USGS-NPS Vegetation Mapping Program

Badlands National Park, South Dakota

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Bureau of Reclamation's Remote Sensing and GIS Group
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The Reclamation Remote Sensing and Geographic Information Group, organized in 1975 provides advice and assistance regarding the application of remote sensing and geographic information system (GIS) technologies to meet the spatial information needs of Bureau of Reclamation and other clients.

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Mapping the vegetation at Badlands National Park was made much easier and more thorough because of the involvement of, and guidance provided by Mr. Bruce Bessken (Chief, Resource Management) and Dr. Glenn Plumb (Wildlife Biologist). Bruce and Glenn assisted in all decision-making and review phases, contributing to scoping meetings, sampling area selection, map class selection, and review of vegetation map products. They were instrumental in securing access from the Oglala Lakota Nation, supplying boundary information and lodging for field crews, and in providing sage advice. Since the project beginning in 1997, both of these men have taken new directions, Bruce in retirement and Glenn at Yellowstone National Park, but their legacy at Badlands National Park remains, partly within this study.

Thanks for the assistance and memories Bruce and Glenn!

EXECUTIVE SUMMARY

The USGS Biological Resources Division (USGS/BRD) in cooperation with the Inventory and Monitoring Program of the National Park Service has initiated a multi-year project to classify, describe, and map vegetation for 250 national parks. As a contractor under this program, the Bureau of Reclamation's Remote Sensing and Geographic Information Group with assistance from The Nature Conservancy has classified and mapped the vegetation occurring in and around Badlands National Park (near Interior, South Dakota). Twenty-three vegetation map classes and ten Anderson Level II land-use classes were used for interpretation of approximately 1.3 million acres encompassing the Park (approximately 242,755 acres) and surrounding environs. From this, approximately 0.9 million acres in and around the Park were digitally transferred into a Geographic Information Systems database.

Vegetation map classes were determined through extensive field reconnaissance, data collection, and analysis in accordance with the National Vegetation Classification System. The vegetation map was created from photographic 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 1995, black-and-white USGS digital orthophoto quarter-quads 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 at 80.6% (78.2% Kappa Index).

Final map products comply with national map accuracy standards, are described in this report, and occur on the accompanying compact disk. They include the following:

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

Badlands National Park and 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. As part of the National Biological Information Infrastructure (NBII), 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 250 National Park units across the United States.

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 successful have led to various work contracts with other government agencies and private organizations. Among those contracted was the United States Bureau of Reclamation's (BOR) Remote Sensing and Geographic Information Group (RSGIG) based at the Denver Federal Center, Colorado. The tasks for the RSGIG were to classify and describe the vegetation and create a digital, spatial database representative of the vegetation and land use occurring at Badlands National Park (BADL), South Dakota during 1997. The primary subcontractor for review of vegetation classification and characterization was The Nature Conservancy (TNC) (Midwest Resource Offices - Minneapolis, MN).

The specific objectives of this study include:

- Collection and analysis of vegetation data.
- Creation of vegetation and mapping classifications based on the National Vegetation Classification System (NVCS).
- Development of a spatial database for the vegetation of BADL using remote sensing and Geographic Information System (GIS) techniques.
- Production of digital and hard copy vegetation maps, assessed to be at least 80% accurate.

Vegetation mapping for BADL 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, Wind Cave National Park, Mount 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.

PROJECT AREA

Badlands was first authorized by Congress on March 4, 1929 and set aside as a national monument in 1939. The management area at this time consisted only of the current North Unit (111,000 acres). Badlands National Monument doubled in size with the addition of the South Unit (133,300 acres) from the Lakota Tribe's Pine Ridge Reservation and subsequent boundary changes in 1936, 1952, and 1968. Wilderness designation was assigned to the Sage Creek area in 1976 and Badlands National Park was designated on November 10, 1978. BADL is best known for its extensive geologic processes/exposures, significant fossil resources, scenic vistas, and its mixed grass prairie ecosystem supporting abundant wildlife.

BADL personnel presently manage 242,756 surface acres in the North and South Units. The South Unit consists of an area contiguous to the North Unit known as the Stronghold Unit and the separate Palmer Creek Unit (Mills 1998) (Figure 1). Both units contain predominantly badlands erosion features and mixed-grass prairie interspersed with swales, draws, and drainages containing trees and shrubs (Figure 2).

Location and Regional Setting

BADL is situated on the Northern Great Plains Region of South Dakota, about 8 miles south of Wall, SD (DeLorme 1997). The Park lies in Pennington, Jackson, and Shannon Counties and is roughly bounded by the towns of Wall, Scenic, Interior, Cactus Flats, Red Shirt, Rockyford, and Kyle. South Dakota Highways 240, 44, and 37, and Bureau of Indian Affairs (BIA) Highways 2 and 27 are the Park's major roads. Secondary roads within BADL include NPS Sage Creek and Sheep Mountain Table Roads and U.S. Forest Service (USFS) roads through the Conata Basin and Quinn Table areas. Tertiary roads include a variety of trails or 2-tracks on Pine Ridge Reservation and USFS lands accessible only by high-clearance vehicles (used primarily for access to public grazing lands).

BADL maintains nature and hiking trails into the North Unit. The three self-guided nature trails are the Fossil Exhibit (0.25 miles), Door (0.75 miles), and Cliff Shelf (0.3 miles) trails. Hiking trails include Sage Creek (6 miles) The Notch (0.5 miles), Saddle Pass (0.5 miles), Medicine Root (3 miles) Window, (0.25 miles) and Castle (6 miles) trails.

Climate

Badlands National Park lies within the northern Great Plains. This region normally records warm summers and relatively cold winters. A semi-arid, continental climate that includes short, hot, and dry summers, long, cold, and dry winters, and precipitation events occurring mostly in late spring and early summer, typify the area. Average temperatures recorded for Wasta, SD (west of the Park) range from 24^{o} F in the winter to 72^{o} F in the summer (the average daily maximum temperature is 87^{o}F) (USDA-SCS 1996). Temperatures in the spring and fall seasons can vary dramatically and change abruptly within short time periods. The Park usually experiences at least 130 frost-free days a year (USDA-SCS 1987).

