrive in these areas. Scattered stands were also observed throughout the Park and big bluestem was observed in other grassland types as well.

The western wheatgrass - green needlegrass and Kentucky bluegrass herbaceous vegetation types are common throughout the Park. The two types appear to occupy very similar habitats: flat to gently sloping areas of better soil development. On less favorable sites, two other types are found. Little bluestem - grama grass vegetation occurs on well developed, moderate-to-steep slopes often underlain with less developed silty to gravelly soils. Large stands of needle-and-thread - blue grama herbaceous vegetation occur on summits of broad benches in the northeast part of the Park, typically on rocky microsites, such as summit margins (Figure 18).

photo by H. Marriott

Figure 18. A needle-and-thread - blue grama grassland on a small hill with a high proportion of leadplant.

Two herbaceous types were newly created for this project. The purple three-awn - fetid marigold herbaceous vegetation (Prairie Dog Town Grassland Complex) is a type created to classify the vegetation occurring in prairie dog towns. Purple three-awn is often locally dominant both in the study area, and in other parts of the Black Hills. However, dominance varies locally as would be expected in this highly disturbed habitat. Big-bract verbena and fetid marigold are two of the more consistently present and common species. The Introduced Weedy Graminoid type is found throughout the Black Hills. This type includes stands of introduced graminoids growing on disturbed sites. The most common species are smooth brome, japanese brome and cheatgrass.

The diverse riparian vegetation occurring along many of the streams and wet meadows in the study area was classified using three riparian/wet meadow herbaceous types. Other types could have been included but these only occurred as small patches, which is typical for riparian types.

The prairie cordgrass - sedge community is found around seeps, springs and along slow-moving shallow streams. Cordgrass is not always present, and some stands could have been classified as Nebraska sedge communities if they were larger. A stand of pale spikerush herbaceous vegetation was found and sampled in a shallow pond within a large prairie dog town. The Western Great Plains Streamside Vegetation community is well developed along stretches of Highland and Beaver Creeks and is widespread at lower elevations throughout the Black Hills (Marriott pers. obs.).

Five sparse vegetation types are recognized for the study area. The Black Hills Rock Outcrop type (granites and schists) is found predominately in the northwest corner of the study area with much smaller outcrops in the Park. The Ponderosa Pine Limestone Cliff type occurs as small limestone outcrops associated with some of the larger streams in the central part of the Park. Redbeds Sparse Vegetation lies on small, badland-like exposures of the red Spearfish Formation in the Red Valley. Gypsum lenses are usually interspersed with this type. The Shale Barren Slope type is found in the outermost Hogback Rim region of the Black Hills, east of Boland Ridge. All exposures of this type within the study areas are privately owned and not accessible for survey. The Recent Burn sparse vegetation type was developed for this project. It includes recently burned stands, usually ponderosa pine, where the fire was sufficiently hot to kill most of the vegetation. Species composition was variable, consisting of early, often weedy and exotic, invaders such as Canada thistle (*Cirsium arvense*).

Vegetation Map Production

Map units

Thirty-eight map classes were recognized and used for WICA (Table 4). These were divided into 32 vegetation and geology units and six Anderson Level II (Anderson *et al*. 1976) land-use classes. These were developed through a combination of fieldwork, preliminary photo interpretation, and the NVCS vegetation association classification for WICA. Deviations from

Table 4. Map Units for WICA and corresponding NVCS classes.

Map Code	Map Unit	Elcode	NVCS Association
	Hardwood Forests and Woodlands		
40	Plains cottonwood / Western snowberry Woodland	CEGL000660	*Populus deltoides / Symphoricarpos occidentalis* Woodland
41	Boxelder / Chokecherry Forest	CEGL000628	*Acer negundo / Prunus virginiana* Forest
42	Bur oak Stand	(No corresponding class, Park Management Concern)	
43	Green ash - American elm / Western snowberry Forest	CEGL002082	*Fraxinus pennsylvanica - Ulmus americana / Symphoricarpos occidentalis* Forest
44	Birch - Aspen Stand	(No corresponding NVCS class, Park Management Concern)	
	Coniferous Forests and Woodlands		
45	Ponderosa pine Woodland Complex I (75%-100% cover)	CEGL000859 CEGL000849 CEGL000188	*Pinus ponderosa / Juniperus communis* Woodland *Pinus ponderosa / Carex inops* ssp. h*eliophila* Woodland *Pinus ponderosa / Pascopyrum smithii* Woodland
49	Young Ponderosa pine Dense Cover Complex	(No corresponding NVCS, Park Mangement Concern)	

Table 4. (continued).

46	Ponderosa pine / Little bluestem Woodland	CEGL000201 *Pinus ponderosa / Schizachyrium scoparium* Woodland
47	Ponderosa pine / Chokecherry Forest	CEGL000192 *Pinus ponderosa / Prunus virginiana* Forest
	Shrublands	
30	Mountain mahogany / Side-oats grama Shrubland I (15%-50% cover)	CEGL001086 *Cercocarpus montanus / Bouteloua curtipendula* Shrubland
31	Mountain mahogany / Side-oats grama Shrubland II (50%-100% cover)	CEGL001086 *Cercocarpus montanus / Bouteloua curtipendula* Shrubland
32	Leadplant Shrubland	(No corresponding NVCS class, Park Management Concern)
33	Chokecherry Shrubland	CEGL001108 *Prunus virginiana* Shrubland
12	Chokecherry Shrubland (with burned ponderosa pine)	(Same NVCS class as above, Park Management Concern)
34	Beaked willow Shrubland	CEGL001173 *Salix bebbiana* Shrubland
35	Western snowberry Shrubland	CEGL001131 *Symphoricarpos occidentalis* Shrubland [Provisional]
36	Creeping juniper / Little bluestem Dwarf-shrubland	CEGL001394 *Juniperus horizontalis / Schizachyrium scoparium* Dwarf-shrubland

Table 4. (continued).

Herbaceous Vegetation, upland	
15 Little bluestem - Grama grass - Threadleaf sedge Herbaceous Vegetation	CEGL001681 *Schizachyrium scoparium – Bouteloua (curtipendula gracilis) - Carex filifolia* Herbaceous Vegetation
11 Little bluestem - Grama grass - Threadleaf sedge Herbaceous Vegetation (with burned ponderosa pine)	(Same NVCS classes as above, Park Management Concern)
16 Western wheatgrass - Kentucky bluegrass Complex	CEGL001583 *Pascopyrum smithii - Nassella viridula* Herbaceous Vegetation CEGL003081 *Poa pratensis* Herbaceous Vegetation CEGL002205 *Andropogon gerardii - Schizachyrium scoparium* Herbaceous Vegetation
13 Western wheatgrass - Kentucky bluegrass Complex (with burned ponderosa pine)	(Same NVCS class as above, Park Management Concern)
17 Introduced Weedy Graminoid Herbaceous Vegetation	(not yet coded) Introduced Weedy Graminoid Herbaceous Vegetation
18 Needle-and-thread - Blue grama - Threadleaf sedge Herbaceous Vegetation	CEGL002037 *Stipa comata - Bouteloua gracilis - Carex filifolia* Herbaceous Vegetation
1 Purple three-awn - Fetid marigold Herbaceous Vegetation	(not yet coded) *Aristida purpurea - Dyssodia papposa* Herbaceous Vegetation

Table 4. (continued).

Herbaceous Vegetation, riparian/wet meadow	
14 Emergent Wetland Complex	CEGL001833 *Eleocharis palustris* Herbaceous Vegetation CEGL001477 *Spartina pectinata - Carex* ssp. Herbaceous Vegetation CEGL005263 Western Great Plains Streamside Streamside
Sparse Vegetation	
2 Ponderosa pine Limestone Cliff Sparse Vegetation	CEGL002055 *Pinus ponderosa* Limestone Cliff Sparse Vegetation
3 Redbeds Sparse Vegetation	CEGL005261 Redbeds (Silt/sandstone) Sparse Vegetation
4 Black Hills Rock Outcrop Sparse Vegetation	CEGL002295 Black Hills Rock Outcrop Sparse Vegetation
5 Shale Barren Slope Sparse Vegetation	CEGL002294 Shale Barrens Slopes Sparse Vegetation
6 White Sedimentary Rock Outcrop	(no corresponding NVCS class)
7 Bison Wallows	(no corresponding NVCS class, Park Management Concern)

the NVCS occurred when distinct photo signatures could not be discerned from aerial photography. This was the case for some of the dense ponderosa pine types and grassland types. Also, new map units that did not correspond to the NVCS types were used to provide more detail on vegetation deemed important for WICA's management needs. Finally, some map classes were added to explain certain geologic formations supporting sparse vegetation or which were devoid of vegetation. These included the shale barren slopes sparse vegetation and white sedimentary rock outcrop classes.

The ponderosa pine / common juniper, ponderosa pine / western wheatgrass, and ponderosa pine / sun sedge types could not be separated from each other on the aerial photography. This was largely due to the thick canopy of ponderosa pine masking any distinctive understory signature that might be present. Further, the intermingling of these types on various slopes, aspects, and topographic positions made predictive modeling impossible. After preliminary interpretation it was decided that accurate mapping of these 3 types would require the use of modified map units. The result was to create two ponderosa pine complexes based on canopy closure. Ponderosa pine complex I includes all stands with 75%-100% canopy closure, *i.e.* where the pine appeared on the photography as dense stands. Ponderosa pine complex II includes stands of pine that had a canopy of 15-75%.

A major management concern of the Park is the location and size of young, dense stands of ponderosa pine trees, commonly referred to as "doghair" stands. Since height of the pine trees could be observed on the aerial photography, a dense young age class was created to separate young "dog-hair stands from more mature, dense stands. This map unit did not correspond to an NVCS class but the understory of this type ranges from barren needles and duff, to sporadic common juniper, to small pockets of sun sedge.

For mapping purposes, the western wheatgrass - green needlegrass and Kentucky bluegrass types were combined into the western wheatgrass – Kentucky bluegrass herbaceous complex. This was largely a result of finding Kentucky bluegrass intermingled with western wheatgrass to some degree throughout the prairie regions of WICA. Separating these two on the aerial photography proved to be impossible. Large pockets of lead plant also occur within the Kentucky bluegrass and western wheatgrass – green needlegrass types. These situations are viewed as local variations of the herbaceous types but are important for the Park's management. To address this condition a separate lead plant map unit was created.

Other Park management concerns include the location of rare deciduous trees and bison wallows. This led to the creation of bur oak stand, aspen-birch stand, and bison wallow map units. These types were not large enough to be sampled at WICA and are not included on the NVCS classification. However, individual deciduous trees and bison wallows could easily be observed on the aerial photography and readily separated from the surrounding vegetation. Additional reference material supplied by the Park helped locate these types accurately (Smith 1978). All three of these map units usually occur below the ½ hectare minimum mapping unit but are included on the maps as small polygons rather than points.

Recent burns within the ponderosa pine forests were readily observable on aerial photography. The resulting seral vegetation was identified as belonging to either the chokecherry shrubland, western wheatgrass – Kentucky bluegrass herbaceous vegetation, or little bluestem - grama grass types (Figure 19). To provide more detailed information on these types, separate map units were created that indicate when these type occur in burned ponderosa pine stands.

Aerial Photograph Interpretation

A brief description of each map unit (map code), their location in the project area, and photo signature characteristics follows:

<u>Plains Cottonwood / Western Snowberry Woodland</u> (40) mapping unit occurs exclusively along some of the major streams and drainages in the project area; especially in the southeastern portion along Beaver Creek. The presence of large plains cottonwood trees occurring within a floodplain or riparian corridor is characteristic of this class. The understory is composed of various shrubs and grasses including snowberry, chokecherry, and western wheatgrass. On the

photo by D. Cogan

Figure 19. A burned ponderosa pine slope now supporting mixed graminoids.

aerial photos, cottonwood crowns appear as large pink, coarse circles or ovals with a rough, pebbly texture. This class is separated from other riparian, deciduous woodlands due to the very large size of cottonwood crowns and overall canopy height (Figure 20A).

Boxelder / Chokecherry Forest (41) is common along the perennial and intermittent streams throughout the project area. The photo signature is a bright red to pink color with a coarse texture due to the height and canopy diameter of the trees. This class may mask or cover other wetland, stream, shrub, or grass classes (Figure 20B).

Bur Oak Stand (42) mapping unit occupies the South Fork of Lame Johnny Creek in Custer State Park and along Reeves Gulch within WICA. The photo signature is almost identical to the boxelder / chokecherry class, however individual bur oak trees often appear smaller and more discrete. Field verification of polygon borders was necessary for accurate mapping of this class (Figure 20C).

Green Ash - American Elm / Western Snowberry Forest (43) unit is rare within the project area and is only found in the southeast corner and within small enclosures of WICA. This class contains some of the same species and the photo signature is almost identical to the boxelder / chokecherry forest map unit (Figure 20D).

Birch - Aspen Stand (44) is a rare class within the WICA project area, restricted to forested uplands in the northern portion. Aspen and birch usually occur within or adjacent to one of the ponderosa pine classes. On aerial photos, aspen and birch trees give identical signatures of a deep, bright red that contrasted with the brown pine signature (Figure 20E).. This type is distinguished from other deciduous classes based on topographic position and location. Whereas the other deciduous types are restricted to floodplains and riparian corridors, aspen and birch stands occur on slopes, benches, valley bottoms, and along the margins of floodplains.

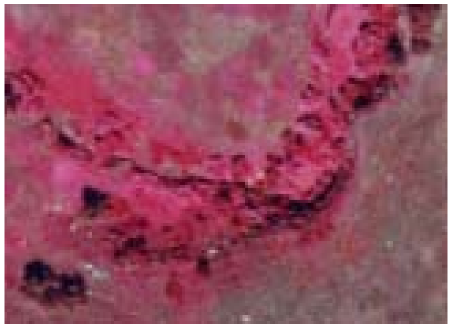
Ponderosa Pine Woodland Complex I (45) includes all forested areas with an approximate ponderosa pine crown density of 75%-100%. Included within this type are ponderosa pine / sun sedge, ponderosa pine / western wheatgrass, and ponderosa pine / common juniper associations. Understory signatures for this class are usually absent and soils supporting this type are typically thin with rock outcrops. On aerial photos, this category appears as a continuous, pebbled, brown layer with little if any color signature variation (Figure 21A).

Ponderosa Pine Woodland Complex II (48) includes forested areas with a probable ponderosa crown density of less than 75% but greater than 15%. Included within this type are ponderosa pine / sun sedge, ponderosa pine / western wheatgrass, and ponderosa pine / common juniper associations. Areas where ponderosa pine encroach onto deep, loamy soils are representative of this class. On aerial photos, this category appears as brown pebbles over a smooth red to pink undertone (Figure 21B). Areas that are in close proximity to grazed or disturbed grasslands are often completely dominated by Kentucky bluegrass yielding a bright red understory signature.

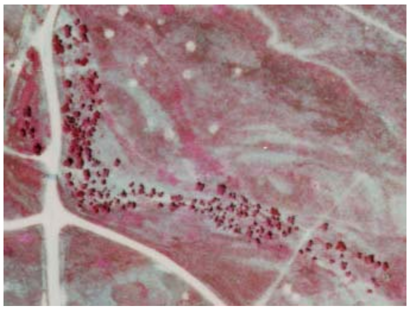
Young Ponderosa Pine Dense Cover Complex (49) unit includes all areas that were recently reforested by ponderosa pine (roughly <20 years old). Young ponderosa pine usually form

Figure 20. Representative photo-signatures for the deciduous tree map units. (all photography by Horizons, Inc. 1997).

A) Plains Cottonwood / Western Snowberry Forest



B) Boxelder / Chokecherry Forest



C) Bur Oak Stand

D) Green Ash - American Elm / Western Snowberry Forest

E) Birch-Aspen Stand

large, dense (dog-hair) stands next to older pine classes and/or burned areas. Mountain mahogany often occurs in close proximity to this class (especially along Wind Cave Canyon) making it difficult to discern. This class appears as small, brick red stipples between gray/pink grass signatures and brown mature pine signatures. Usually a fine network of drainages dissects this class as observed on aerial photography (Figure 21C).

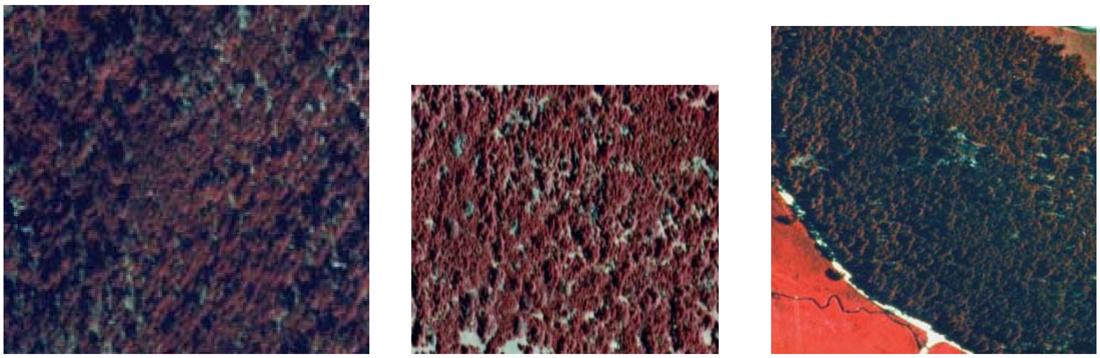
<u>Ponderosa Pine / Little Bluestem Woodland</u> (46) unit includes forested areas with a probable ponderosa crown density of less than 75% but greater than 15%. The semi-open to open canopy of this class supports an understory of grasses and sparse shrubs. Gravelly and sandy soils in these areas typically support little bluestem. On aerial photos, this category appears as brown pebbles over a light gray to white undertone (Figure 21D).

<u>Ponderosa Pine / Chokecherry Forest</u> (47) includes forested areas with a probable ponderosa crown density of less than 75% but greater than 15%. This class occurs in mesic areas such as forested drainages and north-facing slopes (probably representing an ecotone or a transition from dry woodlands to mesic grasslands/ shrublands). The photo signature for this class is relatively complex with brown pebbles and rough-textured bright red blotches (Figure 21E).

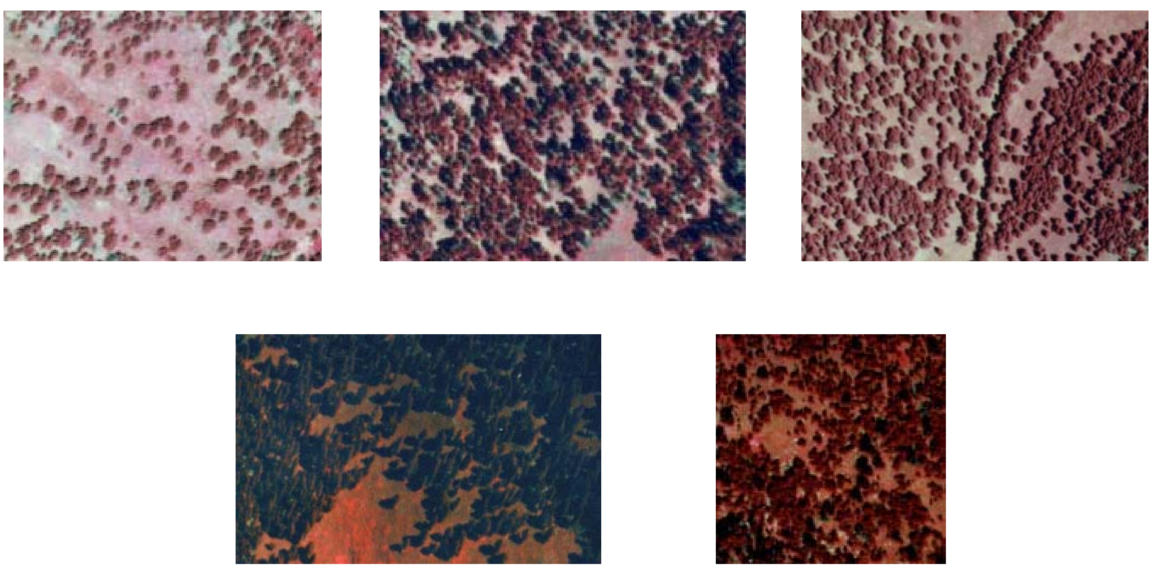
<u>Mountain Mahogany / Sideoats Grama Shrubland I</u> (30) is present along steep, dry, south-facing slopes throughout the Minnelusa foothills and especially the Wind Cave Canyon portion of the project area. Mountain mahogany cover on aerial photography ranges from 50% to less than 15%. Sideoats grama and little bluestem are the dominant grass species occurring in and around this type. Mountain mahogany appears as small, red-pebbled dots against a white to gray background on the aerial photography (Figure 22A).

<u>Mountain Mahogany / Sideoats Grama Shrubland II</u> (31) occurs along steep, north-facing slopes throughout the Minnelusa foothills and especially the Wind Cave Canyon portion of the project area. Mountain mahogany cover on the aerial photography ranges from about 100% - 50% (Figure 22B). Sideoats grama and little bluestem are the dominant grass species (Figure 23). Dense mountain mahogany appears as coarse, red, grainy blotches on the aerial photography

Figure 21. Representative photo-signatures for the ponderosa pine map units.
(all photography by Horizons, Inc. 1997).