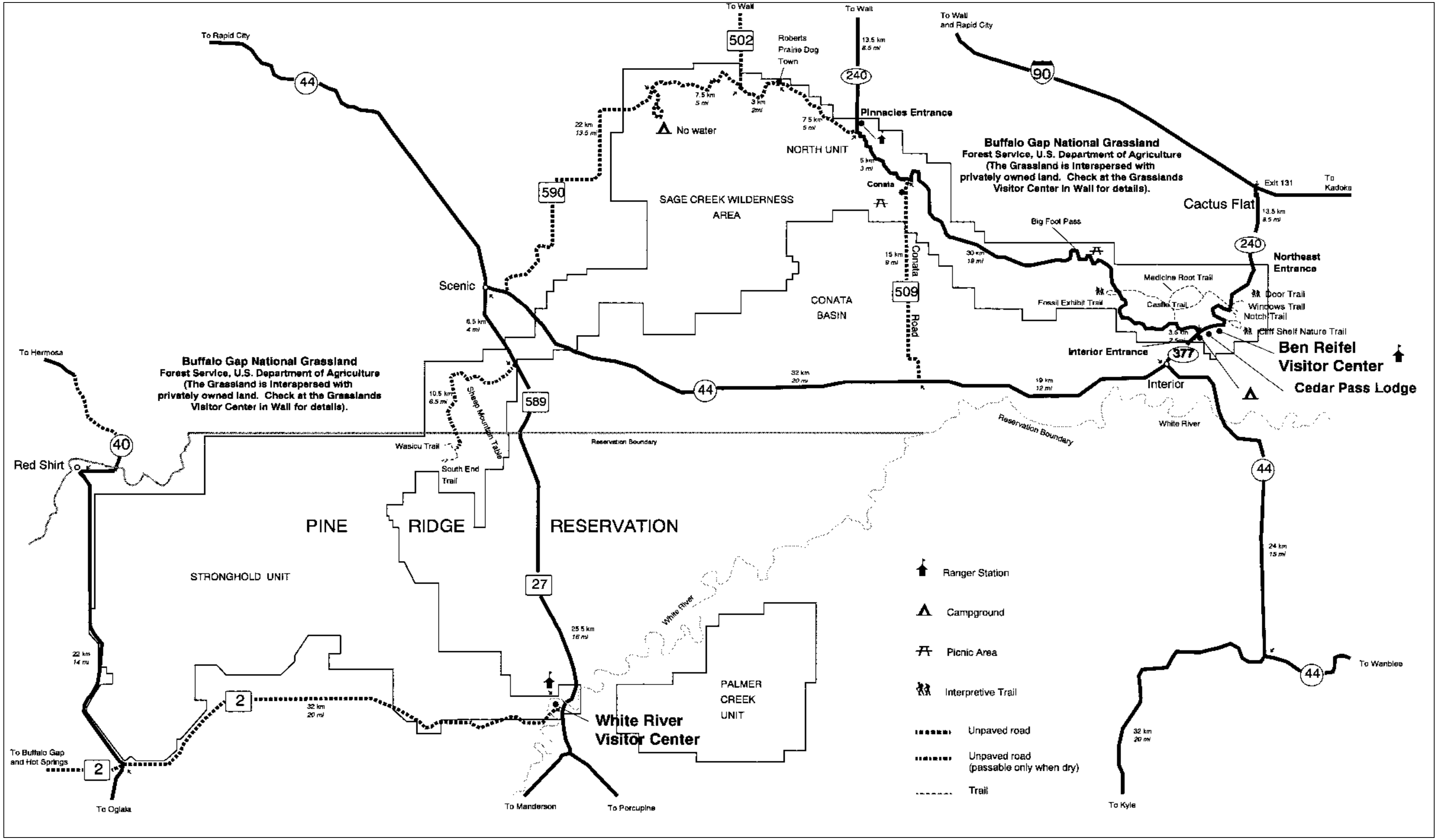


Figure 1. Map of Badlands National Park showing unit boundaries, infrastructure, and facilities (map courtesy of Badlands NP).

photo by D. Cogan

Figure 2. The landscape of Badlands National Park showing pronounced erosion features and mixed-grass prairie.

Precipitation for this region is usually heaviest in late spring and early summer, with a total annual amount of 15.53 inches (USDA-SCS 1996). Local observations by BADL personnel report the last nine years as wetter than normal (Bessken 1999), although average monthly precipitation data for Interior and Wasta, SD show only minor increases (Appendices 1 and 2). However, the weather can be quite active and violent. For example, during the summer of 1997 a large hailstorm flattened the grasslands and stripped leaves from trees and shrubs within the Roberts Prairie Dog Town vicinity. (Note: this area was revisited the following year to insure accurate identification and mapping.)

Geology and Topography

Geologically, the area of Badlands National Park is known as "The Big Badlands" (Gries 1996) or the "White River Badlands" (O'Harra 1920, revised 1976). They have also been referred to as "Mako Sica" (bad land) by the Lakota Tribe and "Mauvaises Terres a Traverser" (bad lands to cross) by French explorers. Badland development can be attributed to the following main factors: 1) a climate with low rainfall that is more or less concentrated into heavy showers, 2) scarcity of deep-rooted vegetation, and 3) slightly consolidated mudstones, siltstones, and sandstones lying at a considerable height above the main drainage channels (the occasional hard layers or beds that may be present being thin and in horizontal position) (O'Harra 1920, revised 1976).

Bedrock within the Park and surrounding area consists principally of Cretaceous Pierre Formation clayey shale; Oligocene White River Group (Brule Formation siltstone and Chadron Formation clayey mudstone and shale); and Oligocene Sharps Formation (Gries 1996, USDA-SCS 1987, O'Harra 1920, revised 1976). The Pierre shale produces dark gumbo clay upon weathering, which is most easily observed west of Scenic, SD and along the Cheyenne River drainage (Gries 1996). The Chadron Formation weathers to low hummocks, locally called "haystacks", and consisting mainly of greenish-gray bentonite clay. The Brule Formation weathers to white, gray, pink, and lavender clays and silty clays; it is capped by bright, white Rocky Ford volcanic ash (Gries 1996). In some places the Chadron and Brule Formations contain veins of dark gray chalcedony (a translucent variety of quartz), which break into shards and covers many acres of underlying soil.

Exposed Chadron and Brule Formation landforms are abundant throughout the Park and veins of chalcedony are most observable in the vicinity of Sheep Mountain Table continuing southward to Cedar Table. Approximately 46% of BADL consists of steeply inclined, narrow gorges, knife-edged ridges, flat-topped buttes, peaks, out-wash fans, and their associated drainages all eroded from the Chadron and Brule Formations (Butler and Batt 1995). Locally the northernmost Brule Formation rock outcrops (capped by Rocky Ford volcanic ash) are known as the "Wall"; named for its nearly vertical cliff of exposed siltstone (a geographical barrier for early travelers moving northward).

A variety of fossils are found within the geologic formations, the oldest being molluscs and other shells of the Cretaceous inland sea that deposited the Pierre shale. Oligocene fossils associated with the Chadron Formation include algae, snails, and clams in limestone lenses and turtles, crocodiles, and many mammals (including titanotheres, oreodons, early horses, rhinoceros, felines, and canines, among others) more generally distributed throughout the formation (Gries 1996 and O'Harra 1920, revised 1976). Oligocene Brule Formation fossils include the richest group of mammals exposed/unearthed in the world, perhaps 150 different genera (Gries 1996 and O'Harra 1920, revised 1976). These range in size from mouse-like rodents to species of rhinoceros and include early relatives of horses, camels, pigs, deer, antelope, beaver, felines, canines, and small rodents.

Badlands topography is a mixture of relatively flat plains, moderately wide flood plains associated with the White and Cheyenne rivers, hills of eolian sands, and highly dissected erosion features. BADL lies in the Pierre Hills and Tertiary Table Lands divisions of the Great Plains (South Dakota Geological Survey n.d. in USDA-SCS 1996). Elevation ranges from below 2,300-ft., where the White River exits the study area to more than 3,100-ft. near "The Pinnacles" at the northern boundary of the North Unit and Red Shirt Table on the western edge of the South Unit. The highest points in the study area occur just west of Stronghold Table and on Sheep Mountain Table both at nearly 3,300-ft. elevation.

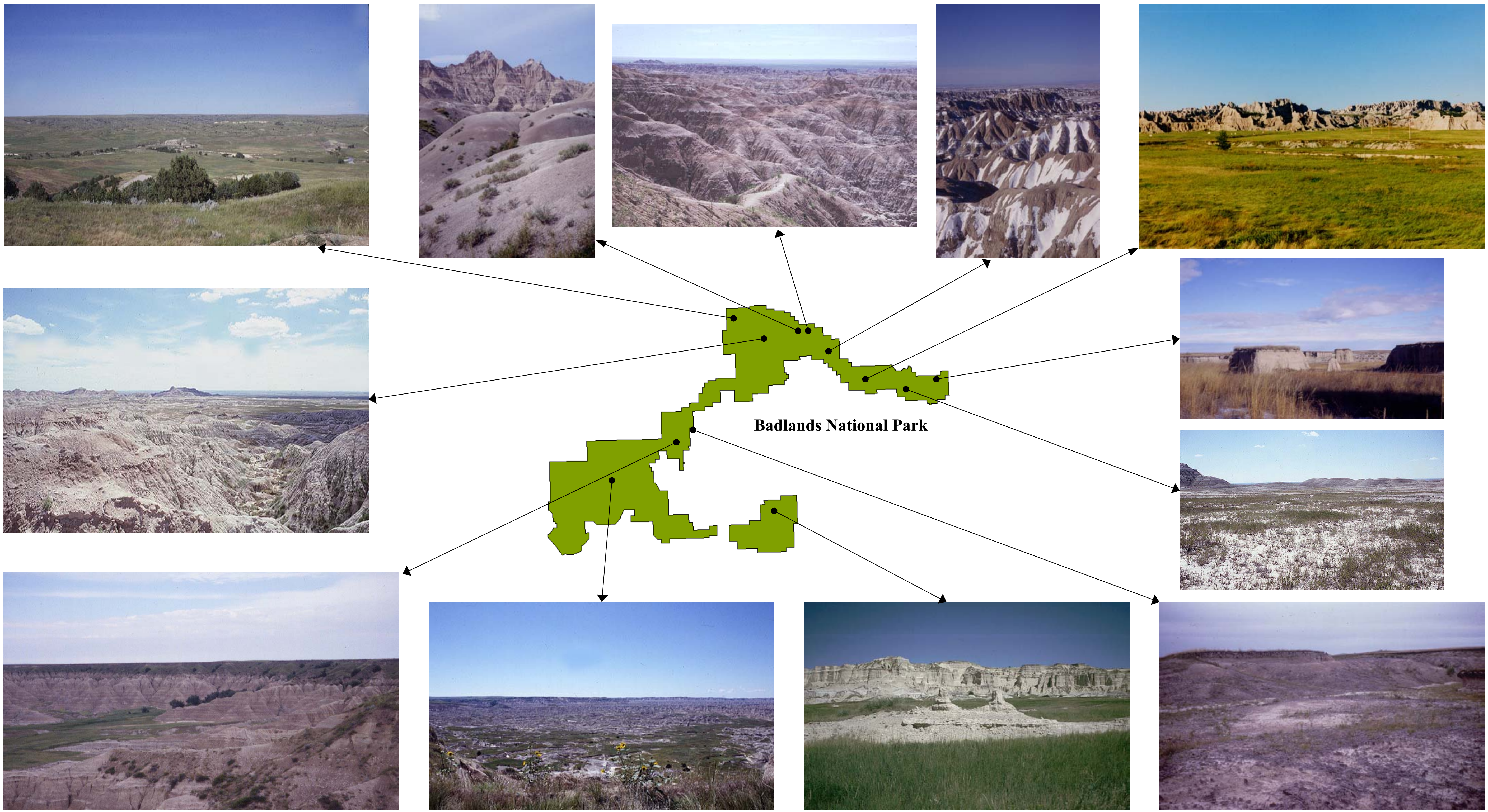


Figure 3. Geologic formations found throughout Badlands National Park. Clockwise from top left corner: hills along Sage Creek derived from Pierre shale; haystack mounds of the Chadron formation (foreground) and cliffs and ridges of the Brule formation (background); cliffs and ridges of the Brule formation; cliffs and slopes of the Brule formation; badlands "wall" (Brule formation) near Interior, SD; small buttes and tables; alkali flats and clay outwash fans; chalcedony beds; cliffs and ridges of the Brule formation; badlands overview with intermingled grasslands; Brule formation capped with eolian sands; rugged Brule formation containing Rocky Ford volcanic ash.

The White and Cheyenne Rivers, flowing generally northeast and east border BADL. Important tributary creeks of these rivers typically trend southeast and northwest. These include Sage, Crooked, Whitewater, Buffalo, Cain, Clifford, Wind, Medicine Root, Palmer, Porcupine, Wounded Knee, Big Hollow, Spring, Cottonwood, Fog, Sand, Battle, and Cedar Creeks, sections of which flow all or most of the year. There are many smaller drainages that are typically dry, flowing only during or immediately following precipitation events. Active springs are occasional and found at scattered locations. Many small ponds and reservoirs are present, in addition to wetland depressions and channels. Water sources have been developed to support bison herds in the North Unit and cattle grazing in the South Unit by using dugouts, check dams, larger earth fill dams, pumped ground water, and natural surface water supplies, as appropriate. Many wildlife species are attracted to the open water and wetlands including a variety of waterfowl and shorebirds.

Soils

Most soil associations occurring at BADL formed from eroded bedrock deposited as old alluvial deposits on high terraces; recent alluvial deposits on flood plains, swales, and in upland depressions; and from sand and loess on uplands. Soils relate to specific geologic landforms, topographic relief, climate, and the corresponding natural vegetation (Ensz 1990). Soils on and adjacent to badland exposures and in drainage channels are rapidly deposited, and support a sparse plant community. Conversely, deeper soils mantling the buttes, hills, and alluvial valleys support relatively dense and diverse plant communities, typically grasslands. In many instances plant associations are further affected by wildlife or grazing livestock use. A common example is the intense grazing in prairie dog colonies, often resulting in different plant associations than otherwise would be present.

Regional soils represent four orders, Entisols, Aridisols, Mollisols, and Vertisols (Batt 1991). Vertisols are upland clays with very high shrink/swell potential characterized by deep, wide cracks formed at the soil surface. Mollisols are prairie soils found on grassy bluffs that are characterized by melanization, a darkening of the soil due to addition of organic matter. Aridisols are soils of arid uplands, typically dry for more than 50% of the year. Entisols are newly formed upland soils developed from steep slope erosion, alluvial floodplain deposition, and eolian deposition.

One way to assess regional soil patterns is to consider Range Site Classifications provided by the U. S. Department of Agriculture in their countywide soil surveys. A range site is a distinctive kind of habitat, or group of soils, that is capable of supporting similar kinds, proportions, and amounts of native vegetation. Factored into these are soil properties important to the distribution of plant associations including moisture supply, nutrient availability, salt content, soil reaction, and seasonal high water levels (USDA-SCS 1996). Table 1 contains range site names and descriptions, the major soil associations present, and the typical NVCS plant alliance or complex observed growing there. Some plant associations can be found on any soil if other parameters occur (such as sufficient hydrology to support wetlands). Each soil association consists of a variety of major and minor soil units that are sometimes combined to form soil complexes.