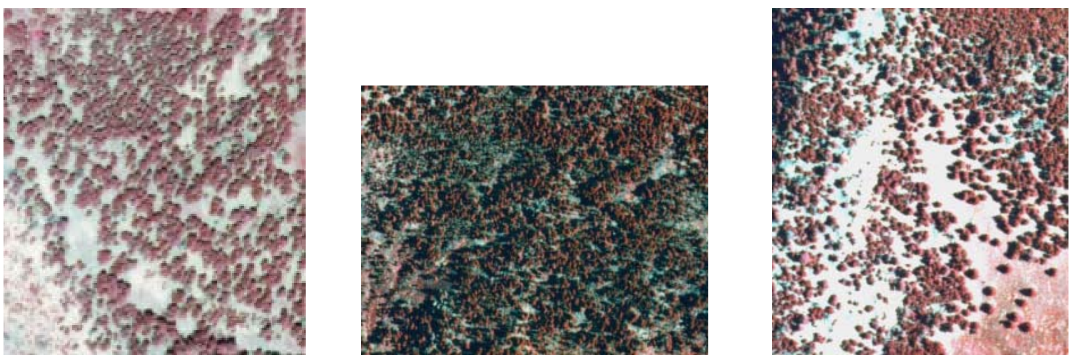
A) Ponderosa Pine Woodland Complex I



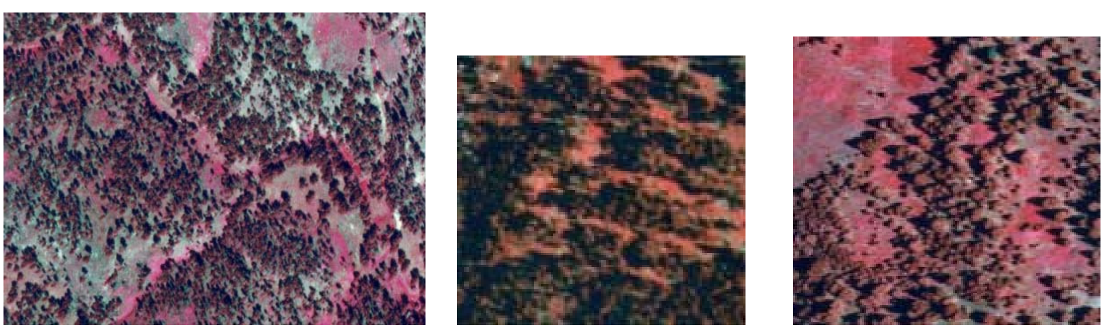
B) Ponderosa Pine Woodland Complex II

Figure 21. (continued).

C) Young Ponderosa Pine Dense Cover Complex



D) Ponderosa Pine / Little Bluestem Woodland



E) Ponderosa Pine / Chokecherry Forest

Lead Plant Shrubland (32) mapping unit occurs on some of the grassy slopes and knolls throughout the project area. This class is difficult to distinguish from the surrounding grassland types due to its short stature and the presence of a grass understory. The photo signature varies in color based on the grass component but usually contains some small pink to gray stipples (Figure 22C).

Chokecherry Shrubland (33) occurs throughout the project area on mesic slopes and drainages, along draws and deep swales, and on rocky soils. On slopes, three-leaved sumac shrubs are often present within this map unit and appear as dense circular blotches, bright red in color. Pure chokecherry stands give a similar red signature but occur in more linear or oval patterns. This class exhibited some height when viewed under stereo-magnification that allowed it to be separated from the western snowberry class (Figure 22D).

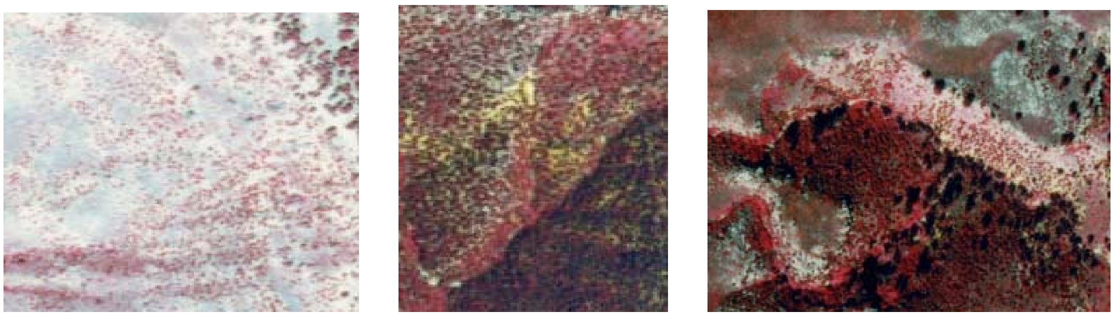
Chokecherry Shrubland (with burned ponderosa pine) (12) is identical to the above chokecherry class except that it occurs within burned ponderosa pine trees. The major species are various deciduous shrubs with a bright pink or red signature. Charred ponderosa pine stumps and standing dead trees are also observable, especially under magnification (Figure 22E).

Beaked Willow Shrubland (34) unit represents a limited riparian shrubland that exists only in the northwest portion of the study area along perennial streams. The photo signatures for this class are very bright red, linear ovals that exhibit a somewhat coarse texture (Figure 22F).

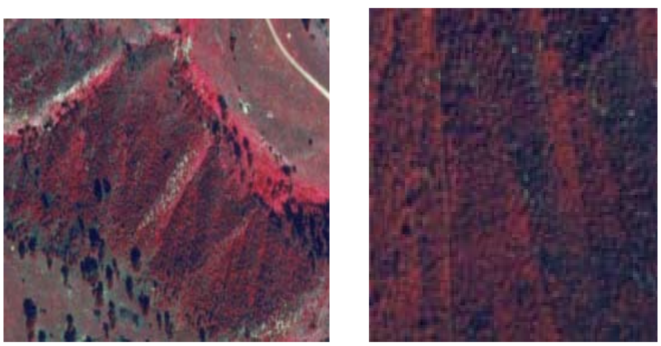
Western Snowberry Shrubland (35) is very common throughout the project area in mesic swales, draws, and drainages. The photo signature for snowberry varies slightly from red to pink and occurs as small blotches or linear "fingers". This class is distinguished from the 3-leaved sumac - chokecherry type by the lack of height under stereo-magnification (Figure 22G).

Creeping Juniper / Little Bluestem Shrubland (36) mapping unit is extremely rare in the project area. This class only occurs in two known locations. The aerial photo signature is nearly indistinguishable from the surrounding vegetation (Figure 22H).

Figure 22. Representative photo-signatures for the shrub map units.
(all photography by Horizons, Inc. 1997).

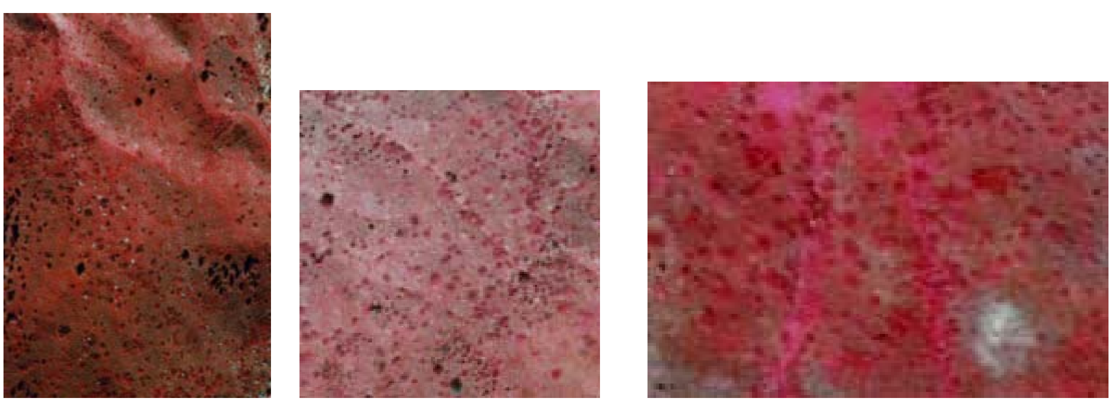


A) Mountain Mahogany / Side-oats Grama Shrubland I



B) Mountain Mahogany / Sideoats Grama Shrubland II

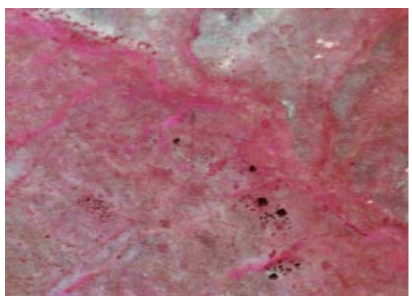
C) Lead Plant Shrubland



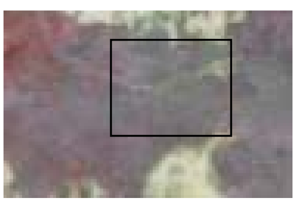
D) Chokecherry – Three-leaved Sumac Shrubland

Figure 22. (continued).

E) Chokecherry Shrubland (with burned ponderosa pine) F) Beaked Willow Shrubland



G) Western Snowberry Shrubland



H) Creeping Juniper / Little Bluestem Dwarf-shrubland

Figure 23. An example of the dense mountain mahogany map unit occurring on a north-facing slope at WICA.

Emergent Wetland Herbaceous Complex (14) is used to map the limited herbaceous wetlands occurring within the project area. This class exhibits typical wetland signatures consisting of a pure dark blue to black color in open water, dark blue to black with red stipples in the emergent zone, and bright red for vegetation occurring along the margins (Figure 24A). Wetlands are identified and mapped to the extent of the associated vegetation. An "open water" mapping unit is used to classify any deep pools or flowing water devoid of vegetation
(Note: Small creeks, streams, and drainages are mapped as linear wetland features).

Little Bluestem - Grama Grass - Threadleaf Sedge Herbaceous Vegetation (15) typically occurs on sparse to barren gravelly slopes and knolls throughout the project area. The grama grass component consists of both side-oats grama and blue grama. The photo signature varies slightly from a smooth bright white to a smooth dull gray. A lack of photosynthetic activity and/or the presence of dead material likely causes these unique colors. This class is mapped to the extent of its characteristic barren or dull signature (Figure 24B).

Little Bluestem – Grama Grass - Threadleaf Sedge Herbaceous Vegetation (with burned ponderosa pine) (11) occurs throughout burned forested regions of the project area. This type is often found on tops of hills and mountains where the soils are gravelly and rocky. Little bluestem and side-oats grama are the dominant plant species and rock outcrops are usually associated with this type. On aerial photos, charred ponderosa pine stumps and standing dead trees are readily observed as small black "toothpicks". The background signature is a pale, rough white (Figure 24C).

Western Wheatgrass - Kentucky Bluegrass Complex (16) mapping unit represents the western wheatgrass - green needle grass and Kentucky bluegrass herbaceous vegetation types. This mapping unit is found throughout the project area on mesic loamy to clayey soils. The photo signature for this class ranges from olive green, to blue green, to light pink in color resulting from a combination of soil depth, moisture, grazing activity, and associated species (Figure 24D).

Western Wheatgrass - Kentucky Bluegrass Complex (with burned ponderosa pine) (13) is found throughout burned-forested regions of the project area. This is the most common of the burned classes and corresponds to the dominance of various grasses and sedges. The aerial photo signature for this type varies from a smooth bright red to a rough pink depending on topographic position and moisture availability. Charred ponderosa pine stumps and standing dead trees are always present (Figure 24E).

Introduced Weedy Graminoid Herbaceous Vegetation (17) represents the few introduced grassland components within the project area. Smooth brome, cheatgrass, and Japanese brome are the chief species and are currently restricted to road rights-of-way, heavily disturbed areas, and agricultural fields. Both grasses, when dominant, grazed, and/or mown give a mottled signature consisting of yellows, pinks, and reds. (Figure 24F).

Needle-and-thread - Blue Grama - Threadleaf Sedge Herbaceous Vegetation (18) unit occurs sparingly at WICA, increasing towards the northeast corner where it occupies cobbly, broad benches. This class likely corresponds to increased grazing pressure and/or a reduction in soil moisture. The photo signature for this type is difficult to distinguish from little bluestem, although it tends to be darker in color (Figure 24G).

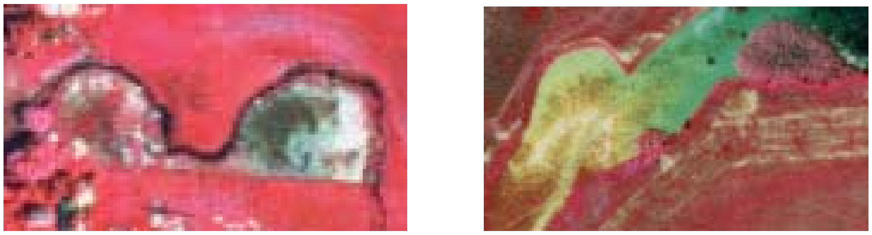
Purple Three-awn - Fetid Marigold Herbaceous Vegetation (1) mapping unit occurs in the grassland portions of the project area, occupying broad drainages, swales, terraces, and very gentle slopes. This type usually contains more forb cover and much less graminoid cover than the other herbaceous types. The photo signature always consists of small white stipples (prairie dog burrows) interspersed among various disturbed grassland signatures. Bison wallows and pocket gopher mounds may have given similar signatures but usually lack the corresponding disturbed grassland colors and small interconnecting trails. This class is mapped up to the obvious border of the undisturbed native grasslands (Figure 24H).

Ponderosa Pine Limestone Cliff Sparse Vegetation (2) is used sparingly to characterize the limestone cliffs and bluffs present in valleys along some of the major streams at WICA. This unit typically includes some sparse ponderosa pine and patches of shrubs and graminoids among limestone outcrops. The photo signature for this type is bright white with some small brown dots caused by high reflectance and the presence of a few ponderosa pine trees (Figure 25A).

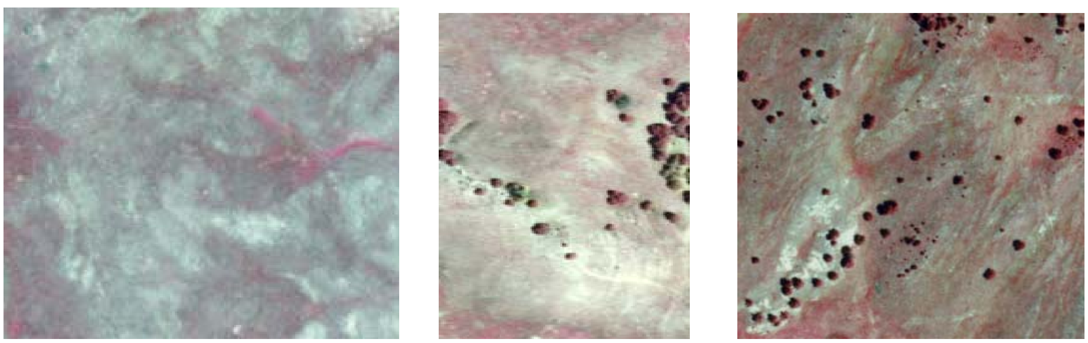
Redbeds Sparse Vegetation (3) mapping unit is used exclusively in the Red Valley region of WICA. This type corresponds to the red erosion faces occurring on some of the steeper hill slopes. Vegetation occurring on these formations is usually sparse, and includes both graminoids and various forbs. These areas appeared as smooth, dark yellow, almost barren, slopes (Figure 25B).

Black Hills Rock Outcrop Sparse Vegetation (4) is found in the northwest corner (CCA region) of the project area. These areas are characterized by large prominent rock outcrops, ridges, and similar formations. Some ponderosa pines are present as are associated stands of aspen and birch. The gray granite and schist rocks appears fractured (small cracks) on the aerial photography (Figure 25C).

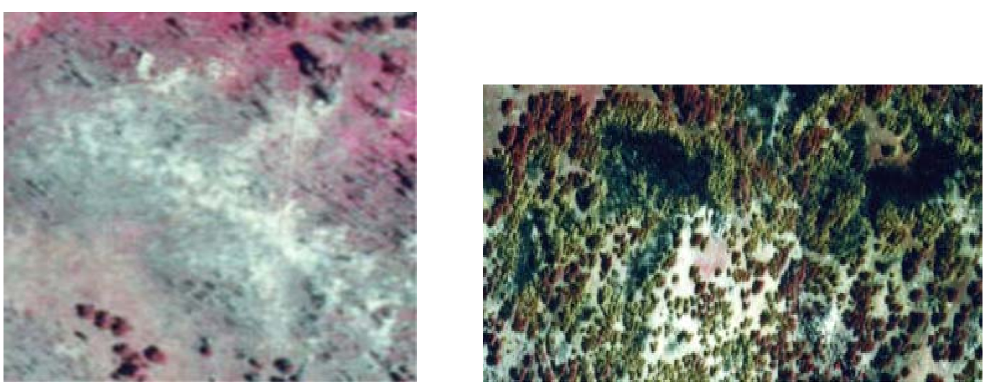
Figure 24. Representative photo-signatures for the herbaceous map units. (all photography by Horizons, Inc. 1997).



A) Emergent Wetland Herbaceous Complex

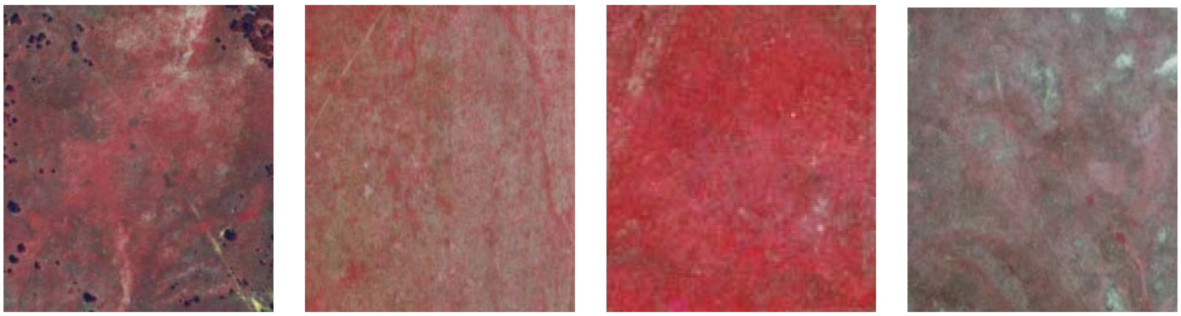


B) Little Bluestem - Grama Grass / Threadleaf Sedge Herbaceous Vegetation

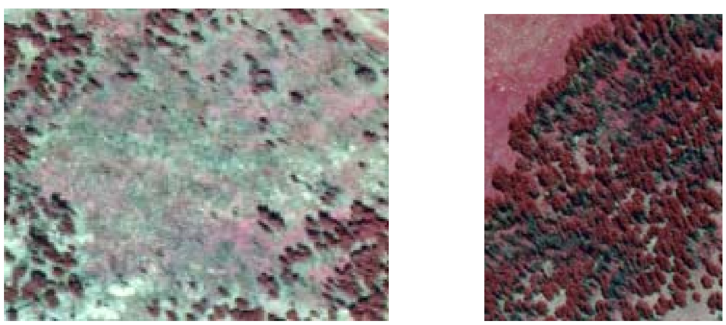


C) Little Bluestem - Grama Grass / Threadleaf Sedge Herbaceous Vegetation (with burned ponderosa pine)

Figure 24. (continued)



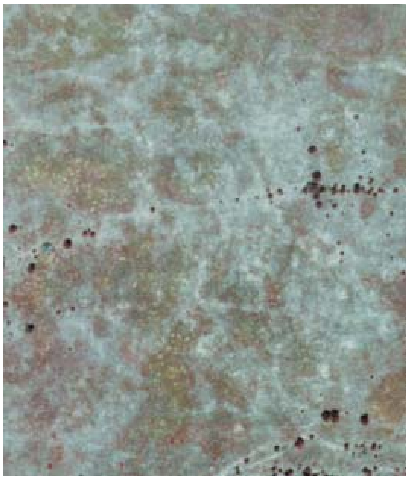
D) Western Wheatgrass - Kentucky Bluegrass Herbaceous Complex



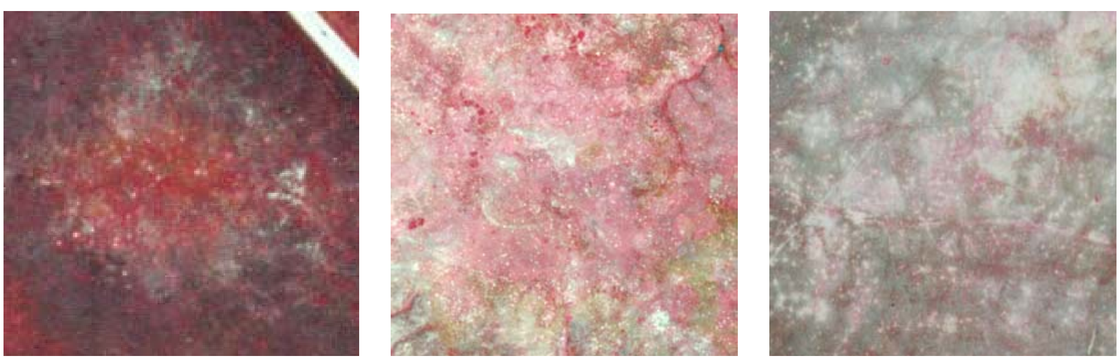
E) Western Wheatgrass - Kentucky Bluegrass Herbaceous Complex (with burned ponderosa pine)

F) Introduced Weedy Graminoid Herbaceous Vegetation

Figure 24. (continued)



G) Needle-and-thread - Blue Grama / Threadleaf Sedge Herbaceous Vegetation



H) Purple three-awn / Fetid marigold Disturbed Vegetation

Shale Barren Slope Sparse Vegetation (5) mapping unit is located in the eastern portion of the environs outside the WICA boundary. This type is common on drainage slopes that are subject to water erosion. On the aerial photography, shale outcrops appear absolutely barren except for some wetland pockets in the lowest areas and are characterized by a dark blue signature (Figure 25D).