Table 1. Range sites, soil associations, and related NVCS vegetation types occurring in the Badlands National Park Vegetation Mapping area. (Note: plant alliances are described in Appendix 12 and Badlands Sparse Vegetation Complex is described in Table 3.)

Range Site: Definition	Soil Association	Typical Vegetation Type
Badland: unvegetated erosion features.	(No soils present)	Badlands Sparse Vegetation Complex
Overflow: sandy to clayey alluvial soils on bottomlands.	Alluvial Land, Bankard, Goshen, Haverson	Western wheatgrass Alliance
Badland Overflow: silty to clayey alluvial soils on badland drainages.	Interior	Badlands Sparse Vegetation Complex and Western wheatgrass Alliance
Subirrigated Range Site: deep, nearly level soils of basins and valleys among or adjacent to sandhills.	Fluvaquents	Western wheatgrass Alliance
Clayey: moderately deep to deep, level to sloping soils.	Buffington, Cactusflat, Clayey Land, Denby, Kyle, Larvie, Metre, Norrest, Ottumwa, Pierre, Promise, Razor	Western wheatgrass Alliance
Clayey Overflow: deep, level soils of floodplains	Hilmoe, Wendte	Western wheatgrass Alliance
Claypan: slight rises between shallow depressions.	Absted, Beckton, Mosher, Wortman	Blue grama Alliance Western wheatgrass Alliance
Closed Depression: claypans on uplands.	Hoven, Kolls	Western wheatgrass Alliance
Dense Clay: thin crust over strongly alkaline subsoil.	Swanboy, Whitewater	Western wheatgrass Alliance
Loamy Overflow: deep, level soils of floodplains	Colombo, Glenburg, Haverson, Lohmiller	Western wheatgrass Alliance
Loamy Terrace: deep, level soils of floodplain terraces	Bridgeport, Colombo, Craft, Haverson, Lohmiller, Owanka	Western wheatgrass Alliance

Table 1. (continued)

Range Site: Definition	**Soil Association**	**Typical Plant Association**
Saline Lowland: Narrow areas along upland drains and flats in stream valleys.	Egas, Hisle, Minatare, Swanboy	Western wheatgrass Alliance
Sands and Choppy Sands: deep, loose undulating, rolling, or hilly soils.	Bankard, Valent, Valentine	Blue grama Alliance Sand sagebrush Alliance
Sandy: deep, level to undulating sands.	Anselmo, Dunday, Jayem, Manter, Tuthill, Whitelake, Wortman	Blue grama Alliance
Shallow: shallow soils over bedded geologic material.	Canyon, Enning, Epping, Gravelly Land, Midway, Orella, Penrose, Samsil, Shingle, Tassel, Terrace Escarpments	Little bluestem Alliance Blue grama Alliance
Shallow Clay: shallow, steep upland soil with scattered stones and/or rock outcrops	Conata, Grummit, Midway, Orella, Samsil	Little bluestem Alliance Western wheatgrass Alliance
Silty: nearly level to sloping soils, moderately deep.	Altvan, Baca, Blackpipe, Cedarpass, Cushman, Dawes, Emigrant, Haverson, Kadoka, Keith, Norka, Nunn, Oglala, Richfield, Rosebud, Savo, Satanta, Tilford, Tuthill, Ulysses	Western wheatgrass Alliance
Thin Claypan: thin surface soils over claypans.	Arvada, Hisle, Hurley, Minatare, Wanblee, Weta	Blue grama Alliance
Thin Upland: thin, alkaline soils.	Colby, Fairburn, Interior, Manvel, Minnequa, Zigweid	Blue grama Alliance Little bluestem Alliance
Very Shallow: deep, sandy and gravelly alluvium.	Nihill, Schamber	Little bluestem Alliance Blue grama Alliance

Wildlife

BADL supports numerous wildlife species including many animals native to the Northern Great Plains. Some of the larger mammals are actively managed by Park personnel to insure the overall health of the Park's vegetation resource. These include bison (*Bison bison*), pronghorn antelope (*Antilocapra americana*), mule and white-tailed deer (*Odocoileus hemionus* and *O. virginianus*), bighorn sheep (*Ovis canadensis*), and black-tailed prairie dog (*Cynomys ludovicianus*) (Figure 4). Two major wildlife programs underway include reintroduction of the federally endangered black-footed ferret (*Mustela nigripes*) to black-tailed prairie dog colonies within the Park and research on bighorn sheep, specifically their reproduction, distribution, and ecology. Bighorn sheep (Rocky Mountain subspecies) were introduced to the Monument in 1964 to replace the now extinct subspecies Audubon bighorn (*O. canadensis auduboni*) (Butler and Batt 1995). It was thought that this would also serve as a supply herd for transplants to other areas within the state of South Dakota.

photos by D. Cogan

Figure 4. Bison, black-tailed prairie dog, and bighorn sheep in Badlands National Park.

Domesticated cattle and sheep do not currently graze within the Park's North Unit, although adjacent grasslands under private ownership or managed by USFS are annually grazed. Livestock grazed the Badlands North Unit up to 1963 when the Monument was fenced to exclude cattle (Butler and Batt 1995). Following fencing, bison were reintroduced into the western half of the North Unit and are currently being managed for a minimum population of 500 animals. Cattle regularly graze the South Unit, but stocking rates are unknown.

Livestock grazing does have an influence on the distribution of some plant species and plant associations. For example, yellow sweetclover (*Melilotus officianalis*) occurs in greater abundance on ungrazed lands of the North Unit versus similar grazed lands in the South Unit and in the surrounding environs (Figure 5). Conversely, Blue grama - Buffalo grass (*Bouteloua gracilis - Buchloe dactyloides*) Xeric Soil grasslands tend to be absent within the lightly grazed (only by bison and other wildlife species) or ungrazed lands of the North Unit. Soil types should also be taken into consideration when determining grazing effects on distribution of plant associations. This is illustrated by the higher incidence of sandy and sandy-loam soils supporting Blue grama - Buffalo grass Xeric Soil grasslands in the South Unit compared to the clay, clay-loam and silty soils supporting Western Wheatgrass Alliance grasslands in the North Unit. Another interesting grazing influence is the large number of prairie dog colonies present within and adjacent to the Park and the plant associations that are maintained or result from prairie dog grazing and burrow construction. This is described in more detail under the vegetation section and under the project results.

photos by J. Von Loh

Figure 5. Biennial yellow sweetclover in Badlands National Park demonstrating the effects of 1) livestock grazing (grazed right of the fence) and 2) coverage within the North Unit of the Park. Photos were taken in 1998, a "sweetclover year".

Vegetation

BADL vegetation can be divided into two major types; sparse vegetation of highly eroded soils and mixed grass prairie. Badlands formations comprise over 46% of the Park, just slightly larger than the area covered by prairie grasslands (42%). Sparse vegetation associated with badlands ridges, slopes, haystack mounds, and drainages is comprised of a mixture of low-growing shrubs, forbs, and grasses. Grasslands are distributed across areas of deeper soils, including plains, valleys, buttes, and sand hills and ridges. They also occupy thin soils on gravelly hill slopes that rapidly release moisture to the plants (Figure 6).