White Sedimentary Rock Outcrop (6) is used to address the unique geologic formations in the southern portion of the project area. Layers of white siltstone, sandstone, gypsum, and limestone occur here as caps on a large number of rolling hills and mounds. These appear to be almost completely devoid of vegetation and reflect a bright white photographic signature (Figure 25E).

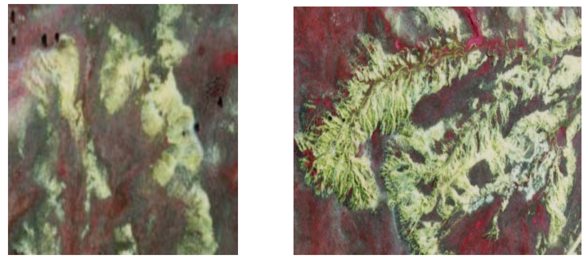
Bison Wallows (7) are common in the grassland portions of this study. These correspond to disturbed areas used by bison as mineral licks and wallows. Wallows are usually small and interconnected by a network of many small trails. The signature for this type is apparent on aerial photography as dark yellow to light green circles or ovals (Figure 25F).

Transportation, Communications, and Utilities (51) land use class represents U.S., state, and other major highways, parking lots, disturbed powerline right-of-ways, and old railroad rights-of-way. Within WICA and surrounding public lands, this class is bounded primarily by native vegetation. In these instances, this map unit is restricted to the road surface or disturbed “core” area. In the remaining areas, the entire disturbed corridor is used as the mapping boundary where road-cuts, mowing, or other maintenance regularly occurs. Paved concrete surfaces on the aerial photographs reflect white, except where black patching occurred. Disturbed areas usually have a multi-colored mottled signature sharply contrasting with adjacent native vegetation (Figure 26A). (Note: Two-track roads and trails are mapped as linear features).

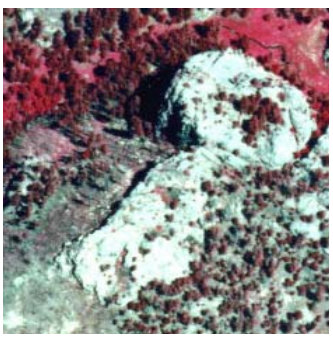
Mixed Urban or Built-up Land (52) corresponds to WICA facilities, developed land, and the town of Pringle, SD. This unit contains many possible photo signatures representing buildings, lawns, bare ground, and storage areas (Figure 26B).

Figure 25. Photo-interpretive key to the sparse vegetation classes.
(all photography by Horizons, Inc. 1997).

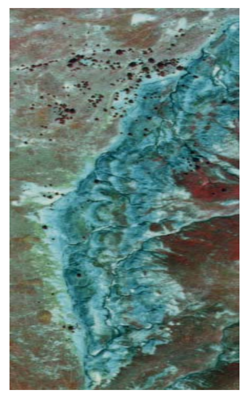
A) Ponderosa pine Limestone Cliff Sparse Vegetation



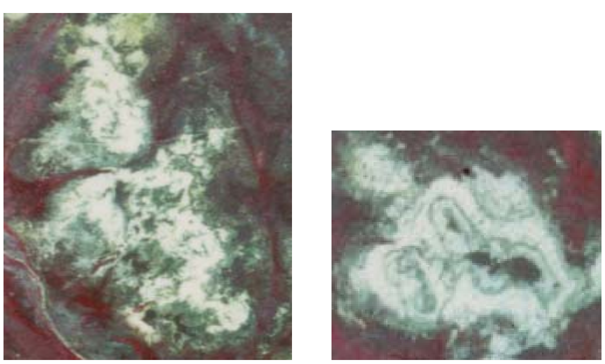
B) Redbeds Sparse Vegetation



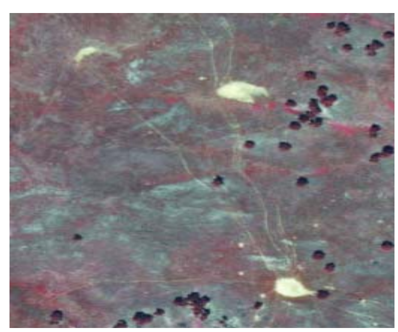
C) Black Hills Rock Outcrop Sparse Vegetation



D) Shale Barren Slopes Sparse Vegetation



E) White Sedimentary Rock Outcrop



F) Bison Wallows

Croplands and Pastures (53) land use class occurs in the project environs outside of WICA. Pastures and fields usually exhibit regular boundaries on relatively flat land, becoming more irregular in floodplains. This class contains various photo signatures ranging from bright red to dull green depending on whether the land is used for hay production, seeded, or fallow. Linear crop-lines are often present on the aerial photography (Figure 26C).

Other Agricultural Lands (55) within the project boundary include homesteads, ranch-sites, corrals, barnyards, and other high-use rural areas. The photo signature for these sites varies from a multi-colored mottled signature to a bright pinkish red. Regular fence lines and access roads are often present (Figure 26D).

Open Water (57) corresponds to standing water devoid of any observable vegetation. This includes wide streams, rivers, sewage pools, and deep ponds. The reflectance is often a smooth, blue to black color depending on turbidity and depth. Certain sun angles increase the reflectivity yielding pure white to gray colors (Figure 26E).

Strip Mines, Quarries, and Gravel Pits (59) map unit class represent areas in the mapping project where the soil and underlying material has been removed and drastically disturbed. These areas appear on the aerial photographs as dark pits or highly reflective rock out-crops. Access roads and dirt/rock piles are usually present (Figure 26F).

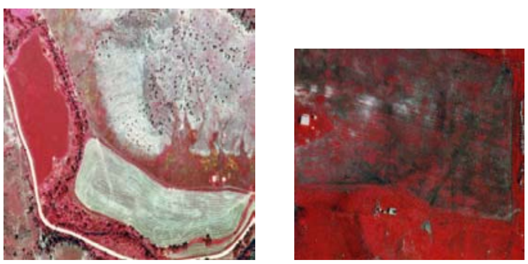
Digital Transfer

Vegetation coverages were created in ArcInfo™ (ESRI, Inc.) for each quarter quadrangle of the WICA study area. A list of quarter quadrangles can be found in Appendix 13. Total area and number of polygons per map unit were generated for each quarter quadrangle. The grand total of polygons and area for the entire study can be found in Table 5.

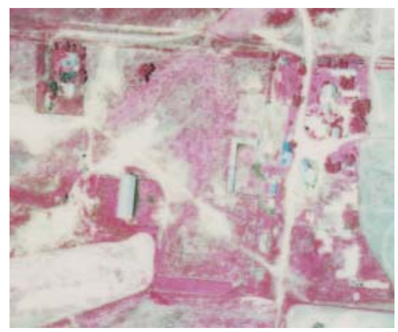
Figure 26. Photo-interpretative key for land-use map units.
(all photography by Horizons, Inc. 1997.)

A) Transportation, Communications, and Utilities

B) Mixed Urban or Built-up Land



C) Croplands and Pastures



D) Other Agricultural Lands

E) Open Water

F) Strip Mines, Quarries, and Gravel Pits

Table 5. Total area (meters^2 / 4046.9acres/m^2 / 2.471 acres/hectare) and number of polygons per mapping unit. The map codes are described in Appendix 10.

Map Unit	WICA		Environs		Total	
	Hectares	Polygon	Hectares	Polygon	Hectares	Polygon
1	530.9	44	330.1	29	861.0	73
2	11.6	36	18.2	40	29.8	76
3	27.7	75	40.9	70	68.6	145
4	4.1	25	90.5	289	94.6	314
5	0	0	70.8	58	70.8	58
6	65.1	182	204.5	352	269.6	534
7	4.0	78	0.3	4	4.3	82
11	40.4	64	116.3	86	156.7	150
12	4.4	13	81.4	36	85.8	49
13	152.3	261	372.1	109	524.4	370
14	10.2	84	44.2	244	54.4	328
15	1896.8	1767	2363.1	2733	4259.9	4500
16	4328.7	1010	6417.9	1771	10,746.6	2781
17	2.7	15	37.1	56	39.8	71
18	89.3	11	197.0	46	286.3	57
30	153.0	121	425.5	146	578.5	267
31	41.4	50	146.4	125	187.8	175
32	130.2	71	3205	20	162.7	91
33	198.3	287	502.9	485	701.2	772
34	0	0	7.9	35	7.9	35
35	328.1	785	429.9	1287	758.0	2072
36	0.1	2	0	0	0.1	2
40	1.3	26	51.4	164	52.7	190
41	31.3	120	118.4	285	149.7	405
42	0.3	4	14.2	13	14.5	17
43	0	0	11.6	24	11.6	24
44	2.4	5	42.0	134	44.4	139
45	322.1	111	2392.1	299	2714.2	410
46	1110.2	552	3114.1	1100	4224.3	1652
47	262.2	224	738.6	469	1000.8	693
48	1404.4	615	3106.2	1173	4507.0	1788
49	162.0	171	833.3	373	995.3	544
51	54.3	18	199.7	29	254.0	47
52	15.2	38	62.0	54	77.2	92
53	5.4	2	1739.0	227	1744.4	229
55	0	0	112.1	92	112.1	92
57	1.4	6	26.7	90	28.1	96
59	0	0	41.4	38	41.4	38
Total	11,391.8	6873	24,528.7	12,585	35,920.5	19,458

Accuracy Assessment

The percentage of the Park that an individual map unit covered was reflected in the number of AA collected for that unit. For example, the western wheatgrass – Kentucky bluegrass (map class 16) had a final area of 4278.7 hectares within the Park and 64 AA points, whereas the ponderosa pine limestone cliff sparse vegetation (map code 2) had only 11.4 hectares and one AA point. Nine of the map units were not assessed due to a variety of reasons relating to their small size, accessibility, or lack of abundance. These include the following:

1. Black Hills Rock Outcrop Sparse Vegetation. This unit only occurs within WICA below the ½ hectare minimum mapping unit.

2. Shale Barren Slopes Sparse Vegetation. This unit only occurs on inaccessible private land in the eastern environs.

3. Introduced Weedy Graminoid Herbaceous Vegetation. Only one relatively inaccessible large site occurs within the project area. An observation point already represented this area.

4. Mountain Mahogany / Sideoats Grama Dense Shrubland. On the ground, dense stands of mountain mahogany could not be identified from sparse stands by the researchers. Density is easier to determine from the aerial photographs. For the purposes of AA, this unit was combined with the mountain mahogany / sideoats grama shrubland mapping class.

5. Beaked Willow Shrubland. This unit does not occur in WICA and was already represented by a sample plot.

6. Plains Cottonwood / Western Snowberry Forest. This unit occurs as small stands below the minimum mapping unit and mainly outside of WICA.

7. Bur Oak Stand. Only one very small stand occurs within WICA and it was not considered large enough to be a separate vegetation association. An observation point already represented this area.

8. Green Ash – American Elm / Western Snowberry Forest. This mapping unit is usually below the minimum mapping unit or intermingled with the boxelder / chokecherry forest mapping unit. The majority of this type was observed on private land outside of WICA.

9. Birch – Aspen Stand. This unit occurs as very small stands below the minimum mapping unit and is not considered large enough to be considered a vegetation association.

The majority of the remaining 23 map units ranged in accuracy from 100% to around 50% correct (both omission and commission error), yielding an overall total accuracy across all classes of 73.0% and a Kappa index of 69.8% (Table 6).

photo by H. Marriott

Figure 27. Bison grazing on western wheatgrass and green needlegrass at WICA.

Table 6. Contingency table for the WICA vegetation mapping accuracy assessment.

																	Reference Data (Accuracy Assessment Class)																Total	Comission	90% Confidence	
	Map Unit	1	2	3	4	5	6	7	11	12	13	14	15	16	17	18	30-	32	33	34	45	36	40	41	42	43	44	45	46	47	48	49	N	Error	Interval	
	Code																31																	% Correct	-	+
	1	6																															6	100	65.5	100
	2		1																														1	100	10.0	100
	3			1																													1	100	10.0	100
	4																																0	NA	-	-
	5																																0	NA	-	-
S	6			1			1						6																				8	12.5	1.3	41.8
A	7							1																									1	100	10.0	100
m	11								1	2	2																						5	20.0	2.1	62.1
p	12																																0	NA	-	-
L	13								1		8																						10	80.0	50.0	94.5
E	14											1																					1	100	10.0	100
	15												24	10		2			1														37	65.0	49.9	80.1
D	16												4	45							1												51	88.0	78.1	94.8
A	17																																0	NA	-	-
t	18													1		2																	3	66.7	19.6	96.5
A	30-31																7												1				8	87.5	58.2	98.7
	32												1	3				10															14	71.4	42.2	86.9
(M	33													2			3		10		1												16	62.5	38.1	81.1
A	34																																0	NA	-	-
p	35													2					2		11												15	73.3	50.0	87.8
	36																					1											1	100	10.0	100
C	40																																0	NA	-	-
L	41																		1					3									4	75.0	32.0	97.4
A	42																																0	NA	-	-
S	43																																0	NA	-	-
s)	44																																0	NA	-	-
	45																											5					5	100	62.1	100
	46												1				1												13		6	1	22	59.1	39.3	76.4
	47													1			1													8	9	1	20	40.0	22.1	63.3
	48										1		1																3	1	48	1	55	87.3	77.4	93.9
	49																													1		4	5	80.0	37.9	97.9
	Total N	6	1	2	0	0	1	1	2	2	11	1	37	64	0	4	12	10	14	0	13	1	0	3	0	0	0	5	17	10	65	7	289			
Omission Error % Correct		100	100	50	NA	NA	100	100	50	0.0	72.7	100	64.9	70.3	NA	50	58.3	100	71.4	NA	84.6	100	NA	100	NA	NA	NA	100	76.5	80	73.8	57.1				
90% Confidence Interval																																				
-		65.5	10	5.1	-	-	10	10	5.1	0	42.3	10	49.8	59.6	-	14.3	29.4	77.8	42.2	-	62.1	10	-	46.4	-	-	-	62.1	56.8	50	63.6	27.9				
+		100	100	94.9	-	-	100	100	94.9	68.4	89.5	100	80	81	-	85.7	81.6	100	86.9	-	95.8	100	-	100	-	-	-	100	89.3	94.5	84	83				

OVERALL TOTAL ACCURACY = 73.0%

OVERALL KAPPA INDEX = 69.8%

OVERALL TOTAL ACCURACY 90% LOWER AND UPPER CONFIDENCE INTERVAL = + 77.6 % - 68.4 %

(Omission and Commision errors were calculated using total accuracy)

(Map Units 30 and 31 were combined for the A.A. since shrub density was not recorded on the reference data.)

DISCUSSION

Wind Cave National Park lies on an interface between the Northern Great Plains grasslands and the Black Hills ponderosa pine forests. The geology and topography of this region creates an ever-changing landscape mosaic of plant associations. This presents challenging vegetation classification, photographic interpretation, and digital transfer needs that were met and addressed in the USGS-NPS National Park vegetation mapping effort. Final accuracy for the vegetation map reflects the time and effort required to understand and appreciate the complex nature of WICA's vegetation.

Vegetation Classification and Characterization

Most of the vegetation found in the Wind Cave study area was classified using existing community types for the Black Hills. In a few cases, new types were created. All of the newly described types occur outside the study area as well, but were not described prior to this project.

Not all ponderosa pine stands found in the project area were easily classified, but the challenges encountered were not unexpected. Many workers have described ponderosa pine forests and woodlands of the Black Hills as being difficult to classify into discreet species assemblages. Types found in more extreme habitats (e.g. most mesic or most xeric) tend to be more consistent in terms of species composition and habitat characteristics. This situation also was found in the Wind Cave study area. Ponderosa pine / chokecherry forest was perhaps the most consistent pine type in terms of habitat characteristics (mesic), although the composition of the shrub stratum was quite variable in some areas. Ponderosa pine / little bluestem woodland is the most consistent pine type in terms of composition, and is usually found on the most xeric pine sites.

Vegetation Map Production

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

The final mapping scheme for WICA contains 5 basic elements:

a) NVCS associations represented by an unique photo-signature, e.g. western snowberry shrubland,
b) multiple NVCS associations that together are represented by unique signature, e.g. western wheatgrass - Kentucky bluegrass herbaceous complex,
c) stands of vegetation that were not addressed by the NVCS but are seen as management concerns for WICA and could be recognized on the aerial photography, e.g . birch-aspen stands and young ponderosa pine (doghair) stands,
d) wildlife associated units that were also identified as management concerns, e.g. Bison wallows,
e) geologic formations and land-use classes that were not addressed by the NVCS.

Crown density of ponderosa pine and mountain mahogany is also an important factor in the development of map units. For example, two distinct density classes of mountain mahogany shrubland were recognized on the aerial photography relating to north vs. south-facing slopes. However, researchers could see no clear distinction on the ground, especially with regards to species composition. WICA personnel determined that this was important information from a management standpoint, therefore two mountain mahogany map units were interpreted and mapped. The opposite situation was encountered in ponderosa pine stands. Community types distinguishable on the ground (based on species composition and understory structure) could not be recognized on aerial photos due to canopy cover. As a result, the three NVCS classes found in these situations were merged into a ponderosa pine complex. Again to provide additional information for the Park, this class was divided based on density as observed on the aerial photography.

The sheer amount and variability of grassland signatures made them difficult to distinguish and consistently interpret. Environmental factors such as grazing pressure (especially in the environs), moisture gradients, presence and density of forbs/shrubs, and soil diversity result in several photographic signatures for each grassland unit. It was apparent early in this study, that Kentucky bluegrass could not be effectively separated from western wheatgrass. This is largely because both species are cool season, sod-forming grasses that occur in the same topographic positions. Therefore a western wheatgrass - Kentucky bluegrass complex mapping unit was created. Another grassland type that presented similar challenges is the needle-and-thread - blue grama / threadleaf sedge herbaceous vegetation association. This type is confined to a few dry plateaus and ridges within WICA and on some grazed areas in the environs. Here the photo signature is very similar to that of the little bluestem - grama grass / threadleaf sedge herbaceous vegetation type. Rather than combining the two, this type was primarily interpreted from the aerial photography using field notes and sample sites of known locations. Finally, some of the grassland slopes at WICA support large stands of leadplant. This shrub type is not considered widespread or typical of the region and is not listed in the NVCS. However at the urging of Park personnel, an attempt was made to interpret and map the leadplant type based on location and slope even though photographic signature were vague.

Prior vegetation mapping projects at other NPS sites in the Black Hills have shown that interpreting ponderosa pine types can be very difficult. Canopy closure, shadows, past forest fires, and logging/thinning can all cause situations where unique photographic signatures are either indistinguishable or extremely disordered. This uncertainty was addressed at WICA by using a stepwise photo interpretive process that sorted the pine types by canopy closure, understory signature, topographic positions, and slope/aspect. Initially, it was determined that the understory below ponderosa pine stands with greater than 80% canopy closure could not be distinguished. Instead, tree height was used to separate dense young (< 20 year old) ponderosa pine dog-hair stands from more mature (> 20 year old) thick stands. The second step was to match the undertone colors present on the aerial photography with NVCS classes. Field reconnaissance was used to match the red-pink understory colors with various graminoids (western wheatgrass, Kentucky bluegrass, oatgrasses, sun sedge, etc...), bright red to shrubs (mainly chokecherry), and pale white-blue to little bluestem (on the color infrared aerial photography). Finally, slope and aspect was used to predict understories of chokecherry along gentle to slightly steep north-facing slopes, and along forested drainageways.

Using the above interpretative processes and methods ordered the map units well, but still resulted in some photo interpretation discrepancies. Various factors dealing with the physiognomy of the vegetation caused some confusion in interpreting photographic signatures. For example, both the chokecherry and the ponderosa pine / chokecherry map units were assessed at relatively low accuracy. Tall forbs and poison ivy are both relatively common at WICA and are similar in height and morphology (e.g. broad leaf) to chokecherry. These characteristics caused areas dominated by either one to appear as chokecherry on the color infrared photography. Further, the timing of the accuracy assessment collection (Sept-Nov. 1998) may have resulted in these deciduous species being relatively inconspicuous and/or absent from the data collection.

Seasonal changes from the time of the aerial photography (June 1997) to the collection of accuracy assessment data (September-November 1998) also results in a change in dominance (with respect to foliar cover) from cool season to warm season grasses. For example, little bluestem is a warm season bunch grass that is somewhat innocuous in the spring but gradually changes to very prominent clumps of reddish - brown stems in the fall. The aerial photography records spring phenology where western wheatgrass and Kentucky bluegrass are the dominant actively growing plants, which would also be readily observable on the ground. Floristic composition changes in the fall, as areas with little bluestem become more pronounced. The distinctness of little bluestem at this time may cause an observer to classify it out of proportion to its actual dominance; especially if the litter layer is not examined for Kentucky bluegrass or western wheatgrass. Further review of WICA's seasonal plant phenology may be needed to ensure consistent sampling and classification at different times within the growing season.