Shrub communities tend to be confined to drainages with meandering rivers or streams, sandy ridges, sand hill complexes, gravelly or rocky draws, and moist swale habitats. Woodlands occur in the river floodplains, in draws and deep swales, hillside slumps, and along ridgelines (Figure 6). A particular habitat for both shrubs and trees is at the edge of sand hill complexes where water seeps from the hills at their interface with underlying, relatively impermeable, clay soils.

Other widely distributed vegetation types at BADL and its surrounding area include emergent wetlands and prairie dog towns (Figure 6). Wetlands occupy depressions, meandering drainages, seeps, springs, and old oxbows throughout the project area. In many cases, stock ponds developed to support livestock grazing also support wetland vegetation in the shallower water stored behind dams and in the zone of seepage below the dam structure. Prairie dog towns are distributed on appropriate soils, comprising 2% of BADL.

Many non-native or exotic plant species have been introduced to BADL mostly prior to its designation as a park. Historic agricultural fields are still dominated by species such as crested wheatgrass (*Agropyron cristatum*) and Kentucky bluegrass (*Poa pratensis*). Disturbed roadsides typically support smooth brome (*Bromus inermis*) and alfalfa (*Medicago sativa*). Yellow sweetclover, a biennial species from Eurasia, prefers relatively moist conditions and has successfully invaded the entire North Unit (Figure 5). However, it does appear to be suppressed in the South Unit by livestock grazing and drier soils (sand and sandy loam).

photos by D. Cogan & J. Von Loh

Figure 6. Characteristic vegetation at Badlands National Park including from upper left corner: mixed grass prairie, sparse vegetation, shrub and tree communities in mesic swale, shrubs on sand hill, floodplain shrubs and trees, and wetland depression with large expanse of prairie dog town in background.

MATERIALS AND METHODS

The organization of this project followed protocols and procedures set forth by the USGS/BRD (Appendix 3) as described in Field Methods for Vegetation Mapping, Standardized National Vegetation Classification System (TNC 1994), and Accuracy Assessment Procedures (TNC 1994). Basic steps to fulfill protocols include:

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

BADL vegetation mapping incorporated the combined expertise and oversight of several organizations. 1) Oversight and programmatic considerations were managed by the Center for Biological Informatics (CBI) of the USGS/BRD; 2) The National Park Service and BADL personnel provided additional guidance on specific Park needs; 3) Fieldwork, data reduction, plant association descriptions, and technical mapping portions were contracted to the Bureau of Reclamation's RSGIG; 4) The Nature Conservancy was sub-contracted to review local plant association descriptions, provide corresponding global descriptions, and review the plant association key and accuracy assessment results; and 5) Management and collection of accuracy assessment data was contracted to Dr. Jack Butler, Central Missouri State University, with logistical assistance provided by RSGIG staff. Specific technical responsibilities and deliverables for the project include the following:

BOR RSGIG Responsibilities and Deliverables:

- Acquire aerial photography under contract to Horizons, Incorporated (Rapid City, SD);
- Conduct a gradsect meeting to determine intensive vegetation sampling locations;
- Design a sampling strategy;
- Collect observation point data to refine the preliminary vegetation classification and familiarize investigators with community characteristics and their range of variation;
- Collect relevϑ plot data to determine plant associations and vegetative variability within BADL by selecting and sampling representative stands for all communities;
- Conduct a meeting to evaluate "park special" mapping concerns, particularly prairie dog colony edge location and distribution;
- Prepare final classification, community descriptions, and key to plant communities;
- Conduct a meeting to determine vegetation and land-use map classes;
- Interpret aerial photographs for map classes;
- Transfer interpreted information to a digital spatial database and produce hard copy (paper) vegetation maps;

- Conduct field verification trip to assess visual accuracy of draft vegetation maps;
- Field test final classification, descriptions, and key during accuracy assessment;
- Collect accuracy assessment points (contracted to Dr. Jack Butler);
- Create digital vegetation coverages including relevant attribute information;
- Produce Arc/Info export file of gradsect locations, 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;
- Review and comment on relevant vegetation data, participate in meetings, and review draft report;
- Prepare global plant association descriptions.

Scoping Meeting:

A scoping meeting was held at the BADL Library with all interested parties during March 1997. The purpose of this meeting was to determine the project mapping extent, aerial photography acquisition, digital orthophoto availability, and discuss logistics. A project boundary covering 44, 7.5-minute USGS topographic quadrangles (Appendix 4) or approximately 1,314,450 acres was determined (Figure 7)*. 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 BADL.

** Budgetary constraints required that the 1.3+ million acre project area be reduced to approximately 920,000 acres, based on a meeting between RSGIG, NPS, and USGS/BRD in June, 1999 and further discussion with BADL staff (Story 1999). Figure 7. shows the originally proposed project boundary and the current mapping area. It should be noted that RSGIG completed aerial photo-interpretation of the 1.3+ million acre area prior to this decision and that the decision affects only digital transfer of interpreted information.*