Digital transfer and registration of information from aerial photographs to a spatial database proved to be a challenging task for WICA. This was largely due to the complex and intricate line work needed to delineate each photograph. To guarantee transfer of all the line work, scanning and multiple transformation processes using landmarks as controls were used for each aerial photograph overlay. Other transfer processes such as on-screen or zoom transfer received discussion and/or experimentation. However, these were either considered too time consuming or insufficient for the needs of this project. Scanning and multiple geographic transformations efficiently produced digital polygons across the entire project area. Further editing and quality checking of the digital polygons created borders that tightly bounded corresponding features on the digital ortho-photo quarter quad (DOQQ) base map.

Ten map units were assessed at or near the 80% accuracy standard. These included the following (map codes): 1, 2, 7, 14, 32, 35, 36, 41, 45, 48 (Table 4). For the most part, these units correspond to associations or complexes that were either easily recognized on the aerial photography or occurred on predictable landscape locations. Eight map units were not assessed for accuracy due to their relative small size and inaccessibility. These classes covered only 10 hectares in WICA and represented less than 0.1% of WICA's total acreage. Map units that were lower in accuracy tended to be those not extensively sampled due to their rarity or were those that tended to intermingle along a broad ecotone. The assessment of accuracy for this project involved the basic comparison of vegetation polygons overlain with datapoints. GPS error (around 5 meters on average), DOQQ base-map error (approximately 10 meters), and data recording inconsistencies between different researchers were not factored into the assessment. Similarly 28 accuracy points considered to be in error with the map data had the correct map unit listed as occurring within a 50-meter radius. Further investigation using these factors could yield additional map accuracy increasing it to approximately 88%.

Some map units, although below the 80% accuracy, should be accepted as representative of their inherent variability. These include the ponderosa pine / little bluestem woodland (59.1% correct commission 76.5% correct omission, respectively) ponderosa pine chokecherry forest (40.0%, 80.0%), and little bluestem - grama grass / threadleaf sedge herbaceous vegetation (65.0%, 64.9%). These types often occur intermingled with other types forming large heterogeneous areas. To combine these with other classes would result in a reduction of map detail and a loss of potentially useful data.

Other map units with low accuracy lend themselves to be merged into larger, more accurate classes without a significant loss of information. These include 1) white sedimentary rock outcrop (map code 6), which could be combined with redbeds sparse vegetation (map code 3) in the confines of the Red Valley geographic formation where it occurs as a true rock outcrop.

Outside of the Red Valley, field research determined the vegetation on these sites to be sufficiently dense and consistent with little bluestem -grama grass / threadleaf sedge herbaceous vegetation. 2) The burned ponderosa pine / sparse vegetation class (map code 11) could readily be merged with the burned ponderosa pine / mixed shrubland (map code 12) yielding a new burned ponderosa pine / shrub-forb map unit at 100% accuracy. This would make sense from an ecological perspective since both were considered early seral associations by the researchers. 3) Needle-and-thread - blue grama / threadleaf sedge herbaceous vegetation map unit lends itself to be merged with either western wheatgrass - Kentucky bluegrass complex or little bluestem - grama grass / threadleaf sedge mapping unit depending on a thorough review of the floristic data. All three of these suggestions could be made using relatively straightforward GIS and database procedures and by themselves would increase initial overall total map accuracy to approximately 78%.

Recommendations for Future Projects

Several recommendations for future mapping projects have come out of the experience gained at WICA. It is strongly recommended that future mapping projects begin fieldwork with a reconnaissance step involving observation point data collection from a large number of points. This type of sampling is conducted relatively fast, and allows investigators to become familiar with plant communities and their variability in the study area. Following this step, representative stands within gradsects can be selected for more detailed vegetation plots. Data collected for observation points also supplements vegetation plot data in preparing community descriptions and provides an interim assessment of accuracy useful for photo-interpretation.

Developing two compatible classification systems (plant communities and map units) has proven to be challenging, not just at Wind Cave, but at other Parks in the Black Hills as well. It is important for users of the map that the two classifications be as similar as possible. At the beginning of future projects, more emphasis should be placed on developing a protocol for communication between photo-interpreters and field ecologists. A preliminary vegetation classification and an initial photo-signature classification with delineated polygons (at least for part of the study area) should be available early so that compatibility problems can be addressed.

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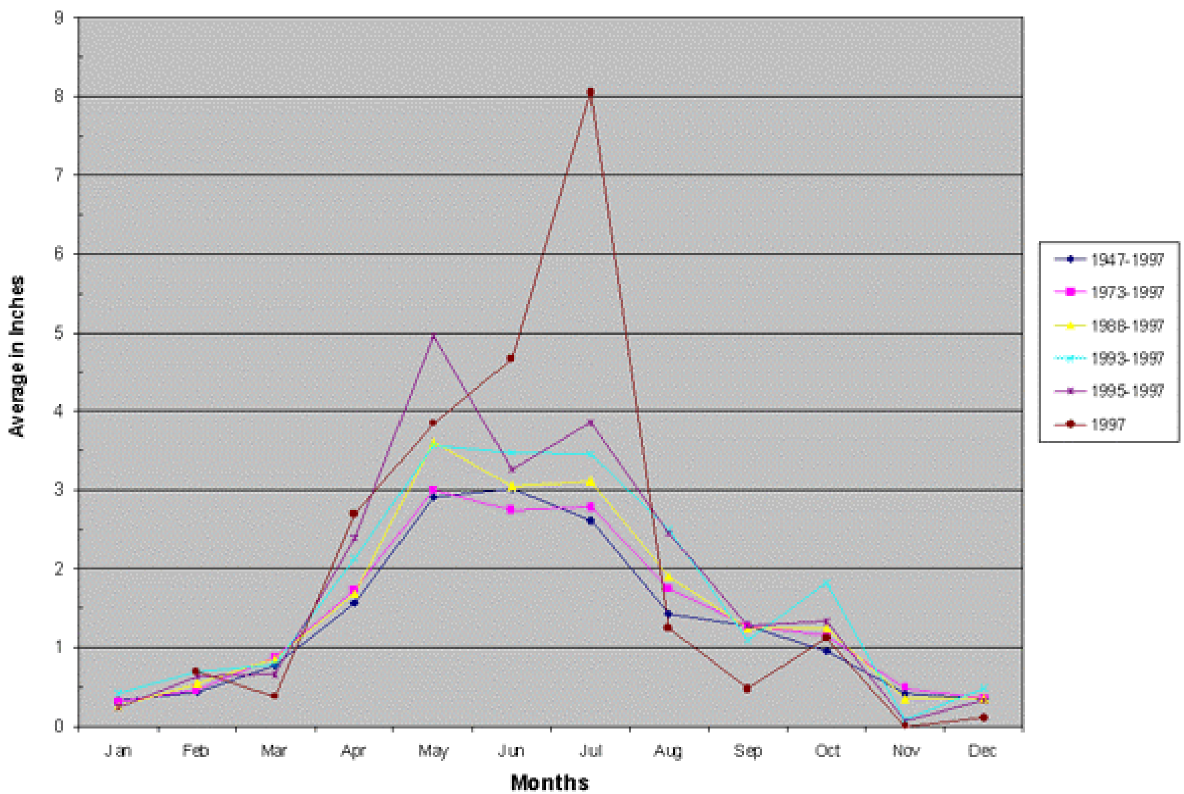
Appendix 1.

Average Monthly Precipitation Values for Hot Springs, SD.
Comparisons of 1997 values with the last 3, 5, 10, 15, and 50 year averages.

(Summarized from National Weather Service (NWS) and monthly precipitation data.)
(website: http://www.ncdc.noaa.gov/ol/climate/online/coop-precip.html).



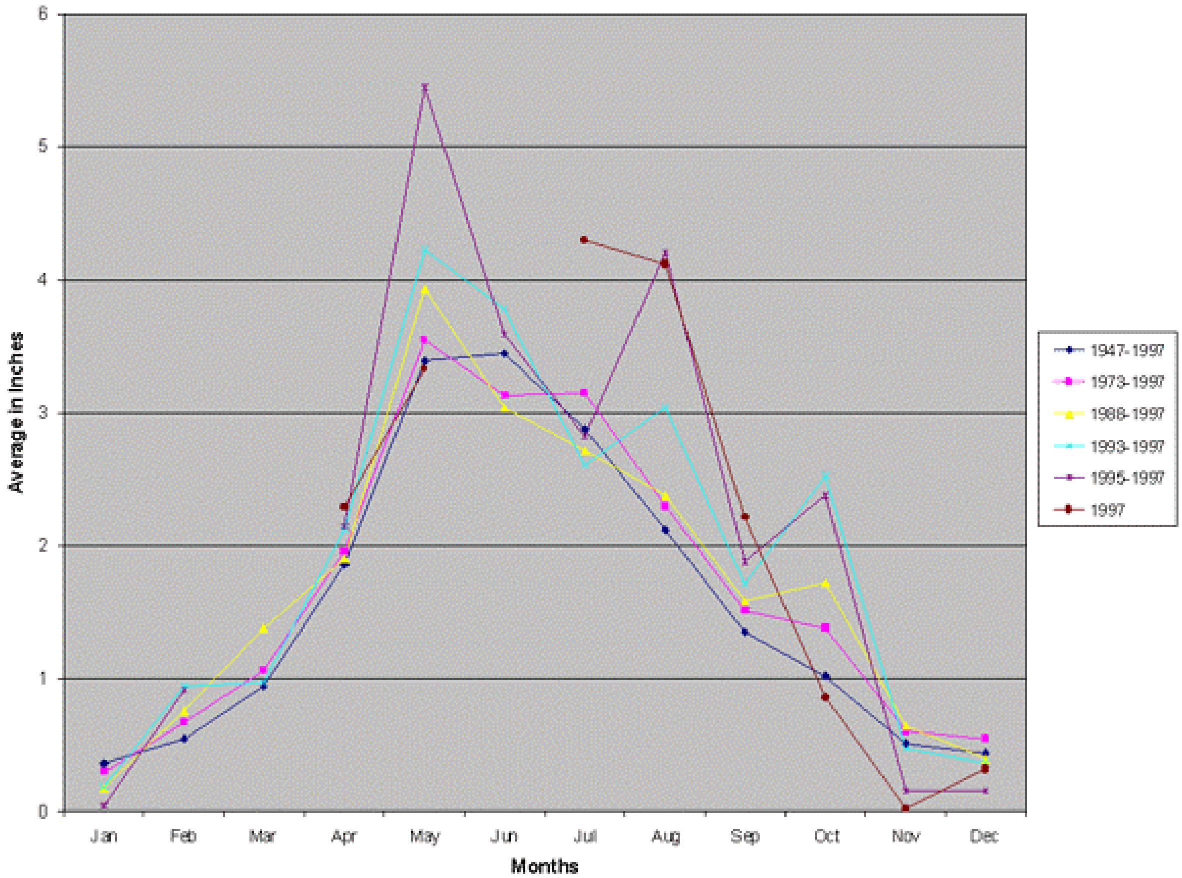
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1947-1997	0.33	0.44	0.77	1.56	2.91	3.02	2.61	1.43	1.28	0.95	0.41	0.34
1973-1997	0.32	0.46	0.88	1.74	3.01	2.75	2.79	1.75	1.27	1.16	0.49	0.36
1988-1997	0.26	0.55	0.87	1.69	3.62	3.05	3.12	1.91	1.25	1.25	0.35	0.36
1993-1997	0.43	0.69	0.79	2.14	3.57	3.48	3.46	2.50	1.10	1.82	0.09	0.49
1995-1997	0.24	0.64	0.66	2.39	4.96	3.26	3.86	2.45	1.28	1.33	0.07	0.33
1997	-	0.70	0.38	2.70	3.85	4.67	8.05	1.25	0.48	1.12	0	0.11

“- ” indicates no average recorded for that month

Appendix 2.

Average Monthly Precipitation Values for Custer, SD.
Comparisons of 1997 values with the last 3, 5, 10, 15, and 50 year averages.

(Summarized from National Weather Service (NWS) and monthly precipitation data.)
(website: http://www.ncdc.noaa.gov/ol/climate/online/coop-precip.html).



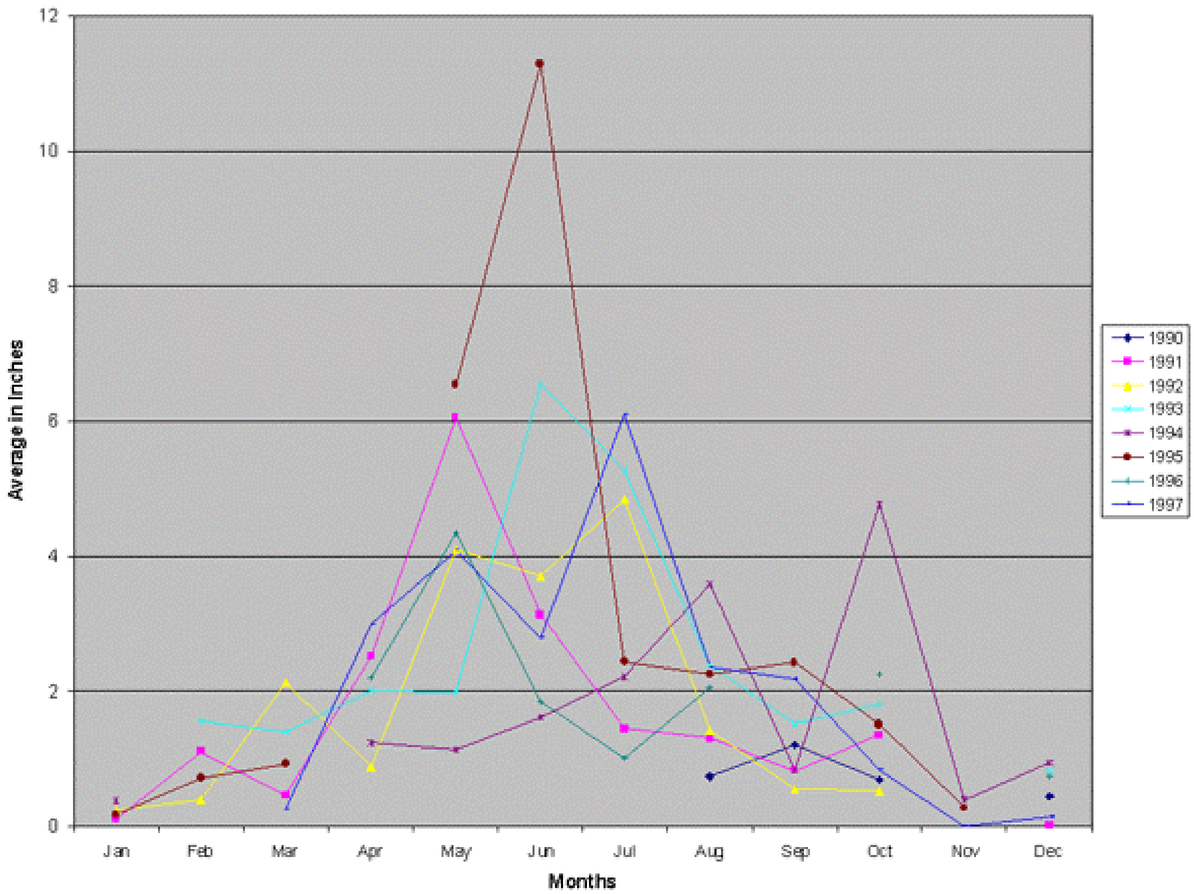
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1947-1997	0.36	0.55	0.95	1.86	3.39	3.45	2.88	2.12	1.35	1.02	0.51	0.44
1973-1997	0.30	0.67	1.06	1.95	3.55	3.13	3.15	2.30	1.51	1.38	0.61	0.55
1988-1997	0.17	0.76	1.38	1.90	3.93	3.04	2.72	2.38	1.58	1.72	0.64	0.40
1993-1997	0.19	0.95	0.97	2.12	4.23	3.78	2.61	3.04	1.71	2.53	0.48	0.37
1995-1997	0.04	0.92	-	2.15	5.45	3.59	2.83	4.21	1.88	2.38	0.16	0.16
1997	-	-	-	2.29	3.33	-	4.30	4.11	2.21	0.86	0.02	0.32

"- " indicates no average recorded for that month

Appendix 3.

Average Monthly Precipitation Values Collected at Wind Cave National Park. Comparisons of 1997 values with ’96, ’95, ’94, ’93, ’92, ’91, and ’90 values.

(Summarized from National Weather Service (NWS) and monthly precipitation data.)
(website: http://www.ncdc.noaa.gov/ol/climate/online/coop-precip.html).



Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1990	-	-	-	-	-	-	-	0.74	1.21	0.69	-	0.44
1991	0.12	1.11	0.46	2.52	6.05	3.13	1.45	1.30	0.82	1.36	-	0.01
1992	0.24	0.40	2.13	0.88	4.10	3.70	4.85	1.42	0.55	0.52	-	-
1993	-	1.56	1.41	2.01	1.99	6.55	5.27	2.39	1.52	1.82	-	0.82
1994	0.38	-	-	1.24	1.13	1.61	2.21	3.59	0.84	4.76	0.40	0.94
1995	0.17	0.71	0.92	-	6.54	11.3	2.44	2.25	2.42	1.51	0.29	-
1996	-	-	-	2.20	4.34	1.85	1.01	2.06	-	2.25	-	0.74
1997	-	-	0.26	3.00	4.09	2.79	6.10	2.35	2.18	0.84	0	0.14

“- ” indicates no average recorded for that month

Appendix 4.

Major Soil Map Units and Descriptions for Wind Cave National Park.

(Summarized from: Soil Survey of Custer and Pennington Counties, Black Hills Parts, South Dakota (Ensz 1990); Soil Survey of Custer and Pennington Counties, Prairie Parts, South Dakota (Nielsen 1996)).

Code	Soil Name	Soil Description	Rock	Vegetation	Physiographic Features
BeB	Barnum-Winetti	complex, 0-6%		native grasses, thin stands of *Pipo*	RV and LP (low areas)
BdA	Barnum	very fine sandy loam, 0-3%		native grasses	RV (terraces and floodplains)
BrA	Bullfat	silt loam, 0-3%		native grasses	LP
BrB	Bullfat	silt loam, 3-6%		native grasses	LP
BsB	Bullfat-Cordeston	silt loams, 2-9%		native grasses and limited trees	CCA (meadows) and LP
BtE	Buska-Mocmount-Rock outcrop	complex, 10-40%	gr granite, schist	*Pipo* (70 s.i.)	CCA
BuE	Buska-Rock outcrop	complex, 10-40%	schist, granite	*Pipo* (70 s.i.) *Scsc*, *Rhtr*	CCA (Mt. sideslopes)
BvC	Buska-Virkula	loams, 2-15%		*Pipo* (70, 72 s.i.) native grasses	CCA (smooth slopes, ridges)
BwE	Butche-Rock Outcrop	complex, 9-60%	Sstone	*Pipo* (34 s.i.)	D. Hogback (Mts.)
CcE	Canyon-Bridget	complex 9-25%		native grasses	D. Hogback (uplands)
CdF	Canyon-Rock outcrop	complex 15-60%	gr-br L-Sstone shale	native grasses	D. Hogback (uplands)
CxC	Cordeston-Winetti	complex, 2-9%		native grasses clusters of trees	LP (low areas)
CvB	Cordeston	loam, 2-10%		native grasses (hardwoods)	CCA (floodplains Mt. meadows)
CwB	Cordeston-Marshbrook	loams, 0-6%		native grasses (wetlands)	CCA (floodplains Mt. meadows)
GuC	Gurney-Butche	complex, 2-9%		native grasses	D. Hogback (Mt. prairies)
GvD	Gypnevee-Rekop-Rock outcrop	complex, 6-15%	red-white alabaster	native grasses with sparse *Pipo*	RV (uplands)
HeE	Heely	channery loam, 9-30%		native grasses	CCA (Mt. prairies)
HfC	Heely-Cordeston	complex, 6-15%		native grasses	CCA (Mt prairies upland swale)
HgB	Hilger	cobbly loam, 0-6%		native grasses,encroached by *Pipo*	RV (high terraces) and LP
HgD	Hilger	cobbly loam, 6-40%		native grasses,encroached by *Pipo*	RV (high terraces) and LP
HmE	Hilger-Metre	complex, 10-40%		native grasses and scattered *Pipo*	RV (uplands)
HtG	Hopdraw-Sawdust-Rock Outcrop	complex, 40-80%	br L-Sstone ledges	*Pipo* (30, 45 s.i.), tall shrubs, *Jusc*	LP (southern part)
MhA	Marshbrook	loam, 0-3%		native grasses (wetlands)	CCA (floodplains in Mt. valleys)
MnC	Metre-Norrest	complex, 2-9%		native grasses	RV (upland meadows)
MtE	Mocmont-Rock outcrop	complex, 10-40%	gr granite (domes)	*Pipo* (65 s.i.)	CCA (Mt. slopes)
NaC	Navee	channery loam, 6-15%		native grasses	RV (terraces and alvl. fan
NcE	Navee-Gullied land	complex, 6-40%		native grasses	RV (low terraces, swales)