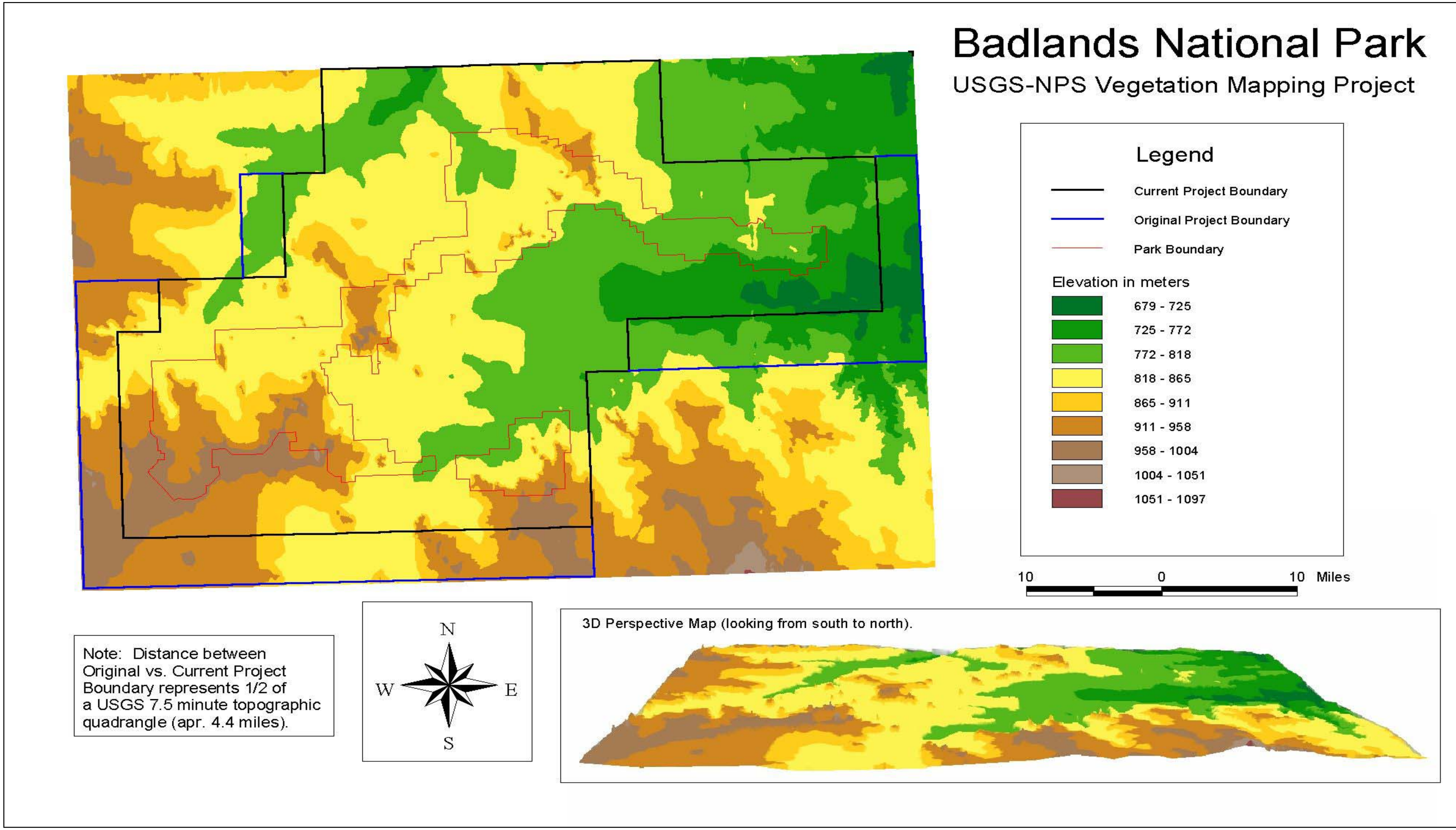


Figure 7. Elevation maps of Badlands National Park showing the Park boundary and both project boundaries

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 BADL provided digital and hard copy background material for boundaries, geology, soils, and prairie dog town locations. The Bureau of Indian Affairs (BIA) and Lakota Tribe provided transportation and prairie dog colony maps for the southern portion of the project area along with letters of permission to access tribal lands for data collection. The U.S. Forest Service (Buffalo Gap National Grassland, Wall District Office) supplied field maps and vegetation information. Soil surveys were obtained from the Natural Resources Conservation Service (NRCS) (formally Soil Conservation Service) for Shannon, Jackson, and Pennington Counties. The NRCS also provided information for Conservation Reserve Program registered lands (mapped as "Seeded Mixed Grass Prairies"). Topographic maps, 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. USGS digital orthophoto quarter-quads (DOQQ's) based on 1995 black-and-white photography, were obtained and used as base maps.

A preliminary list of community types thought to have a high likelihood of being in the mapping area was prepared by TNC and 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 BADL and Northern Great Plains vegetation, and by contacting knowledgeable experts. Final revisions were made during a map classification meeting where results of field studies were also presented for consideration.

3. Aerial Photography Acquisition

Horizons, Incorporated of Rapid City, South Dakota acquired the aerial photography for BADL. Forty-seven flight lines were used to cover the entire project area (Figure 8). Flight lines were flown and photographs taken on June 16, 18, and 26, 1997. A total of 2,461 color-infrared (CIR) photographs were taken at 1:12,000 (1"=1,000') scale and printed as 9"x9" contact glass positives. Overlap between photos is approximately 50-60% and sidelap between flight lines is approximately 20-30%. Additional aerial photography information is presented in Appendix 5.

4. Environmental Gradient Transect (Gradsect) Design

The BADL study area was deemed sufficiently large to allow 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).

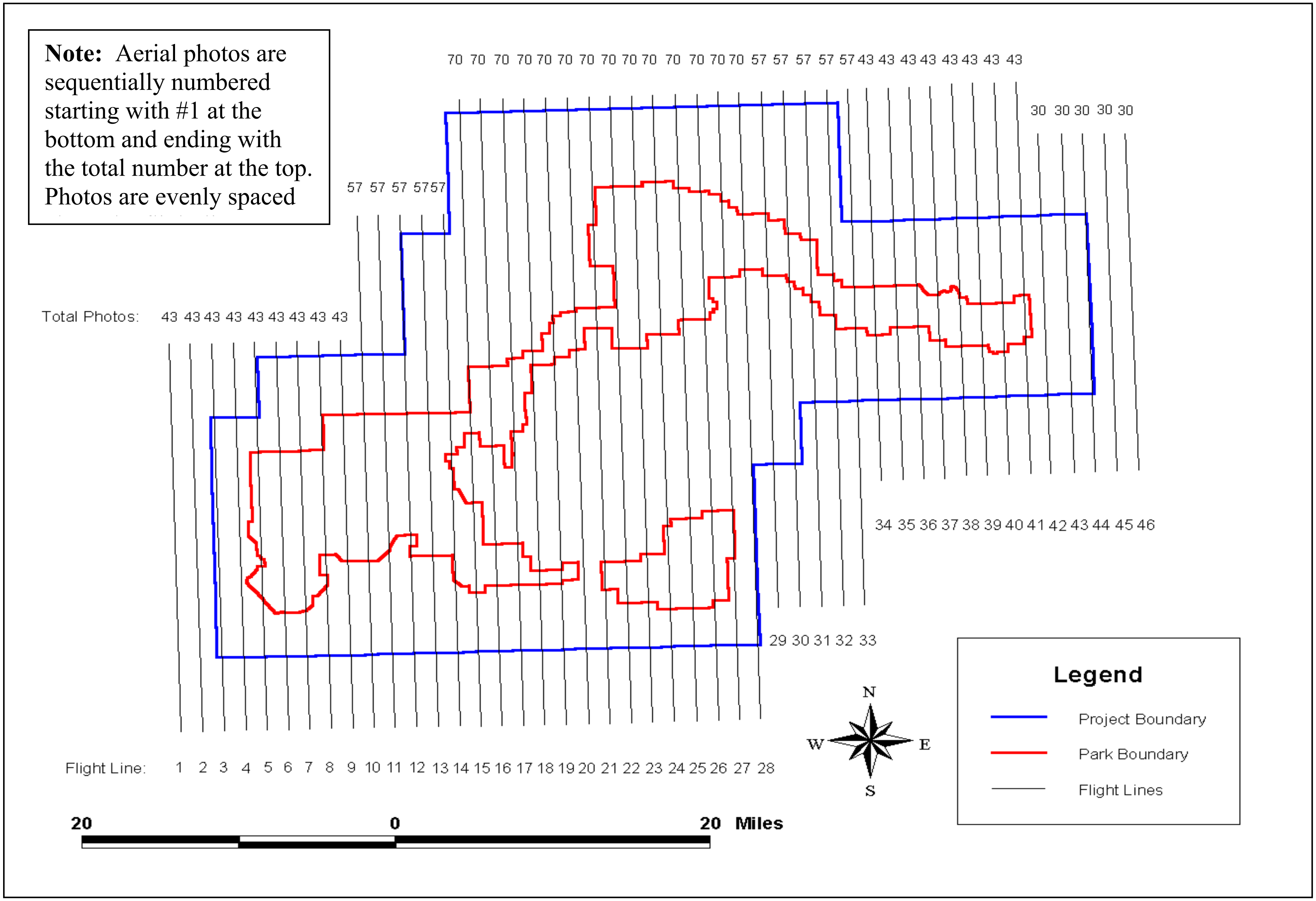


Figure 8. Flight line map for the Badlands National Park vegetation mapping program (photos flown in June 1997).