NfE	Nihill-Zigweid	complex, 15-50%		native grasses and limited *Pipo*	RV (upland ridges), LP (low)
NnE	Norrest-Fairburn-Metre	complex, 9-40%		native grasses and limited *Pipo*	RV (uplands)
PaE	Pactola-Virkula-Rock outcrop	complex, 10-40%	gray metamorphic	*Pipo* (60, 72 s.i.) and other trees	CCA (Mt. slopes)
PbD	Paunsaugunt-Gurney	complex, 2-15%		native grasses and *Rhtr-Cemo*	LP (low Mt. prairies)
PcD	Paunsaugunt- Rock outcrop	complex, 6-30%	br-pink Lstone.	*Pipo* (45 s.i.)	LP (low elevation mts.)
RhD	Rock outcrop - Butche	complex, 2-25%	Sstone	*Pipo* (35 s.i.)	D. Hogback, LP (low)
RfE	Rekop-Gypnevee-Rock outcrop	complex, 15-40%	pink-white gypsum	native grasses and sparse *Pipo*	RV (uplands)
RiG	Rock outcrop - Pactola	complex, 40-80	gr metamorphic	*Pipo* (55 s.i.)	CCA (Mt. slopes)
RkG	Rock outcrop-Mocomont	complex, 40-80%	gr granite	*Pipo* (60 s.i.)	CCA (peaks and canyons)
RmG	Rock outcrop-Rekop	complex, 40-80%	pink-white gypsum	native grasses	RV (uplands)
RnG	Rock outcrop - Sawdust	complex, 40-80%	br Lstone	*Pipo* (45 s.i.)	LP (mts and canyons)
			red Sstone		
RsF	Rockoa - Rock outcrop	complex 25-60%	Sstone (shale)	*Pipo* (55 s.i.)	D. Hogback (Mts.)
ShD	Satanta-Canyon	loams, 6-15%		native grasses	D. Hogback (side slopes, fans)
SpE	Sawdust-Hopdraw-Paunsaugunt	complex, 10-40%		*Pipo* (50, 35, 45 s.i.)	LP (southern part)
SrE	Sawdust-Vanocker-Paunsaugunt	complex, 10-40%		*Pipo* (50, 62, 45 s.i.)	LP (low areas)
SwE	Shirttail	channery loam, 10-40%		native grasses and thin *Pipo*	CCA (Mt. slopes)
SxaE	Spearfish-Nevee	silt loam 9-30%,		native grasses	RV
SxbF	Spearfish-Rock outcrop	complex, 25-60%	red siltstone	native grasses and scattered *Pipo*	RV
TfB	Tilford	silt loam, 2-6%		native grasses	RV (terraces and uplands)
TfC	Tilford	silt loam, 6-15%		native grasses	RV (upland slopes)
TpC	Tilford-Paunsaugunt	complex, 6-9%		native grasses and some *Pipo*	RV uplands adjacent to LP
VcE	Vanocker-Citadel	complex, 10-40%		*Pipo* (62, 70 s.i.)	LP (low elevation Mts.)
VkE	Vanocker-Lakoa	complex, 10-40%		*Pipo* (62, 70 s.i.)	LP (low elevation Mts.)
VoG	Vanocker-Sawdust-Rock outcrop	complex, 40-80%	br Lstone y Sstone	*Pipo* (58, 45 s.i.)	LP (Mts. & canyon slopes)
WtB	Winetti	cobbly loam, 2-10%		native grasses and thin *Pipo*	RV (floodplains), LP (low)
ZnD	Zigweid-Nihill	complex, 6-15%		native grasses and sparse *Pipo*	RV and LP (old terraces)

RV = Red Valley, LP = Limestone Plateau, CCA = Central Crystalline Area, D. Hogback = Dakota Hogback

Lstone = Limestone, Sstone = Sandstone, s.i. = site index, Mt. = mountain, br = brown, y = yellow, gr = gray

Pipo = Pinus ponderosa, Rhtr = Rhus trilobata, Cemo = Cercocarpus montanus, Scsc = Schizachyrium scoparium, Jusc = Juniperus scopulorum

Appendix 5.

National Park Vegetation Mapping Program: Observation Point 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___ ___ ___ ___ ___ ___ mE Field UTM Y___ ___ ___ ___ ___ ___ mN

Please do not complete the following information when in the field.
Corrected UTM X___ ___ ___ ___ ___ ___ mE Corrected UTM Y___ ___ ___ ___ ___ ___ ___mN UTM Zone_________________

Survey Date_____________ Surveyors____

ENVIRONMENTAL DESCRIPTION

Elevation _____________________________ Slope_______________________ Aspect_____________________________________

Topographic Position____

Landform____

Cowardian System	Hydrologic Regime			
	<u>Tidal</u>	<u>Non-Tidal</u>		<u>Salinity/Halinity Modifiers</u>
____Upland	____Irregularly Exposed	____Permanently Flooded	____Saturated	____Saltwaters
____Riverine	____Regularly Flooded	____Semipermanetly Flooded	____Seasonally Flooded/Saturated	____Brackish
____Palustrine	____Irregularly Flooded	____Seasonally / Temporarily Flooded	____Intermittenly Flooded	____Freshwater
____Lacustrine	____Unknown			

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)
	____%
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 ____Microphyllous ____Graminoid ____Forb ____Pteridophyte	____Forest ____Woodland ____Shrubland ____Dwarf Shrubland ____Herbaceous ____Nonvascular ____Sparsely Vegetated	01 0 - 10% 02 10 - 25% 03 25 - 60% 04 60 - 100%	01 < 0.5 m 02 0.5 -1 m 03 1-2 m 04 2-5 m 05 5-10 m 06 10-15 m 07 15-20 m 08 20-35 m 09 35-50 m 10 > 50 m

Strata	Height	% Cover	Dominant species (mark any known diagnostic species with a *) % Cover
T1 Emergent	_____	_______	______________________________
T2 Canopy	_____	_______	______________________________
T3 Sub-canopy	_____	_______	______________________________
S1 Tall Shrub	_____	_______	______________________________
S2 Short Shrub	_____	_______	______________________________
H Herbaceous	_____	_______	______________________________
N Non-vascular	_____	_______	______________________________
V Vine/liana	_____	_______	______________________________
E Epiphyte	_____	_______	______________________________

Please see the table on the previous page for height and cover scales

Other Comments

Appendix 6.

National Park Vegetation Mapping Program: Plot Survey 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___ ___ ___ ___ ___ ___ mE Field UTM Y___ ___ ___ ___ ___ ___ mN

Please do not complete the following information when in the field.
Corrected UTM X___ ___ ___ ___ ___ ___ mE Corrected UTM Y___ ___ ___ ___ ___ ___ ___mN UTM Zone________________

Survey Date_____________ Surveyors____

Directions to Plot

Plot length__________ Plot width__________ Plot photos (y/n)___ Roll Number____ Frame Number_____ Plot Permanent (y/n)___

Plot Representativeness

ENVIRONMENTAL DESCRIPTION

Elevation ____________________________ Slope______________________ Aspect____________________________________

Topographic Position____

Landform____

Surficial Geology

Cowardian System	Hydrologic Regime			
	<u>Tidal</u>	<u>Non-Tidal</u>		<u>Salinity/Halinity Modifiers</u>
____Upland ____Riverine ____Palustrine ____Lacustrine	____Irregularly Exposed ____Regularly Flooded ____Irregularly Flooded ____Unknown	____Permanently Flooded ____Semipermanetly Flooded ____Seasonally / Temporarily Flooded	____Saturated ____Seasonally Flooded/Saturated ____Intermittenly Flooded	____Saltwaters ____Brackish ____Freshwater

Environmental Comments:	Soil Taxon/Description
	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) ____% Other:____
Soil Texture ____sand ____sandy loam ____loam ____silt loam ____clay loam ____clay ____peat ____muck	Soil Drainage ____Rapidly drained ____Well drained ____Moderately drained ____Somewhat poorly drained ____Poorly drained ____Very poorly drained

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 ____Microphyllous ____Graminoid ____Forb ____Pteridophyte	____Forest ____Woodland ____Shrubland ____Dwarf Shrubland ____Herbaceous ____Nonvascular ____Sparsely Vegetated	01 0 - 10% 02 10 - 25% 03 25 - 60% 04 60 - 100%	01 < 0.5 m 02 0.5 -1 m 03 1-2 m 04 2-5 m 05 5-10 m 06 10-15 m 07 15-20 m 08 20-35 m 09 35-50 m 10 > 50 m

Strata	Height	% Cover	Dominant species (if known)
T1 Emergent	_____	_______	____________________
T2 Canopy	_____	_______	____________________
T3 Sub-canopy	_____	_______	____________________
S1 Tall Shrub	_____	_______	____________________
S2 Short Shrub	_____	_______	____________________
H Herbaceous	_____	_______	____________________
N Non-vascular	_____	_______	____________________
V Vine/liana	_____	_______	____________________
E Epiphyte	_____	_______	____________________

Please see the table on the previous page for height and cover scales

Animal Evidence

Natural and Anthropogenic Disturbance Comments

Other Comments

Species/percent cover: Starting with the uppermost stratum, list all species with % cover for each species in the stratum. For forests and woodlands, on a separate line below each tree species, list the DBH of all trees above 10 cm diameter. Separate measurements with a comma. Put an asterick next to any species that are known diagnostics for a particular community in the classification. Also list speicies outside the plot.

Species Name	% Cover	Species Name	% Cover

Cover Scale for Species

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

Appendix 7.

National Park Vegetation Mapping Program: Accuracy Assessment Form and Instructions

ACCURACY ASSESSMENT FIELD FORM
USGS-NPS VEGETATION MAPPING PROGRAM

1. Plot Number_______________ 2. Park Code______________ 3. Date______________________

4. Observer(s)___________________________ 5. Datum__________ 6. Accuracy____________

7. UTM Coordinates: Easting__ __ __, __ __ __ Nothing__, __ __ __, __ __ __

8. UTM Zone________ 9. Offset from Point: Easting_____________m Northing_____________m

10. Topographic Description____

11. Elevation________________m 12. Aspect_________________

13. Veg Assoc. at Site____

14. Veg Assoc. 2 within 50m of Site____

15. Veg Assoc. 3 within 50m of Site____

16. Major Species Present (by strata)____
____
____
____

17. Canpoy Closure of Top Layer_____________________

18. Rationale for Classification____
____
____
____
____

19. Comments____
____
____
____
____

Instructions for Accuracy Assessment

The basic document for accuracy assessment is "Accuracy Assessment Procedures", developed by the Program in 1994. The document can be downloaded from the Program web site at http://biology.usgs.gov/npsveg. This accuracy assessment (AA) form is the result of an additional 4 years of field experience. The purpose of this form is to generate concise data to document the accuracy assesment procedure that occurred in the field and to compare it to the mapped data.

All navigation must occur with either a Y-code GPS receiver (e.g. Rockwell PLGR) or in real time differential mode if using other types of receivers. This unit allows the user to navigate to sites within a few meters of their actual locations. The AA sites will be selected using randomly located samples stratified according to the associations. Before beginning each morning, make sure the datum is set to NAD83, and that the projection system is UTM, with the proper zone. A comass is needed to estimate aspect.

The materials you should have before you begin are a 1) plots of the DOQQ's showing the polygon boundaries, but no information on polygon attributes, and the location of the AA sites with numbers, 2) AA site coordinates loaded into your GPS receiver, 3) the field key, and 4) association descriptions.

Once you have navigated to an accuracy assessment site, and the FOM (Figure of Merit) is at 1, if using a PLGR, observe the vegetation within a 50 meters radius of the site. To gauge how far 50 meters is, it is helpful to have the navigator pace 50 meters in one direction. Document what the vegetation community is at the site, and if there are more than one community present within a 50 meter radius, document those as well under Veg Assoc 2 & 3.

Specific Instructions:

1. Plot Number - self explanatory
2. Park Code - the four character code for the park (e.g. Voyageurs is VOYA, Scotts Bluff is SCBL)
3. Date - self explanatory
4. Observor(s) - self explanatory
5. Datum - the reference system for the projection, should be NAD83 (NAR on the PLGR)
6. Accuracy - the distance in meters the GPS receiver displays, if using a PLGR
7. UTM Coordinates - easting and northing in meters
8. UTM Zone - UTM zones in continental US range between 10 (126' W longitude on the Pacific Coast) and 19 (66' W longitude on the Alantic Coast)
9. Offset from Site - if you are unable to navigate directly to a site due to terrain problems (e.g. rivers, canyons), record the distance from the site displayed on your GPS receiver, record 0 if there is no offset
10. Topographic Description - where you are on the terrain; on the top of a hill, in a small valley, midslope on a south facing slope, etc.
11. Elevation - above sea level in meters
12. Aspect - using a compass estimate the aspect of the whole site, record in degrees of azimuth (0-360)
13. Veg Assoc at Site - use the field key determine the association directl on the AA site
14. Veg Assoc 2 within 50 m of Site - if a second vegetation association is found within 50 meters of the site, record that association.
15. Veg Assoc 3 within 50 m of Site - if a third vegetation association is found within 50 meters of the site, record that association
16. Major Species Present (by strata) - record the major and indicator species present
17. Canopy Closure of Top Layer - estimate canopy closure of top stratum, eliminating the contribution from lower strata.
18. Rationale for Classification - record the logical procedure you used to determine the vegetation association based on indicator species, major species, structure, etc.
19. Comments - all relevant information that does not fit into the fields above. Note such things as multiple associations near the site, indications of artificial influences on the vegetation, such as grazing, logging, animal presence or use, influences of elevation, aspect, water tables, etc.

Appendix 10.

Wind Cave National Park Vegetation Mapping Classes and Map Codes

Wind Cave Vegetation Class Key

Map Code	Map Class Name
1	Purple Three-awn - Fetid Marigold Herbaceous Vegetation
2	Ponderosa Pine Limestone Cliff Sparse Vegetation
3	Redbeds Sparse Vegetation
4	Black Hills Rock Outcrop Sparse Vegetation
5	Shale Barren Slope Sparse Vegetation
6	White Sedimentary Rock Outcrop
7	Bison Wallows
11	Little Bluestem - Grama Grass - Threadleaf Sedge Herbaceous Vegetation (with burned ponderosa pine)
12	Chokecherry Shrubland (with burned ponderosa pine)
13	Western Wheatgrass - Kentucky Bluegrass Grassland Complex (with burned ponderosa pine)
14	Emergent Wetland Herbaceous Complex
15	Little Bluestem - Grama Grass - Threadleaf Sedge Herbaceous Vegetation
16	Western Wheatgrass - Kentucky Bluegrass Grassland Complex
17	Introduced Weedy Graminoid Herbaceous Vegetation
18	Needle-and-thread - Blue Grama – Threadleaf Sedge Herbaceous Vegetation
30	Mountain Mahogany / Sideoats Grama Shrubland I (15-50% cover)
31	Mountain Mahogany / Sideoats Grama Dense Shrubland II (50-100% cover)
32	Lead Plant Shrubland
33	Chokecherry Shrubland
34	Beaked Willow Shrubland
35	Western Snowberry Shrubland
36	Creeping Juniper / Little Bluestem Shrubland
40	Plains Cottonwood / Western Snowberry Forest
41	Boxelder / Chokecherry Forest
42	Bur Oak Stand
43	Green Ash - American Elm / Western Snowberry Forest
44	Birch - Aspen Stands
45	Ponderosa Pine Woodland Complex I (75-100% cover)
46	Ponderosa Pine / Little Bluestem Woodland
47	Ponderosa Pine / Chokecherry Forest
48	Ponderosa Pine Woodland Complex II (15-75% cover)
49	Young Ponderosa Pine Dense Cover Complex
51	Transportation, Communications, Utilities
52	Mixed Urban or Built-up Land
53	Croplands and Pastures
55	Other Agricultural Lands
57	Open Water
59	Strip Mines, Quarries, & Gravel Pits

Appendix 11.

Prairie Dog Mapping Protocols

Date: August 8, 1997

Reply To Attn Of: Glen Plumb, Ph.D., Wildlife Biologist, Badlands NP

Subject: Badlands National Park and Wall District 1997 Prairie Dog Aerial Photo Interpretation

To: Bruce Bessken, Chief RM Badlands National Park
Greg Schenbeck, USFS Nebraska National Forest
Jim Vonloh, US Bureau Reclamation
Tim Langer, North Carolina State University

On August 6, 1997, we met at Cedar Pass Park HQ library to develop simple, qualified and consistent methodology for interpreting prairie dog colonies from a series of June 1997 1:12,000 CIR aerial photos covering Badlands National Park and a large portion of USFS Wall District, Buffalo Gap National Grassland. The principal purpose of these photos is to support development of a plant community map of Badlands NP. An additional goal of the NPS and USFS is to produce a digital map delineating prairie dog colonies. After three hours of discussions we agreed on the following photo interpretation criteria.

1. There will be no minimum size threshold for interpreting prairie dog colonies, in contrast to the 0.5 hectare minimum size for other plant communities.

2. Prairie dog colonies are to be considered as distinct plant communities characterized principally by concentrations of whitened stipples indicative on mounded prairie dog burrows. Depending on disturbance story, soils and yearly climate, differences in the reflectance signature between prairie dog colony plant communities and adjacent uncolonized plant communities will vary substantially. It may be that the lack of apparent change in reflectance signature between the area of concentrated burrow mounds and adjacent area with no burrow mounds will indicate no change in predominate plant community classification while retaining a prairie dog colony classification. As such, two potential classesof prairie dog colonies will likely be interpreted. Photo interpretation criteria should include:

a) Prairie dog colony with substantial change in plant community: the linear edge is delineated by eliminating whitened stipples indicative of mounded prairie dog burrows which are greater than 0.10" (30 meters) from the contiguous concentration of whitened stipples indicative of mounded prairie dog burrows accompanied by an obvious whitened color change from surrounding plant community reflectance signature(s), or

b) Prairie dog colony with little apparent change in plant community: the linear edge is delineated by eliminating whitened stipples indicative of mounded prairie dog burrows which are greater than 0.10" (30 meters) from the contiguous concentration of whitened stipples indicative of mounded prairie dog burrows characterized by greater than 35 whitened mounded burrows per hectare and **not** accompanied by an obvious whitened color change from surrounding plant community reflectance signature(s).

3. When appropriate, prairie dog colony delineation will also incorporate physical features such as surface roads (not 2 track roads), erosion features, ephemeral gullies and washes, permanent water sources (i.e. creeks and stock dams) and major badlands topographic features (i.e. spires, ridges).

4. In the case where the two above classifications are contiguous, final prairie dog colony map could combine different but contiguous prairie dog colony plant communities.

Appendix 12.

Parks GIS Database Design, Layout, and Procedures

Created by Doug Crawford and Jay Carlson od the Bureau of Reclamation's RSGIS group 1997
Revised 01-19-98

Parks GIS Database
Design, Layout, and Procedures

<u>I. Design and Layout</u> - Each GIS park project directory should be set up as follows:

1. Each park project should have its own directory. Naming convention for the directory should be either the first four letters of its name, or if the name consists of two or more words, the first two letters of the first two words.

Example:	Badlands directory name is:	>badl=
	Jewel Cave directory name is:	>jeca=

2. The main project directory should consist primarily of directories / workspaces with very few individual files and no coverages/grids. All coverages/grids should be located in workspaces below the main project directory.

3. All coverages should be in datum NAD83. If you need a working coverage in nad27, put suffix '_d27' at the end of the coverage name. For a project such as Badlands which covers more than one utm zone, the final, main coverages should be in one particular zone and if you need working covers in another zone, indicate its difference by putting suffix '_z14' (for zone 14 for example) at the end of the coverage name. If you need to designate different datum and zone, use suffix 'z14d27' for example. This would limit your coverage name to 7 characters before the addition of the suffix.

4. Each park project directory should have the following sub-directories and workspaces. Naming convention for coverages should include either the four-letter park name (same as the directory name; ie; for Badlands it is 'badl') or the workspace name (ie: for bndry workspace, covers named 'bndrypark')

amls: This directory contains amls particular to its project. All AMLS associated with the shell menu are not located here - see item 6. below.

aspect: Workspace containing any aspect coverages.
Naming convention: <park>_asp

biology: Workspace containing all coverages related to biological features.
Note: this workspace has sub-workspaces named according to associated USGS quads.

Naming convention: biology/<quadname>/<quadname>_veg#
where # indicates the quarterquad area (1,2,3, or 4)

A 'base' coverage may exist (biology_base) which is used in creating all the individual quarter-quad '_veg' coverages.
If aerial photos will have mylars scanned, each quad biology workspace needs to

have a blank coverage named cirtics with is used for transforming arcs into the correct geo-space.

bndry: Workspace containing all boundary coverages.
Naming convention: bndrypark (Park boundary coverage)
bndryproj (GIS mapping project area)
bndryquad (Boundaries of all the 7.5m quads)
bndrygrds (Grad- sect boundaries)

data: Workspace containing all data point coverages.
Naming convention: dataobsv (Coverage of observation data points)
dataplot (Coverage of plot data points)

doqq: Directory of all the doqq files.
Naming convention: <quadname>#.bil & .hdr
Note: >quadname= needs to be the same as the attribute of the label point in the bndryquad coverage.

The ># > refers to the quarterquad area as follows:
= 1 for the nw quadrant
2 for the ne quadrant
3 for the se quadrant
4 for the sw quadrant

hydro: Workspace containing all hydrological coverages.
Naming convention: <park>_strm (Streams coverage)

manmade: Workspace containing all coverages of manmade features.
Naming convention: <park>_road
<park>_rail
<park>_bldg

menus: Directory of arc/info aml menus particular to its project. All menus associated with the shell menu are not located here - see item 6. below.

misc: Directory / Workspace containing miscellaneous files and special coverages.

plot: Directory / Workspace containing plot files, grids, etc.

slope: Workspace for slope coverage.
Naming convention: <park>_slp

soils: Workspace for soils coverages:
Naming convention: soil_park

soil_proj
soil_state

5. Each coverage should be setup for attributing as follows:

biology_veg: Polygon coverage with labels in each polygon with item '**veg_code**' (3 3 I) attributed with the proper vegetation *classification number*; item '**location**' (6 6 c) attributed with either *park* or *buffer*; item '**photo**' (4 4 I) attributed with the CIR *photo number* from which the polygons were derived; and item >pdog= (2 2 I) attribute with 0 (none) or 1 (yes). Also, the .aat file (for the arcs) should have the '**veg_code**' item and another item that indicates the type of arc called '**digtype**' (2 2 I) with attributes of :

1 = indicates arc derived from heads-up, on screen dig
2 = indicates arc derived from scanned mylar.
3 = border arc representing edge of gis study area
4 = border arc of the quarter-quad
5 = border arc representing park boundary

bndrypark: line coverage - no special attributing needed. Exception: THRO has three units (north, middle, south) therefor it is built as a polygon cover with labels in each unit with item '**unit**' (6 6 c) attributed with 'north', 'middle', or 'south'.

bndryproj: line coverage - no special attributing needed. Exception: same as bndrypark for THRO.

bndryquad: polygon coverage with labels in each quad with the following items:
quadname (8 8 c) - abbreviated name for each quad
fullname (20 20 c) - full quadname with 1st letter in caps
Exception: each quad label is also attributed with '**unit**' for THRO (same as bndrypark for THRO).

dataobsv &: dataplot: point coverages of label points with items as follows:
plot_code (3 3 n) with plot number from plot data sheets
veg_code (14 14 c) with veg class text.
type (10 10 c) with broad veg type (eg: woodland)
x-coord and y-coord added with addxy command

6. Special considerations:

6.1) Note, ARC/Info=s maximum filename length is 13 characters, therefore, base cover names should not exceed 9 characters so the >_veg#=, >_z##= or >_d##= (see 6.2 and 6.3 below) can be added.

6.2) For Badlands project, the GIS project area encompasses more than one utm zone, therefore, preliminary coverages may have a suffix on its covername, either '_z13' for zone 13 or '_z14' for zone 14. All final coverages should be in zone 13 and the '_z13' would be dropped from the covername.

6.3) For the Data point coverages, the data points usually were collected using GPS units set to datum NAD27, therefore preliminary coverages may have suffix '_d27' added to distinguish from (final) coverage in datum nad83. CAUTION: If you need coverages in nad27, do not re-project bndryquad into nad27 - the tics will be wrong - need to create a new bndryquad cover from scratch and name it bndryquad_d27.

7. Shell AMLs and MENUs. - At the main login directory, there is a directory called >shell=. It contains three sub-directories called 'amls', 'menus' , and 'misc'. The 'misc' directory contains miscellaneous files used by the shell amls and menus. The 'amls' and 'menus' directories contain files used by 'shell.aml'. You can use this shell to do most all of your arc/info work. To use it, you must have 'shell.aml' in your project directory and type &r shell from the arc prompt. If you have or make any changes to these amls and menus, please let Doug Crawford know.

Note, the database setup conventions mentioned under items 4. and 5. above must be maintained for 'shell.aml' to function properly.

<u>II. Digital Orthophoto Quarter Quads.</u> - The parks projects will be using DOQQ's as the basemap for transfer of information from the CIR photos to the GIS database. The images are stored on CD-ROM's and are located in Doug Crawford's (badl & wica) or Dan Cogan's (thro) office. As mentioned above, the naming convention for the doqq's should be <quadname>#.bil. In addition to the image, there needs to be a world header file and its name should be <quadname>#.hdr.

The filenames on the CD-ROM's (form USGS) do not match this format and will need to be renamed. The cd-rom=s also do not contain the needed .hdr files. The shell menu has an AAux Program@ named 'doqqhdr' that renames the file and creates the .hdr file.

The header file for each bil (.hdr) is a simple text file that should be set up as follows for display in Arc/Info:

nrows <value>	(Number of rows or lines in the image)
ncols <value>	(Number of columns or samples in the image)
skipbytes <value>	(Old header format = 4 x ncols; new format = ncols)
ulxmap <value>	(X-Coordinate of upper left pixel)
ulymap <value>	(Y-Coordinate of upper left pixel)
xdim 1	(Size of pixel in x direction in meters)

ydim 1 (Size of pixel in y direction in meters)
nbands 1 (These BIL=s only have one band)

All data for this file can be read from the image file. For the old file format, use program header.exe on DOS machine (note - all ':' must be deleted after the .hdr file is generated). For the new format, USGS has not made an executable file yet to read the header info directly into a text file so you have to read from the image file using the 'more' command at unix prompt.

III. Registration and Transfer Procedures. -

A. Introduction.

Data interpreted from aerial photography must often be joined together in one large file. In most cases these data must be geo-referenced, so that a point in the data can be explicitly associated with a point on the earth=s surface, so that:

1) The point can be located on a map or with a Global Positioning System receiver, for field checking.

2) Area can be measured in hectares, acres, etc. more accurately (since each photo scale varies).

3) Data interpreted on one photograph don=t overlap or have gaps with the adjacent photograph, due to distortion in the photograph introduced by aircraft pitch, roll, and yaw as well as elevation change of the aircraft relative to the ground.

There are various ways to get air photo classification linework onto a georegistered map base. Three main methods exist: (1) heads-up digitizing, (2) use of a projector such as a Map-o-Graph or Saltzman, and (3) scanning the air photo mylar overlay.

Briefly, heads-up digitizing is a procedure whereby the operator digitizes by hand and eye on a computer terminal screen showing a digital image of an ortho-rectified photo. By looking at similar features on both the aerial photograph from which the classification was made and on the orthophoto, the line drawn on the aerial photo overlay is transferred to the digital image, which is registered to coordinates on the earth. This technique should produce good results except where there is little feature contrast on the ortho, in which case the operator must estimate the shape and location of the linework. Using this technique, a curve on the photo may appear to be a series of short, differently-angled straight line segments, since it is easier to make a curve with a pencil or pen than it is with digitized discrete points. Depending on the density of digitized points, this may or may not be a problem. The analyst may set the digitizing software to calculate a pseudo-curve of many points by inputting as few as three points to define a curve.

The Saltzman or Map-o-Graph is a device which projects the image of an air photo onto a map base (orthophoto, topo quad map, etc.). By adjusting the scale of projection, the operator can match features from one image to the other. The classification lines, projected with the photo, can be traced on the orthophoto hard copy map base. This technique should produce good results if the scale of projection is accurate and the focus is crisp. In some places, the orthophoto can be dark and consequently the projected line to be traced is difficult to see. It can be difficult to get the scale precise enough to do all but a small area, and then either the photo or the map must be shifted to the next small area. The tracing of one line with another introduces an additional (small, the analyst hopes) source of error.

The third technique of scanning involves digital manipulation of the scanned mylar by first converting the scanned image into a line coverage and then geo-referencing the coverage (scale, shift, rotate, and rubber-sheet). It still relies on the human eye, just like the other two, but only for fine-tuning the transfer accuracy, not for the transfer itself. The essential idea is that the air photo overlay has a certain number of scanner inches for a particular distance on the ground; so does the orthophoto. If the scale of the overlay can be adjusted to the scale of the orthophoto, then the lines should match features of the orthophoto without any digitizing or tracing. The shift accounts for the different origin on each photo: approximately 0,0 on the air photo and probably some high number on the orthophoto (whose coordinates are determined by a map projection and grid system). The rotation occurs due to the unlikelihood of perfect alignment of axes between the air photo and the orthophotomap. Finally, the rubber sheeting occurs due to minor error in the scale, shift, and rotate procedures. Even if these things were perfect, there would be distortion in the air photo that has been removed from the orthophotomap, necessitating rubber-sheeting the air photo. Rubber sheeting involves the recording of origin and destination points (i.e., links) and the higher-order mathematical adjustment of locations to best fit the origin points to the new. If many adjustment links are used and are evenly distributed throughout the data, and locations linked actually represent the same place on the earth, the adjustment should be good.

B. Procedures and Techniques.

Transfer work for the parks projects will consist of two methods, either heads-up digitizing or scanning. Heads-up digitizing will be used whenever the CIR photo (1) does not include many complicated grassland polygons as these are the most difficult to transfer using heads-up digitizing, and (2) does not differ in time of photography from the doqq by more than a couple of years. This will usually mean photos that have polygon boundaries that are easy to see on the digital ortho image will be transferred using the heads-up method. All others will be scanned as describe below.

B.1 Manual Method. -

B.1.1) Mark photocontrol points (i.e., road junctions, farmhouses, boulders, other identifiable small points that don't move or disappear) on each Mylar. Six control points should be located for best results though a minimum of 4 are required for a projective transform and 3 for an affine transform plus one additional tic if you want an RMS error generated. Mark each control point with sequential ID numbers (Important if using the AML as described below). The control points are found by displaying the DOQQ in an ArcEdit session.

If you use the AML, choose coverage *bndrycirtics* as the editcoverage for displaying the DOQQ. When a control point is found, place (Add) a tic at the location with tic id same as the ID marked on the Mylar. Save *bndrycirtics* with the new tics you just added. Make sure the Tic ID you choose does not already exist in the coverage.

B.1.2) Scan Mylar (into scanner inches). - Both options below are for the Scansmith Scan software either on the color or B&W scanner:

a) Gray scale scan. - Scan as Gray scale, around 300dpi, tif image. This will produce a file about 5Meg in size. Using the Scansmith software, can crop and rotate the image as needed.

b) Line art scan. - Scan as linear, around 400 dpi, tif image, packbits option with the following additional settings:

Threshold:	For graphite line work - 125 to 150
	For green lead - 100
	For red lead - 75
Hysteresis:	7
Dynamic:	4

B.1.3) Use ***imagegrid*** (arc command) to convert scanned image (probably .tif format) into Arc Grid format.

B.1.4) Use ***gridline*** (arc command) to convert grid into arc/info line coverage format. Use the photo number (4 digits) in the arc cover name. Could also use Provec software to convert into line coverage.

B.1.5) In ArcEdit:

a) Edit line coverage fixing badly converted lines, dangles, and extraneous arcs such as those associated with the class numbers that are marked on the Mylars.

b) Add, or move, if necessary, tics until you have five or more tics located at the perimeter of the linework area. Must have at least five tics to do a projective transform.

c) Put labels where photocontrol marks exist on line coverage (with image or grid as backdrop to show marks, if necessary). Idea is to have labels at places that can be seen both on orthophotoquad and on air photo (the control points mentioned in step 1).

d) Instead of c), you can add tics to the line coverage at the photocontrol points AND a blank coverage in the exact real-world locations as shown on the ortho. Then bypass items B.1.6 and 7 below.

Alternative: Instead of turning the image into a line coverage, use the image as backdrop and digitize over the lines to make a line coverage, thereby avoiding possibly excessive editing of poorly scanable mylars.

B.1.6) Create an empty coverage containing only tics that are located in the real-world location of the photo as follows:

a) Determine scale factor between CIR photo and real-world units. Measure distance between two points on photo and same two points on digital. These points should be chosen such the line connecting them goes through the center area of the photo, and ideally should not be very close together, nor close to photo edge, nor be greatly different in elevation. These measurements will allow calculation of a rescaling factor, i.e., how many inches on the scan correspond to how many orthophotoquad units on the ground (typically in meters). The approximate number will be 12000/39.37 (air photo nominal scale 1:12,000 divided by 39.37 inches/meter). The actual number will usually be slightly above or below this number.

b) Rescale the line coverage using the scaling factor just calculated,. Copy the line coverage AND delete all arcs in the copy coverage. Go into tables or info (in arc), select the .tic file for the copy coverage. Subtract the lowest xtic and ytic values from the xtic and ytic items so that the lower left corner has value 0,0. Then multiply the xtic and ytic items by the rescaling factor. Example:

input tics 1,1; 1,6; 6,1; 6,6
Shift to: 0,0 0,5 5,0 5,5 Multiply by 12,000/39.37: 0,0; 0,1524; 1524,0; 1524,1524

c) Add appropriate x + y offsets to the output copy coverage tics in info, so that you will end up in approximate neighborhood of your ortho. That is, if the coordinates of the area of interest on your ortho are approximately x=100000 and y=500000, then in info or tables, calculate your x tics to be your x tics + 100000 and your y tics to be your y tics + 50000, in effect shifting the tics.

d) Now you have a copy coverage that is approximately the right size and position. You may want to make a backup copy before transforming. Transform (arc command) the scanned image line coverage to the empty (tics only) copy coverage. Try with the affine (default) option and with the projective (specifically for air photo) option and see which appears better.

B.1.7) Now, in ArcEdit, you may have to rotate or move the coverage to get it to line up approximately with the (backdrop) orthophotoquad features. You can use the multipleselect command in ArcEdit to select both the labels and the arcs simultaneously for movement/rotation. Don=t forget to make your snap distance small so that lines don=t snap together inappropriately.

B.1.8) Once things line up approximately (i.e., the best you can get from shift, rotate, & scale), add links from the label locations to the same feature locations on the (backdrop) orthophotoquad.. The more links, the better. Link any additional features you can make out (that are unlikely to have changed) between coverage and orthophotoquad, e.g., sharp points, small ponds, stream junctions, etc. Try to distribute the links throughout the coverage instead of clustering them in one portion. If a point on the cover is already exactly where it's supposed to be and you don=t want it to move, put a link of zero displacement (appears square) there. If you have trouble making one, copy it from the outside of the coverage, where outermost zero displacement links were automatically created when the Aeditfeature link@ and Aadd@ commands were selected. Read the arc info documentation on links and rubber sheeting. Make a backup copy of the coverage in case the rubber sheeting doesn=t come out the way you=d like.

B.1.9) Use the adjust command in ArcEdit to rubber sheet. Make sure snap distance is very small. If the results are bad, you can issue the oops command and go back (unless you issue a save command first).

B.1.10) Place the completed, converted coverage in the biology directory for final attribution and rubbersheeting to other linework. Naming convention for this coverage should be:
p####_arcs where #### is the photo number.

B.2 Automated Method using AML. - Run LINK program from the shell menu. This aml has been developed to automate the transfer process. The AML incorporates 3 steps as follows:

Step 1 - Establish Control Tics. - Step one starts an arcedit session where you will be adding at least 6 tics that are common 'control' points between the Cir photo and the doqq to a coverage named *cirtics*. Mark these control points on the mylar overlaying the cir photo and 'add' tics in coverage *cirtics* in exact same location as the photocontrol points marked on the mylar. Make sure tic id matches id on the mylar **AND** that the tic id number does not already exist in the coverage.

Quit and save at this point.

CAUTION: Do Not Build the *CIRTICS* coverage!

Step 2 - Scan the mylar and ftp it to your workspace. The scanned image file (.tif) needs to be in the same workspace as your biology "_veg" coverage.

Step 3 - Convert Scanned Image. - This session :

a. Converts the scanned image (.tif) into an arc coverage. The program names the coverage ***p####_1_scan***. (the #### refers to the cir photo number)

b. Starts an arcedit session so you can clean-up the arc coverage (which is not geo-referenced yet, ie, it is in digitizer inches) and add tics (and label points*). First, delete the 'generic' tics that where created when the image was converted into an arc coverage. Second, add tics at the locations that where marked on the mylar. *Third, at the location of each tic you have added, you need to add a label point. Set snapfeature to lab tic (sf lab tic), set the snapping tolerance to a circle surrounding the tic (snapping button on the menu under >TOLERANCES=), and add labels with the 'add' command. The labels should snap right to the tics. Last, edit linework as needed to clean up dangles and unclosed polygons that may not have come thru during the conversion.

c. Once the arc coverage has tics/labels added and arcs cleaned up, Quit (and save) and you will be asked to transform the coverage. Once the transform completes, the program will ask you to proceed, ie, is the RMS error acceptable. If the RMS is not ok, will need to stop and assess the situation ... otherwise, answer 'yes'. This step creates and intermediate coverage that will be named ***p####_2_xfrm***. (note, xfrm is abbreviation for transform)

d. The next session starts another arcedit session where you will be adding 'links' from the label points to the tics. After the transform, the tics have moved relative to the arcs/lables so this step adds links that will be used to 'adjust' or 'rubber-sheet' the linework according to the new (transformed) tic locations.

The editcover is ***p####_2_xfrm*** and the backcover is ***p####_3_ltic***. NOTE: the program copies the *cirtics* coverage to *p####_3_ltic* at this point. Also, the program sets snapping so that links snap to the tic in *p####_3_ltic*. However, the user needs to set the snapping distance tolerance with the 'snapping' button on the menu. Once you have added links from all the labels to tics, Quit (and save) and you will be asked to 'Adjust' the coverage. If you answer yes, you will be done converting and a coverage named ***p####_4_link*** is created.

e. After the adjust, your arcedit session will display the adjusted coverage and its associated doqq image. At this point, you need to examine the coverage for accuracy, ie, how well does the linework match features on the doqq. If everything looks ok and only minor changes are needed to the linework, type '&return' and the program with ask you if the *_4_link* coverage is acceptable. If you answer 'yes', the program will clean _4_link and a new and final coveage name ***p####_final*** is created. If you answer 'no', the program will terminate without creating the *_final* coverage and you will need to start the program again and edit either the *_1_scan* or *_2_xfrm* coverage in order to improve the result achieved in the *_4_link* coverage.

B.3 Editing. - The final arc coverage should be compared to the doqq and existing "_veg" coverage and erroneous linework should be cleaned up. You can build this coverage and add labels and attribute at this point or bring the arcs (get) into the main "_veg" coverage and attribute the lables there. Edge-matching should also be performed between the "_final" and "_veg" coverages.

IV. Edgematch, Merge, and Attribute Coverages.

The coverage produced from the transfer procedure (*p<photo_no>_final*) needs to be edge matched, attributed, and merged into the associated quarter-quad veg coverage (<*quadname*>*_veg#*). The polygons can be attributed either before or after it is merged. However, before it is merged, the "_final" coverage should be 'edge-matched' to any existing linework in the "_veg#" coverages. Suggested procedures are as follows:

A. Edgematch.

1. Start an arcedit session and choose the "**_final"** coverage as the edit coverage.

2. Display the "_veg#" coverage(s) associated with the edit coverage as a backcover. This may involve displaying more that one "_veg#" coverage if the A_final@ coverage overlaps into another quarter-quad area.

3. Edit arcs as needed to match to arcs in the backcover. Best edit commands to use are '**snap**', '**split**', '**vmove**', and '**extend**'. You can also display doqq=s to aid in the edge matching (you may need to fill in gaps via 'heads-up digitizing'). This step may show that arcs in the "_final" coverage are better than arcs in the "_veg#" coverage. If so, **save** the current editcoverage and then reverse coverages so that the "_veg#" coverage is the editcover and A_final@ is the backcover and edit arcs in "_veg#" to match those in "_final".

4. If you want to attribute polygons now, make "**_final**" the editcoverage and go to keyboard prompt and type **build**. If the build is successful, it will add labels to each polygon. If the build fails, you will need to quit and save. You will then be asked if you want to build, clean, or exit. Choose clean. When the clean is done, you will be asked to create labels - hit 'yes'. Get back into arcedit and begin attributing the polygon labels (see Section IV.C. below for attributing procedures).

B. Merge Coverage.

1. Start an arcedit session and select the "**_veg#**" coverage associated with the "_final" coverage as the edit cover.

2. On the AE menu, there is a button titled "**MENUS**". Click on it and there will be a list of programs you can run. Choose '**GetFeatures**'. Select the appropriate "_final" coverage from the pop-up list. The program will merge arcs (and labels) from "_final" into the current edit coverage. You will need to do some arc editing at this point to clean up dangles and to connect arcs as needed. Note, if you get

major snapping errors after the merge, check the PRECISION on your coverage as you may need to switch to double precision.

3. After all linework has been edited, you are ready to add labels and attribute. Note, even if you added and attributed labels in the "_final" coverage, there will be >new= polygons created in the "_veg#" coverage (due to the merge) that will need to have labels added and attributed. To add labels, either (1) go to keyboard prompt and type **build**; or (2), quit and save, build, and create labels from arc, i.e., using the List button on the main menu, go to the appropriate workspace, highlight the coverage you want, and hit the 'Create labels' button on the List menu.

<u>C. Attribute Polygons</u>. -

The vegetation coverages need to have the polygons attributed for 'veg_code', 'location', 'photo number', and for certain projects, 'pdog':

'veg_code':	refers to the vegetation or land use classification.
'location' :	refers to polygons that are in the >park= or outside the park (buffer).
'photo no':	refers to the CIR photo number which the polygon was interpreted from.
'pdog':	Some projects need two classifications for veg-code. If a polygon is for example a grassland type and it has prairie dog colony which has not resulted in complete mowing down of the grass, the polygon would be attributed '1' for the pdog item which would mean it includes pdog's. Answering 'yes' to the pdog menu item calc's the pdog item to '1'.