Gradsects for BADL were designed at a meeting of Park, BOR/RSGIG, and TNC staff held in the BADL Library prior to the 1997 field season. Aerial photography was reviewed and compared with soils, geologic, topographic, slope and aspect, and transportation/access 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 major drainages within the study area. Accessibility and land ownership influenced placement of the gradsects, Park personnel from Pine Ridge Reservation provided input on access to the less-visited southern lands. Locations and design were also slightly modified based on prior knowledge of the BADL vegetation. The resulting gradsects included roughly 5-10% of the overall study area, and were considered highly likely to include the full range of plant communities found in the area (Figure 9).

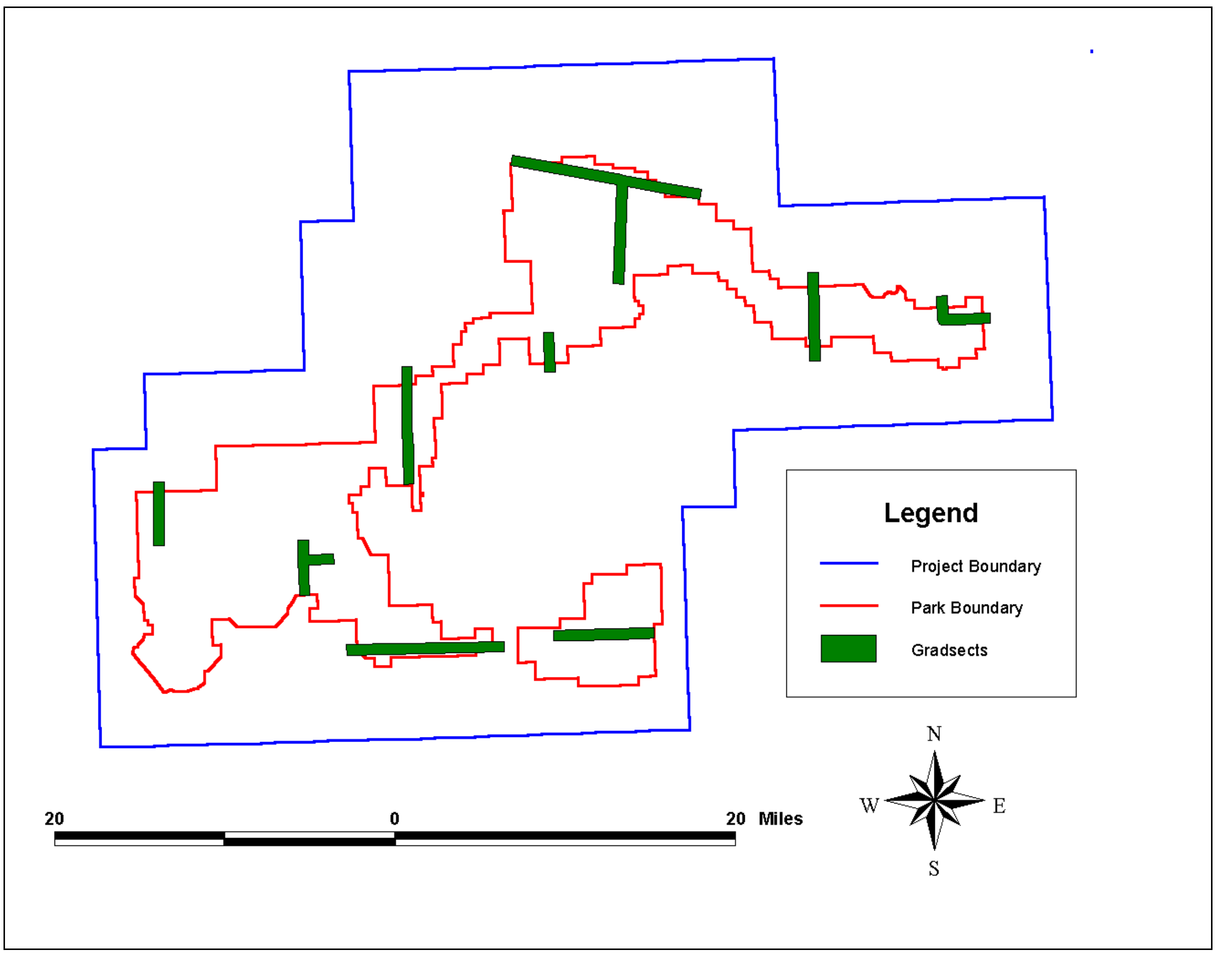


Figure 9. Map of the gradsect locations for Badlands National Park.

5. Field Survey

Field surveys began in the second week of August 1997 after aerial photography was acquired. Data collection included both plot and observation points, which allowed investigators to record typical vegetation types and also to record variation within plant communities across larger areas. Observation points were used to become quickly familiar with community characteristics, 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 6). 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 137 observation points were collected during the field survey. 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 10).