Each of these items can be attributed via the button titled '**ATTR**' on the AE menu. Note: the word 'cal' on the ATTR list means *calculate* which is the ArcEdit command to attribute a label or arc.

There are several ways that one can attribute the labels. What follows is the author's technique:

1. After new labels have been created, go to the SELECT button on the AE menu and choose 'Sel Photo No' (note, must do a save if the labels were created in arcedit before this button will recognize the new labels). Select '0' and all the new labels will be highlighted in red. May need to do a 'reselect' if there are other un-attributed labels in the coverage that are not associated with the photo you are working on. Once all the desired labels are selected, can attribute for 'photo no', 'location', and color ($symbol) all at once. I like to change the color of the labels so they stand out better plus the color tells me that I just attributed the labels for 'photo_no' and 'location'.

2. Next, select labels randomly for veg_code. Notice that after you calc the veg_code via the menu button, the color of the label point changes to green. This will help you see which labels have been attributed for veg_code and which ones have not.

<u>D. Attribute Arcs</u>

The vegetation coverages may need to have some arcs attributed with 'veg_code' for linear features such as wetlands. For example, if wetland was class 14 and you needed to attribute an arc as a linear wetland, select the arc, go to the **ATTR** button on the menu, select 'Cal Veg' and enter 14 at the prompt.

Also, all arcs should be attributed with 'digtype' as explained under section I. above. From the **ATTR** button on the menu, select 'Cal digtype' and select the appropriate number from the pop-up list. To repeat, the numbers are defined as follows:

1 = arcs derived from heads-up digitizing.
2 = arcs derived from scanning (Note: the Link program automatically calc's arcs in the A_final= coverage to digtype 2).
3 = arcs representing GIS project area boundary.
4 = arcs for the veg cover border (same as quarter-quad boundary).
5 = arcs representing a park boundary.

E. Put Features.

In certain instances you may have arcs (and labels) that fall outside of the "_veg#" cover=s boundary since the original CIR photo covered an area that overlapped into another doqq. You will need to 'put' those features into the neighboring "_veg#" coverage as follows:

1. Select the arcs that need to be moved.

2. From the **MENUS** button on the AE menu, chose '**PutFeatures**'. You will be asked where you want to put the features via pop-up menus. Once you select the correct coverage, the program will put the selected features into the selected coverage and then it will ask you if you want to delete the selected features in the current editcover. If the 'put' was successful, answer 'yes'. Do a **save** immediately after putting so as to save the features in the put-to coverage.

3. If there are any labels that need 'putting', select them and repeat step #2 above.

F. On-Screen QA/QC.

1. When you are done attributing for a particular photo or the entire veg coverage, there are several quick checks you can do to make sure that all labels have been attributed.

1.1 The '**Sel Photo No**.' item under the SELECT button on the AE menu. -. This will display all the photo_no=s that have been attributed and will list a '0' if there are any labels that have not been attributed for this item. It also will list all the photo numbers so if you typed the photo number wrong, that 'wrong' number will show up on the pop-up list so check the entire to list to make sure there are no typo's.

1.2 The '**Sel VegCode**' item under the SELECT button on the AE menu. - This will display all the veg_codes that have been attributed and will list a '0' if there are any labels that have not been attributed for veg_code. It also will list all the veg_code numbers so if you typed the veg_code number wrong, that 'wrong' number will show up on the pop-up list so check the entire to list to make sure there are no typo's. Note: this button is set for editfeature label so you cannot use it check arcs that have been attributed for veg_code.

1.3 The '**Sel Location**' item under the SELECT button on the AE menu. - This will display all the location attributes and will list a >blank= for a label that has not been attributed for 'location'. You can also use this button to highlight all the labels that you attributed for in the 'park' or in the 'buffer' to see if you made any mistakes.

2. Once the veg cover is complete, there are two qaqc programs you should run on the entire coverage as follows:

2.1 The '**PhotoChk**' item under the MENUS button on the AE menu. - This program checks to see if you attributed all the polygons correctly related to the photo flight-line number. Follow the prompts given by the program. When the program completes, your screen will have the labels highlighted based on flightline - if there is a 'color' out of place or a label that is still white, it means that label has the wrong photo number or is not attributed at all.

2.1 The '**LblError**' item under the MENUS button on the AE menu. - This program checks for label errors, ie, it will check to see that all polygons have a label and/or check to see if there is a polygon that has more than one label - every polygon should have ONE label. NOTE: This program may not run if the coverage needs building - if it fails, quit and save and build the cover (do not do the build in arcedit) and then run the 'LblError' program again.

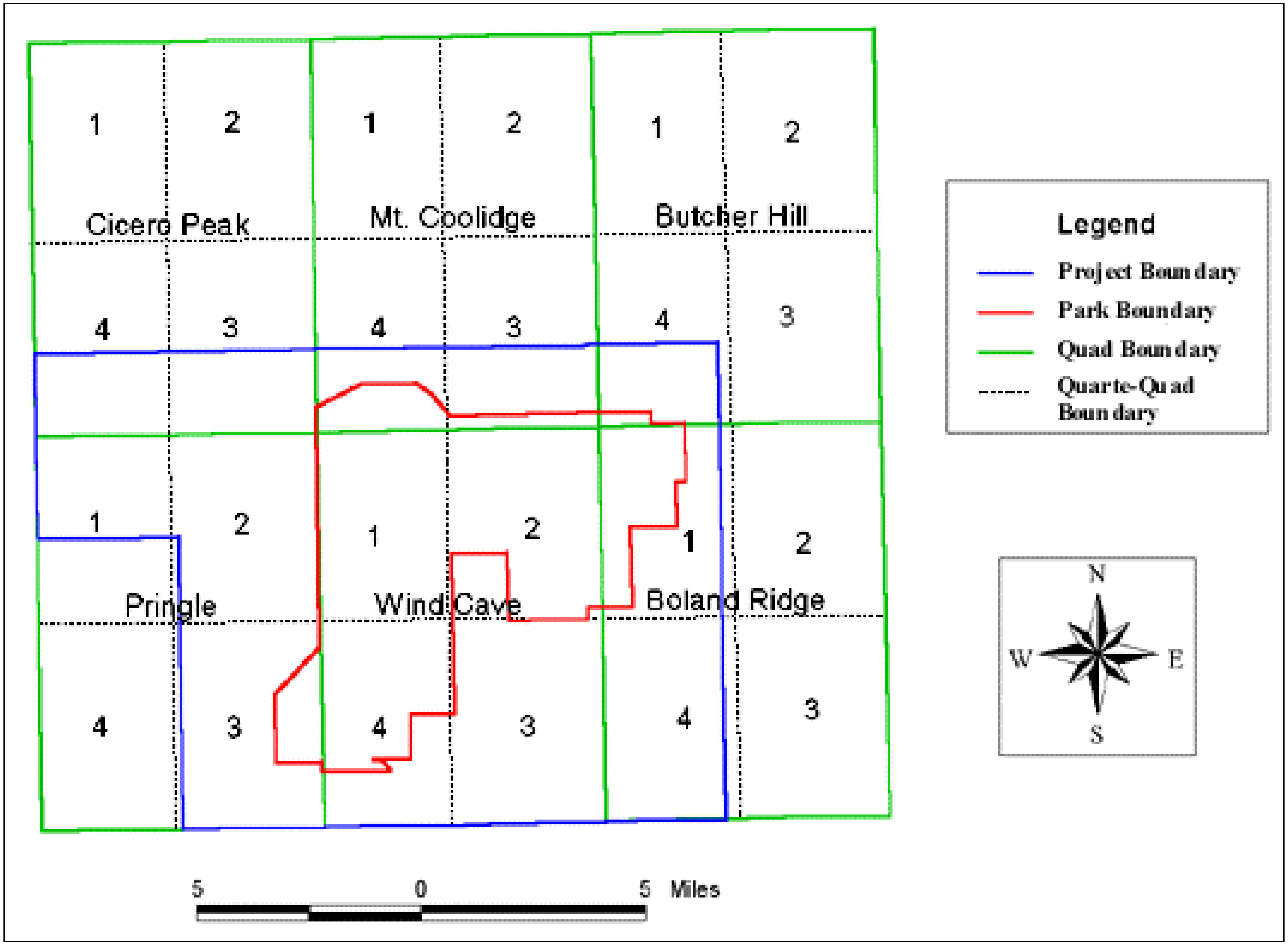
You may notice a lot of polygons that have duplicate labels. This usually arises when you have done some editing where you have deleted or changed a polygon that had a label in it. So whenever you edit a polygon, make sure to move or delete its label point.

Doug Crawford, Jay Carlson
Revised 01-19-98

Appendix 13.

USGS Digital-ortho Quarter Quadrangles (DOQQ's) used for the Wind Cave National Park Mapping Project.

USGS Catalog Number	7.5 Minute Quadrangle	Quadrant
04310329.NWS	Wind Cave	1 (Wind Cave nw)
04310329.NES	Wind Cave	2 (Wind Cave ne)
04310329.SES	Wind Cave	3 (Wind Cave se)
04310329.SWS	Wind Cave	4 (Wind Cave se)
04310322.SWS	Butcher Hill	4 (Butcher Hill sw)
04310330.SES	Boland Ridge	3 (Boland Ridge se)
04310330.SWS	Boland Ridge	4 Boland Ridge sw)
04310321.SES	Mt. Coolidge	3 (Mt. Coolidge se)
04310321.SWS	Mt. Coolidge	4 (Mt. Coolidge sw)
04310328.NWS	Pringle	1 (Pringle nw)
04310328.NES	Pringle	2 (Pringle ne)
04310328.SES	Pringle	3 (Pringle se)
04310320.SES	Cicero Peak	3 (Cicero Peak se)
04310320.SWS	Cicero Peak	4 (Cicero Peak.sw)


1
2
Cicero Peak
4
3
1
2
Mt. Coolidge
4
3
1
2
Butcher Hill
4
3
1
2
Pringle
4
3
1
2
Wind Cave
4
3
1
2
Boland Ridge
4
3
Legend
Project Boundary
Park Boundary
Quad Boundary
Quarte-Quad Boundary
N
W
E
S
5
0
5
Miles

Appendix 14.

Wind Cave National Park Species List

(Species obtained from all plot and observation data points collected in 1997 as part of the NPS-USGS National Mapping Program)

Family	Scientific Name	Common Name
Aceraceae	*Acer negundo L.*	boxelder
Agavaceae	*Yucca glauca Nutt.*	small soapweed
Amblystegiaceae	*Calliergon richardsonii (Mitt.) Kindb. in Warnst.*	Richardson's calliergon Moss
Anacardiaceae	*Rhus aromatica Ait.*	fragrant sumac
	Rhus trilobata Nutt.	skunkbush sumac
	Toxicodendron pubescens P. Mill.	Atlantic poison oak
	Toxicodendron rydbergii (Small ex Rydb.) Greene	western poison ivy
Apiaceae	*Cicuta maculata L.*	spotted water hemlock
	Heracleum sphondylium L.	eltrot
	Musineon tenuifolium (Nutt. ex Torr. & Gray) Coult. & Rose	slender wildparsley
	Osmorhiza berteroi DC.	Sweetcicely
	Osmorhiza depauperata Phil.	bluntseed sweetroot
	Osmorhiza longistylis (Torr.) DC.	longstyle sweetroot
	Sanicula L.	sanicle
	Sanicula marilandica L.	Maryland sanicle
	Zizia aptera (Gray) Fern.	meadow zizia
Apocynaceae	*Apocynum androsaemifolium L.*	spreading dogbane
	Apocynum cannabinum L.	Indianhemp
Araliaceae	*Aralia nudicaulis L.*	wild sarsaparilla
Asclepiadaceae	*Asclepias ovalifolia Dcne.*	ovalleaf milkweed
	Asclepias pumila (Gray) Vail	plains milkweed
	Asclepias speciosa Torr.	showy milkweed
	Asclepias verticillata L.	whorled milkweed
	Asclepias viridiflora Raf.	green milkweed
	Asclepias viridula Chapman	southern milkweed
Asteraceae	*Achillea millefolium L.*	common yarrow
	Adenocaulon bicolor Hook.	American trailplant
	Agoseris glauca (Pursh) Raf.	pale agoseris
	Ambrosia psilostachya DC.	Cuman ragweed
	Ambrosia trifida L.	great ragweed
	Anaphalis margaritacea (L.) Benth. & Hook. f.	western pearlyeverlasting
	Antennaria Gaertn.	Pussytoes
	Antennaria neglecta Greene	field pussytoes
	Antennaria parvifolia Nutt.	smallleaf pussytoes
	Antennaria plantaginifolia (L.) Richards.	woman's tobacco
	Arctium minus Bernh.	lesser burdock
	Arnica cordifolia Hook.	heartleaf arnica
	Arnica frigida C.A. Mey. ex Iljin	snow arnica
	Arnica lonchophylla Greene	longleaf arnica
	Arnica rydbergii Greene	Rydberg's arnica
	Arnoglossum atriplicifolium (L.) H.E. Robins.	Armoglossum
	Artemisia L.	sagebrush
	Artemisia campestris L.	field sagewort

Artemisia dracunculus L.	wormwood
Artemisia filifolia Torr.	sand sagebrush
Artemisia ludoviciana Nutt.	Louisiana sagewort
Aster L.	aster
Aster ciliolatus Lindl.	Lindley's aster
Aster ericoides L.	heath aster
Aster falcatus Lindl.	cluster aster
Aster laevis L.	smooth aster
Aster oblongifolius Nutt.	aromatic aster
Balsamorhiza sagittata (Pursh) Nutt.	arrowleaf balsamroot
Brickellia eupatorioides var. *eupatorioides (L.) Shinners*	false boneset
Cirsium P. Mill.	Thistle
Cirsium arvense (L.) Scop.	Canadian thistle
Cirsium flodmanii (Rydb.) Arthur	Flodman's thistle
Cirsium ochrocentrum Gray	yellowspine thistle
Cirsium undulatum (Nutt.) Spreng.	wavyleaf thistle
Cirsium vulgare (Savi) Ten.	bull thistle
Conyza Less.	horseweed
Conyza canadensis (L.) Cronq.	Canadian horseweed
Conyza ramosissima Cronq.	dwarf horseweed
Dyssodia papposa (Vent.) A.S. Hitchc.	fetid marigold
Echinacea Moench	purple coneflower
Echinacea angustifolia DC.	blacksamson echinacea
Echinacea pallida (Nutt.) Nutt.	pale purple coneflower
Ericameria pinifolia (Gray) Hall	pinebush
Erigeron L.	fleabane
Erigeron formosissimus Greene	beautiful fleabane
Erigeron speciosus (Lindl.) DC.	aspen fleabane
Erigeron strigosus Muhl. ex Willd.	prairie fleabane
Erigeron subtrinervis Rydb. ex Porter & Britt.	threenerve fleabane
Grindelia squarrosa (Pursh) Dunal	curlycup gumweed
Gutierrezia sarothrae (Pursh) Britt. & Rusby	broom snakeweed
Helianthus annuus L.	common sunflower
Heterotheca villosa (Pursh) Shinners	hairy goldenaster
Heterotheca villosa var. *villosa (Pursh) Shinners*	hairy goldenaster
Hieracium albiflorum Hook.	white hawkweed
Hieracium umbellatum L.	narrowleaf hawkweed
Lactuca L.	lettuce
Lactuca canadensis L.	Canada lettuce
Lactuca serriola L.	prickly lettuce
Lactuca tatarica var. *pulchella (Pursh) Breitung*	blue lettuce
Liatris Gaertn. ex Schreb.	gayfeather
Liatris punctata Hook.	dotted gayfeather
Liatris spicata (L.) Willd.	dense gayfeather
Lygodesmia juncea (Pursh) D. Don ex Hook.	rush skeletonplant
Machaeranthera pinnatifida ssp. *-pinnatifida* var. *pinnatifida (Hook.) Shinners*	lacy tansyaster
Nothocalais cuspidata (Pursh) Greene	sharppoint microseris
Oligoneuron rigidum var. rigidum (L.) Small	goldenrod
Ratibida columnifera (Nutt.) Woot. & Standl.	upright prairie coneflower
Rudbeckia hirta L.	blackeyed Susan
Senecio canus Hook.	woolly groundsel
Senecio L.	groundsel
Senecio integerrimus Nutt.	lambstongue groundsel
Senecio plattensis Nutt.	prairie groundsel

	Senecio pseudaureus Rydb.	falsegold groundsel
	Senecio rapifolius Nutt.	openwoods groundsel
	Senecio vulgaris L.	common groundsel
	Solidago L.	goldenrod
	Solidago canadensis L.	Canada goldenrod
	Solidago missouriensis Nutt.	Missouri goldenrod
	Solidago speciosa Nutt.	showy goldenrod
	Stenotus acaulis var. *acaulis (Nutt.) Nutt.*	stemless goldenweed
	Taraxacum G.H. Weber ex Wiggers	dandelion
	Taraxacum officinale G.H. Weber ex Wiggers	common dandelion
	Tetraneuris acaulis var. acaulis (Pursh) Greene	stemless hymenoxys
	Tragopogon dubius Scop.	yellow salsify
Berberidaceae	*Mahonia repens (Lindl.) G. Don*	Oregongrape
Betulaceae	*Betula neoalaskana Sarg.*	Alaska paper birch
	Betula papyrifera Marsh.	paper birch
	Corylus cornuta Marsh.	beaked hazelnut
	Ostrya virginiana (P. Mill.) K. Koch	eastern hophornbeam
Boraginaceae	*Cryptantha Lehm. ex G. Don*	cryptantha
	Cryptantha celosioides (Eastw.) Payson	buttecandle
	Cynoglossum L.	hound's tongue
	Cynoglossum officinale L.	gypsyflower
	Cynoglossum virginianum var. *boreale (Fern.) -Cooperrider*	wild comfrey
	Hackelia deflexa (Wahlenb.) Opiz	nodding stickseed
	Lithospermum incisum Lehm.	narrowleaf gromwell
	Mertensia lanceolata (Pursh) DC.	lanceleaf bluebells
	Onosmodium molle Michx.	smooth onosmodium
Brassicaceae	*Alyssum L.*	
	Arabis X divaricarpa A. Nels. (pro sp.)	spreadingpod rockcress
	Erysimum inconspicuum (S. Wats.) MacM.	shy wallflower
Cactaceae	*Echinocereus Engelm.*	hedgehog cactus
	Echinocereus viridiflorus Engelm.	nylon hedgehog cactus
	Escobaria missouriensis var. missouriensis -(Sweet) D.R. Hunt	Missouri foxtail cactus
	Opuntia P. Mill.	pricklypear
	Opuntia fragilis (Nutt.) Haw.	brittle pricklypear
	Opuntia humifusa (Raf.) Raf.	pricklypear
	Opuntia polyacantha Haw.	plains pricklypear
Campanulaceae	*Campanula rotundifolia L.*	bluebell bellflower
	Triodanis perfoliata (L.) Nieuwl.	clasping Venus' lookingglass
Caprifoliaceae	*Linnaea borealis L.*	twinflower
	Lonicera dioica L.	limber honeysuckle
	Symphoricarpos Duham.	snowberry
	Symphoricarpos albus (L.) Blake	common snowberry
	Symphoricarpos occidentalis Hook.	western snowberry
Caryophyllaceae	*Cerastium arvense L.*	field chickweed
	Cerastium nutans Raf.	nodding chickweed
	Moehringia lateriflora (L.) Fenzl	bluntleaf sandwort

	Paronychia depressa (Torr. & Gray) Nutt. -ex A. Nels.	spreading nailwort
	Silene L.	silene
	Silene antirrhina L.	sleepy silene
	Silene latifolia ssp. *alba (P. Mill.) Greuter & Burdet*	bladder campion
Chenopodiaceae	*Krascheninnikovia lanata (Pursh) Guldenstaedt*	winterfat
Cistaceae	*Helianthemum bicknellii Fern.*	hoary frostweed
Clusiaceae	*Hypericum perforatum L.*	common St. Johnswort
Commelinaceae	*Tradescantia bracteata Small ex Britt.*	longbract spiderwort
	Tradescantia occidentalis (Britt.) Smyth	prairie spiderwort
Convolvulaceae	*Calystegia sepium (L.) R. Br.*	hedge false bindweed
	Convolvulus L.	bindweed
	Evolvulus nuttallianus J.A. Schultes	shaggy dwarf morningglory
Cornaceae	*Cornus canadensis L*.	bunchberry dogwood
Cucurbitaceae	*Echinocystis lobata (Michx.) Torr. & Gray*	wild cucumber
Cupressaceae	*Juniperus communis L.*	common juniper
	Juniperus horizontalis Moench	creeping juniper
	Juniperus scopulorum Sarg.	Rocky Mountain juniper
Cyperaceae	*Carex L*.	sedge
	Carex aurea Nutt.	golden sedge
	Carex bebbii Olney ex Fern.	Bebb's sedge
	Carex blanda Dewey	eastern woodland sedge
	Carex brevior (Dewey) Mackenzie	fescue sedge
	Carex concinna R. Br.	low northern sedge
	Carex deweyana Schwein.	Dewey sedge
	Carex filifolia Nutt.	threadleaf sedge
	Carex foenea Willd.	dryspike sedge
	Carex inops ssp. *heliophila (Mackenzie) Crins*	sun sedge
	Carex microptera Mackenzie	smallwing sedge
	Carex peckii Howe	Peck's sedge
	Carex richardsonii R. Br.	Richardson's sedge
	Carex rossii Boott	Ross' sedge
	Carex saximontana Mackenzie	Rocky Mountain sedge
	Carex sprengelii Dewey ex Spreng.	Sprengel's sedge
	Carex torreyi Tuckerman	Torrey's sedge
	Carex xerantica Bailey	whitescale sedge
	Scirpus microcarpus J.& K. Presl	panicled bulrush
Dennstaedtiaceae	*Pteridium aquilinum (L.) Kuhn*	western brackenfern
Dryopteridaceae	*Cystopteris fragilis (L.) Bernh.*	brittle bladderfern
	Woodsia R. Br.	woodsia
	Woodsia oregana D.C. Eat.	Oregon woodsia
Elaeagnaceae	*Shepherdia canadensis (L.) Nutt.*	russet buffaloberry

Equisetaceae	*Equisetum laevigatum A. Braun*	smooth horsetail
Ericaceae	*Arctostaphylos uva-ursi (L.) Spreng.*	kinnikinnick
	Vaccinium scoparium Leib. ex Coville	grouse whortleberry
Euphorbiaceae	*Chamaesyce fendleri (Torr. & Gray) Small*	Fendler's sandmat
	Chamaesyce glyptosperma (Engelm.) Small	ribseed sandmat
	Chamaesyce maculata (L.) Small	spotted sandmat
	Euphorbia L.	spurge
	Euphorbia spathulata Lam.	warty spurge
Fabaceae	*Amorpha L.*	indigobush
	Amorpha canescens Pursh	leadplant
	Amorpha fruticosa L.	desert indigobush
	Amorpha nana Nutt.	dwarf indigobush
	Astragalus L.	milkvetch
	Astragalus adsurgens Pallas	standing milkvetch
	Astragalus alpinus L.	alpine milkvetch
	Astragalus crassicarpus Nutt.	groundplum milkvetch
	Astragalus flexuosus (Hook.) Dougl. ex G. Don	flexile milkvetch
	Astragalus gilviflorus Sheldon	plains milkvetch
	Astragalus gracilis Nutt.	slender milkvetch
	Astragalus miser Dougl.	weedy milkvetch
	Astragalus spatulatus Sheldon	tufted milkvetch
	Dalea L.	prairieclover
	Dalea candida var. *candida Willd.*	white prairieclover
	Dalea purpurea var. *purpurea Vent.*	violet prairieclover
	Glycyrrhiza lepidota Pursh	American licorice
	Hedysarum alpinum L.	alpine sweetvetch
	Lathyrus L.	peavine
	Lathyrus ochroleucus Hook.	cream peavine
	Lupinus argenteus Pursh	silvery lupine
	Medicago lupulina L.	black medick
	Melilotus officinalis (L.) Lam.	yellow sweetclover
	Oxytropis campestris (L.) DC.	cold mountain crazyweed
	Oxytropis lambertii Pursh	Lambert's crazyweed
	Oxytropis sericea Nutt.	silvery oxytrope
	Pediomelum Rydb.	pediomelum
	Pediomelum argophyllum (Pursh) J. Grimes	silverleaf scurfpea
	Psoralidium argophyllum (Pursh) Rydb.	silverleaf scurfpea
	Pediomelum esculentum (Pursh) Rydb.	breadroot scurfpea
	Psoralidium tenuiflorum (Pursh) Rydb.	slimflower scurfpea
	Thermopsis rhombifolia (Nutt. ex Pursh) Nutt. -ex Richards.	prairie thermopsis
	Trifolium hybridum L.	alsike clover
	Trifolium reflexum L.	buffalo clover
	Trifolium repens L.	white clover
	Vicia americana Muhl. ex Willd.	American vetch
Fagaceae	*Quercus macrocarpa Michx.*	bur oak
Gentianaceae	*Frasera speciosa Dougl. ex Griseb.*	showy frasera
	Gentianella amarella ssp. *acuta (Michx.) J. Gillett*	autumn dwarfgentian
	Halenia deflexa (Sm.) Griseb.	American spurredgentian
	Geranium L.	geranium

	Geranium bicknellii Britt.	Bicknell's cranesbill
	Geranium richardsonii Fisch. & Trautv.	Richardson's geranium
Grossulariaceae	*Ribes L.*	currant
	Ribes amarum McClatchie	bitter gooseberry
	Ribes aureum Pursh	golden currant
	Ribes aureum var. *villosum DC*.	golden currant
	Ribes cereum Dougl.	wax currant
	Ribes lacustre (Pers.) Poir.	prickly currant
	Ribes missouriense Nutt.	Missouri gooseberry
	Ribes oxyacanthoides ssp. *setosum (Lindl.) Sinnott*	inland gooseberry
Iridaceae	*Iris missouriensis Nutt.*	Rocky Mountain iris
	Sisyrinchium angustifolium P. Mill.	narrowleaf blueeyed grass
	Sisyrinchium montanum Greene	mountain blueeyed grass
Juncaceae	*Juncus confusus Coville*	Colorado rush
Lamiaceae	*Galeopsis bifida Boenn.*	splitlip hempnettle
	Hedeoma Pers.	falsepennyroyal
	Hedeoma hispida Pursh	rough falsepennyroyal
	Leonurus cardiaca L.	common motherwort
	Lycopus americanus Muhl. ex W. Bart.	American waterhorehound
	Mentha arvensis L.	wild mint
	Monarda fistulosa L.	wildbergamot beebalm
	Monarda L.	beebalm
	Nepeta cataria L.	catnip
Liliaceae	*Allium L*.	wild onion
	Allium canadense L.	meadow garlic
	Allium cernuum Roth	nodding onion
	Allium textile A. Nels. & J.F. Macbr.	textile onion
	Calochortus nuttallii Torr. & Gray	sego lily
	Disporum trachycarpum (S. Wats.) Benth. -& Hook. f.	roughfruit fairybells
	Lilium philadelphicum L.	wood lily
	Maianthemum canadense Desf.	Canada beadruby
	Maianthemum racemosum ssp. racemosum -(L.) Link	feather Solomon's seal
	Maianthemum stellatum (L.) Link	starry false Solomon's seal
	Polygonatum biflorum (Walt.) Ell.	King Solomon's seal
	Zigadenus elegans Pursh	mountain deathcamas
	Zigadenus venenosus S. Wats.	meadow deathcamas
Linaceae	*Linum perenne L.*	blue flax
Loasaceae	*Mentzelia oligosperma Nutt. ex Sims*	chickenthief
Malvaceae	*Sphaeralcea coccinea (Nutt.) Rydb.*	scarlet globemallow
Monotropaceae	*Pterospora andromedea Nutt.*	woodland pinedrops
Nyctaginaceae	*Abronia fragrans Nutt. ex Hook.*	snowball sand verbena
	Mirabilis hirsuta (Pursh) MacM.	hairy four o'clock
	Mirabilis linearis (Pursh) Heimerl	narrowleaf four o'clock

Oleaceae	*Fraxinus pennsylvanica Marsh.*	green ash
Onagraceae	*Calylophus serrulatus (Nutt.) Raven*	yellow sundrops
	Circaea alpina L.	small enchanter's nightshade
	Epilobium angustifolium L.	fireweed
	Epilobium halleanum Hausskn.	glandular willowherb
	Gaura coccinea Nutt. ex Pursh	scarlet beeblossom
	Oenothera coronopifolia Torr. & Gray	crownleaf eveningprimrose
	Oenothera villosa Thunb.	hairy eveningprimrose
Orchidaceae	*Coeloglossum viride var. viride (L.) Hartman*	longbract frog orchid
	Corallorrhiza maculata (Raf.) Raf.	summer coralroot
	Goodyera oblongifolia Raf.	western rattlesnake plantain
	Goodyera repens (L.) R. Br. ex Ait. f.	lesser rattlesnake plantain
Orobanchaceae	Orobanche fasciculata Nutt.	clustered broomrape
Oxalidaceae	*Oxalis L.*	woodsorrel
Pinaceae	*Picea glauca (Moench) Voss*	white spruce
Pinaceae	*Pinus ponderosa P.& C. Lawson*	ponderosa pine
Plantaginaceae	*Plantago L.*	plantain
	Plantago patagonica Jacq.	woolly plantain
Poaceae	*Achnatherum hymenoides -(Roemer & J.A. Schultes) Barkworth*	
	Achnatherum occidentale ssp. *occidentale -(Thurb. ex S. Wats.) Barkworth*	
	Achnatherum richardsonii (Link) Barkworth	
	Agropyron Gaertn.	wheatgrass
	Agrostis L.	
	Agrostis hyemalis (Walt.) B.S.P.	winter bentgrass
	Agrostis scabra Willd.	rough bentgrass
	Agrostis stolonifera L.	creeping bentgrass
	Andropogon gerardii Vitman	big bluestem
	Aristida purpurascens Poir.	arrowfeather threeawn
	Aristida purpurea Nutt.	purple threeawn
	Aristida purpurea var. *longiseta (Steud.) Vasey*	Fendler threeawn
	Bouteloua curtipendula (Michx.) Torr.	sideoats grama
	Bouteloua gracilis (Willd. ex Kunth) Lag. -ex Griffiths	blue grama
	Bouteloua hirsuta Lag.	hairy grama
	Bromus anomalus Rupr. ex Fourn.	nodding brome
	Bromus ciliatus L.	fringed brome
	Bromus inermis Leyss.	smooth brome
	Bromus japonicus Thunb. ex Murr.	Japanese brome
	Bromus pubescens Muhl. ex Willd.	hairy woodland brome
	Bromus tectorum L.	cheatgrass
	Buchloe dactyloides (Nutt.) Engelm.	buffalograss
	Calamagrostis canadensis (Michx.) Beauv.	bluejoint
	Calamovilfa longifolia (Hook.) Scribn.	prairie sandreed
	Danthonia intermedia Vasey	timber oatgrass
	Danthonia spicata (L.) Beauv. -ex Roemer & J.A. Schultes	poverty danthonia

Dichanthelium (A.S. Hitchc. & Chase) Gould	rosette grass
Dichanthelium acuminatum (Sw.)	
-Gould & C.A. Clark	tapered rosette grass
Dichanthelium leibergii (Vasey) Freckmann	Leiberg's panicum
Dichanthelium oligosanthes (J.A. Schultes) Gould	Heller's rosette grass
Dichanthelium oligosanthes var. *scribnerianum*	
-(Nash) Gould	Scribner's rosette grass
Dichanthelium wilcoxianum (Vasey) Freckmann	fall panicum
Distichlis spicata (L.) Greene	inland saltgrass
Elymus L.	wildrye
Elymus canadensis L.	Canada wildrye
Elymus caninus (L.) L.	bearded wheatgrass
Elymus elymoides (Raf.) Swezey	bottlebrush squirreltail
Elymus elymoides ssp. *elymoides (Raf.) Swezey*	
Elymus elymoides ssp. *hordeoides*	
-(Suksdorf) Barkworth	
Elymus lanceolatus ssp. *lanceolatus*	
-(Scribn. & J.G. Sm.) Gould	thickspick wheatgrass
Elymus trachycaulus (Link) Gould ex Shinners	slender wheatgrass
Elymus trachycaulus ssp. subsecundus	
-(Link) A.& D. Love	slender wheatgrass
Elymus trachycaulus ssp. trachycaulus	
-(Link) Gould ex Shinners	slender wheatgrass
Elymus virginicus L.	Virginia wildrye
Elytrigia repens var. *repens (L.) Desv.*	
-ex B.D. Jackson	quackgrass
Festuca L. *fescue*	
Festuca idahoensis Elmer	Idaho fescue
Festuca octoflora Walt. = Vulpia octoflora	
-var. *octoflora*	sixweeks fescue
Festuca ovina L.	sheep fescue
Festuca subulata Trin.	bearded fescue
Glyceria R. Br.	mannagrass
Glyceria grandis S. Wats.	American mannagrass
Hesperostipa comata ssp. *comata (Trin. & Rupr.)*	
-Barkworth	needle-and-thread
Hesperostipa spartea (Trin.) Barkworth	porcupine grass
Koeleria Pers.	koeleria
Koeleria macrantha (Ledeb.) J.A. Schultes	prairie Junegrass
Leymus innovatus (Beal) Pilger	downy ryegrass
Melica subulata (Griseb.) Scribn.	Alaska oniongrass
Muhlenbergia cuspidata (Torr. ex Hook.) Rydb.	plains muhly
Muhlenbergia racemosa (Michx.) B.S.P.	marsh muhly
Nassella viridula (Trin.) Barkworth	green needlegrass
Oryzopsis asperifolia Michx.	roughleaf ricegrass
Oryzopsis micrantha (Trin. & Rupr.) Thurb.	
= Piptatherum micranthum	Little seeded ricegrass
Oryzopsis pungens (Torr. ex Spreng.) A.S. Hitchc.	mountain ricegrass
Panicum virgatum L.	switchgrass
Pascopyrum smithii (Rydb.) A. Love	western wheatgrass
Phleum pratense L.	timothy
Piptatherum micranthum (Trin. & Rupr.) Barkworth	
Poa L.	bluegrass
Poa compressa L.	Canada bluegrass
Poa interior Rydb.	inland bluegrass
Poa palustris L.	fowl bluegrass

	Poa pratensis L.	Kentucky bluegrass
	Schizachne purpurascens (Torr.) Swallen	false melic
	Schizachyrium scoparium (Michx.) Nash	little bluestem
	Spartina pectinata Link	prairie cordgrass
	Sporobolus R. Br.	dropseed
	Sporobolus airoides (Torr.) Torr.	alkali sacaton
	Sporobolus cryptandrus (Torr.) Gray	sand dropseed
	Sporobolus heterolepis (Gray) Gray	prairie dropseed
	Stipa comata Trin. & Rupr.	
	= *Hesperostipa comata* ssp. *Comata*	needle-and-thread
	Stipa spartea Trin. = Hesperostipa spartea	porcupine grass
	Vulpia octoflora var. *octoflora (Walt.) Rydb*.	sixweeks fescue
Polemoniaceae	*Collomia linearis Nutt*.	narrowleaf mountaintrumpet
	Phlox alyssifolia Greene	alyssumleaf phlox
	Phlox andicola E. Nels.	prairie phlox
	Phlox gracilis ssp. *gracilis (Hook.) Greene*	slender phlox
	Phlox hoodii Richards.	spiny phlox
Polygalaceae	*Polygala alba Nutt.*	white milkwort
	Polygala senega L.	Seneca snakeroot
	Polygala verticillata L.	whorled milkwort
	Eriogonum pauciflorum Pursh	fewflower buckwheat
	Polygonum arenastrum Jord. ex Boreau	ovalleaf knotweed
	Polygonum convolvulus L.	black bindweed
	Rumex crispus L.	curly dock
	Polypodium hesperium Maxon	western polypody
Portulacaceae	*Claytonia perfoliata* ssp. *perfoliata Donn ex Willd.*	miner's lettuce
	Portulaca oleracea L.	little hogweed
Primulaceae	*Androsace septentrionalis L.*	pygmyflower rockjasmine
	Dodecatheon meadia ssp. *meadia L*.	pride of Ohio
	Lysimachia ciliata L.	fringed loosestrife
Pteridaceae	*Cheilanthes feei T. Moore*	slender lipfern
	Pellaea atropurpurea (L.) Link	purple cliffbrake
Pyrolaceae	*Chimaphila umbellata (L.) W. Bart*.	pipsissewa
	Orthilia secunda (L.) House	sidebells wintergreen
	Pyrola asarifolia Michx.	liverleaf wintergreen
	Pyrola chlorantha Sw.	greenflowered wintergreen
	Pyrola elliptica Nutt.	waxflower shinleaf
Ranunculaceae	*Aconitum columbianum Nutt*.	Columbian monkshood
	Actaea rubra (Ait.) Willd.	red baneberry
	Anemone L.	anemone
	Anemone canadensis L.	Canadian anemone
	Anemone cylindrica Gray	candle anemone
	Anemone multifida Poir.	Pacific anemone
	Anemone virginiana var. *virginiana L*.	tall thimbleweed
	Aquilegia canadensis L.	red columbine
	Clematis columbiana var. *columbiana (Nutt.)*	
	-Torr. & Gray	rock clematis
	Clematis columbiana var. *tenuiloba (Gray)*	
	-J. Pringle	rock clematis

	Clematis ligusticifolia Nutt.	western white clematis
	Delphinium nuttallianum Pritz. ex Walp.	Nuttal's larkspur
	Pulsatilla patens ssp. *patens (L.) P. Mill*.	American pasqueflower
	Ranunculus abortivus L.	littleleaf buttercup
	Ranunculus macounii Britt.	Macoun's buttercup
	Thalictrum aquilegifolium L.	columbine meadowrue
	Thalictrum dasycarpum Fisch. & Ave-Lall.	purple meadowrue
	Thalictrum L.	meadowrue
	Thalictrum dioicum L.	early meadowrue
	Thalictrum venulosum Trel.	veiny meadowrue
Rhamnaceae	*Ceanothus L.*	
	Ceanothus velutinus Dougl. ex Hook.	snowbrush ceanothus
	Rhamnus alnifolia L'Her.	alderleaf buckthorn
	Rhamnus cathartica L.	common buckthorn
Rosaceae	*Agrimonia striata Michx.*	roadside agrimony
	Amelanchier alnifolia (Nutt.) Nutt. ex M. Roemer	Saskatoon serviceberry
	Amelanchier humilis Wieg.	low serviceberry
	Cercocarpus montanus Raf.	true mountain mahogany
	Coleogyne ramosissima Torr.	blackbrush
	Crataegus succulenta Schrad. ex Link	fleshy hawthorn
	Fragaria L.	strawberry
	Fragaria virginiana Duchesne	Virginia strawberry
	Geum triflorum Pursh	prairiesmoke
	Physocarpus monogynus (Torr.) Coult.	mountain ninebark
	Physocarpus opulifolius (L.) Maxim.	common ninebark
	Potentilla L.	cinquefoil
	Potentilla concinna Richards.	elegant cinquefoil
	Potentilla fissa Nutt.	bigflower cinquefoil
	Potentilla gracilis Dougl. ex Hook.	northwest cinquefoil
	Potentilla hippiana Lehm.	woolly cinquefoil
	Prunus L.	prunus
	Prunus americana Marsh.	American plum
	Prunus pumila var. *besseyi (Bailey) Gleason*	western sandcherry
	Prunus virginiana L.	common chokecherry
	Rosa L.	rose
	Rosa acicularis Lindl.	prickly rose
	Rosa arkansana Porter	prairie rose
	Rosa woodsii Lindl.	Woods' rose
	Rubus L.	blackberry
	Rubus idaeus L.	American red raspberry
	Rubus occidentalis L.	black raspberry
	Rubus parviflorus Nutt.	thimbleberry
	Rubus pubescens Raf.	dwarf red blackberry
	Spiraea betulifolia Pallas	white spirea
Rubiaceae	*Galium aparine L*.	stickywilly
	Galium boreale L.	northern bedstraw
	Galium obtusum Bigelow	bluntleaf bedstraw
	Galium triflorum Michx.	fragrant bedstraw
Salicaceae	*Populus deltoides Bartr. ex Marsh.*	eastern cottonwood
	Populus tremuloides Michx.	quaking aspen
	Salix L.	willow
	Salix scouleriana Barratt ex Hook.	Scouler's willow

Santalaceae	*Comandra umbellata (L.) Nutt*.	bastard toadflax
Saxifragaceae	*Heuchera parviflora Bartl*.	littleflower alumroot
	Heuchera richardsonii R. Br.	Richardson's alumroot
	Lithophragma parviflorum (Hook.) Nutt. ex Torr. & Gray	smallflower woodlandstar
Scrophulariaceae	*Besseya wyomingensis (A. Nels.) Rydb.*	Wyoming besseya
	Castilleja sulphurea Rydb.	sulphur Indian paintbrush
	Orthocarpus luteus Nutt.	yellow owlclover
	Penstemon gracilis Nutt.	lilac penstemon
	Verbascum thapsus L.	common mullein
Selaginellaceae	*Selaginella densa Rydb.*	lesser spikemoss
Smilacaceae	*Smilax herbacea L.*	smooth carrionflower
Solanaceae	*Physalis L.*	groundcherry
	Physalis longifolia Nutt.	longleaf groundcherry
	Solanum triflorum Nutt.	cutleaf nightshade
Ulmaceae	*Celtis occidentalis L.*	hackberry
	Ulmus americana L.	American elm
	Ulmus rubra Muhl.	slippery elm
Urticaceae	*Parietaria pensylvanica Muhl. ex Willd.*	Pennsylvania pellitory
	Urtica dioica L.	stinging nettle
Verbenaceae	*Phryma leptostachya L*.	American lopseed
	Verbena bracteata Lag. & Rodr.	bigbract verbena
	Verbena hastata L.	swamp verbena
	Verbena stricta Vent.	hoary verbena
Violaceae	*Viola L.*	violet
	Viola adunca Sm.	hookedspur violet
	Viola canadensis L.	Canadian white violet
	Viola pedatifida G. Don	prairie violet
	Viola renifolia Gray	white violet
Vitaceae	*Parthenocissus quinquefolia (L.) Planch.*	Virginia creeper
	Parthenocissus vitacea (Knerr) A.S. Hitchc.	woodbine
(Various)	Cryptogams	
	Ferns spp.	
	Mosses and Lichens	