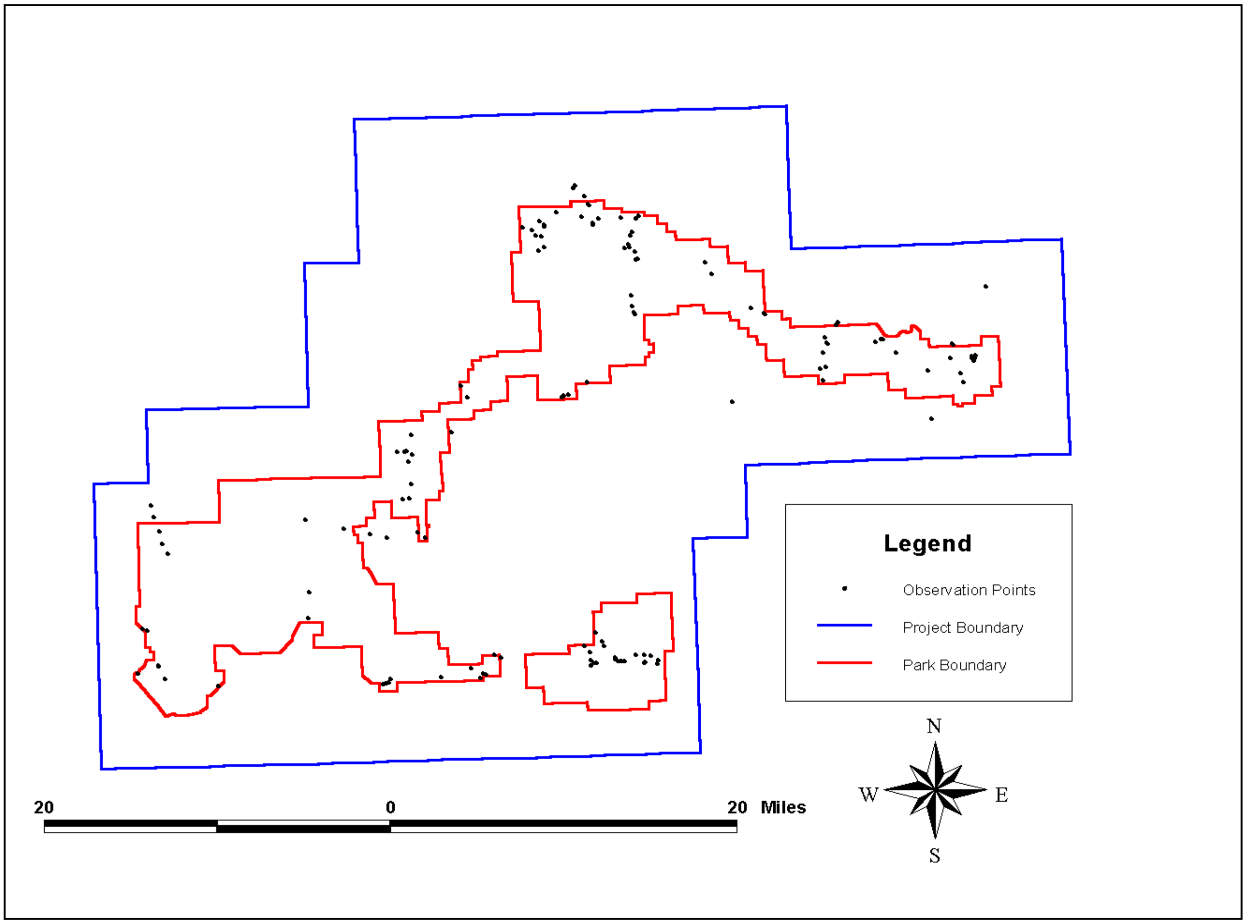


Figure 10. Map of observation point locations sampled during summer of 1997.

Investigators chose representative stands of plant communities to collect 130 data plots for BADL (Figure 11). Plot sample sites were identified in the field within gradsects using standard relevè methodology (Mueller-Dombois 1974). Plots were subjectively placed in vegetation that was representative of an area, relatively homogeneous, and covered more than 1/2 hectare (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 7). At least three plots were sampled for each plant community found in the study area, as long as three stands were available. For a few uncommon plant communities, only one or two plots were sampled. In order to collect large river riparian data, investigators selected a few sample sites outside, but near Park boundaries. All sampled data were entered into TNC=s APLOTS@ database program.

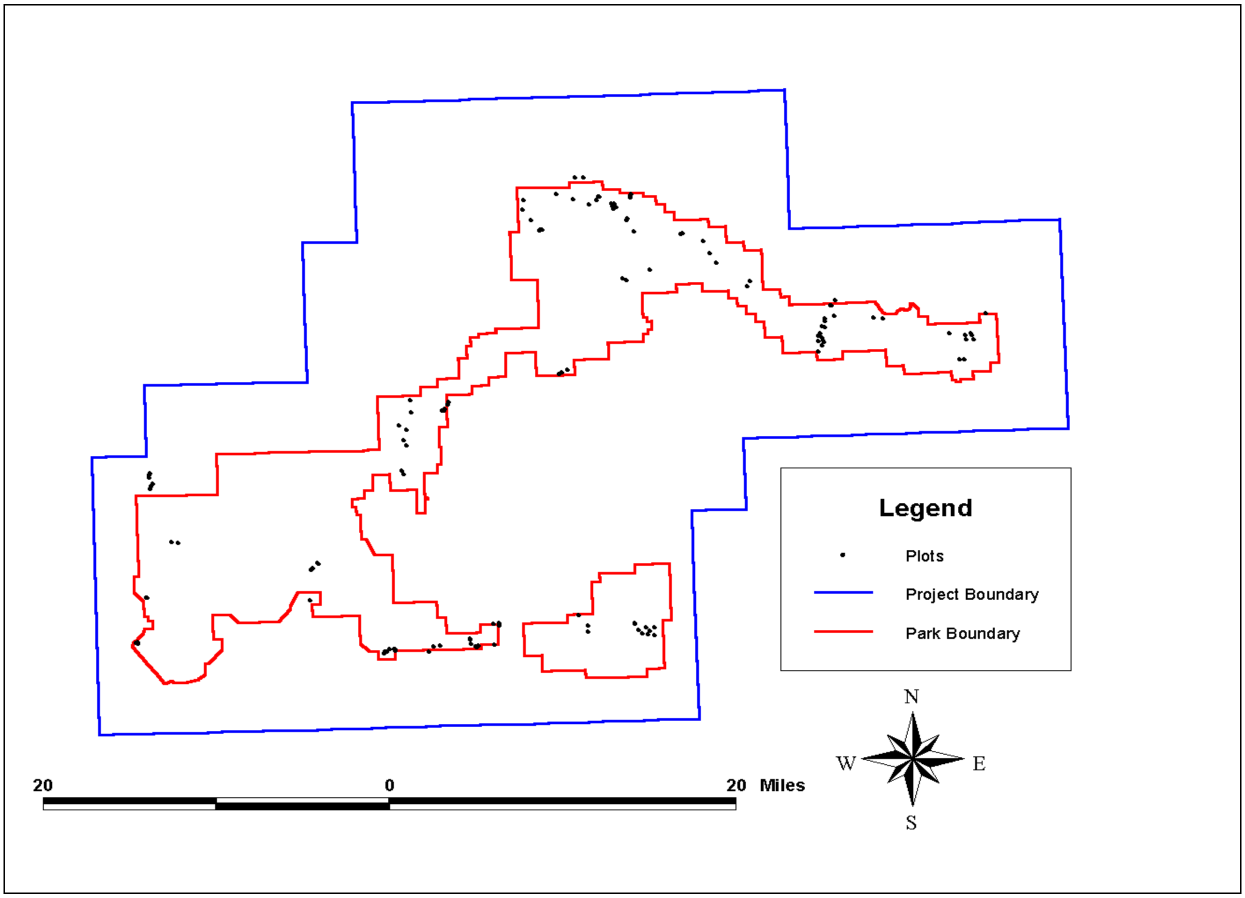


Figure 11. Map of plot locations sampled during summer of 1997.

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 Lightweight Global Positioning System (GPS) Receiver (PLGR) unit. 35mm slides were taken for each plot and scanned representatives are included in this report (Appendix 8).

6. Vegetation Classification and Characterization

The procedure for classifying vegetation followed guidelines set forth in the Vegetation Classification Standard (FGDC 1996) 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 BADL 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 data to provide a better regional perspective on vegetation types. TNC quantitatively analyzed the plot data using ordination techniques (Detrended Correspondence Analysis ADCA@and Non-Metric Multidimensional Scales ANMS@), 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 dichotomous vegetation key for BADL was prepared following the 1997 field season (Appendix 8). The key was tested during the Accuracy Assessment process and reviewed by TNC, resulting in some modifications. This dichotomous key leading to association descriptions provided guidance to researchers in the field during the accuracy assessment.

7. Vegetation Map Preparation

Map Units

Final BADL map units used for photo-interpretation were based on a combination of 1) NVCS, 2) Anderson (1976) Level II classification system, and 3) special requests by BADL 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 associations had to be merged into a larger map unit (*i.e.* complex). Anderson (1976) Level II classes were used to classify land-use types including semi-natural and cultural types (*i.e*. roads, facilities, and agricultural fields). Finally, prairie dog colonies, a special vegetation type/habitat recognized by the Park but not included in the NVCS at the time of preparation, was also included as a map unit. In this situation, the vegetation had an unique photo signature and could be easily interpreted from the aerial photography.

Aerial Photograph Interpretation

All aerial photographs for BADL 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, if available, to refine the preliminary delineation into the appropriate map units. Finally, in order to ensure completeness and accuracy, digital transfer specialists 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 Pennington, Shannon, and Jackson Counties, SD (USDA-SCS 1996, 1980, 1971), USGS topographic maps, and previous vegetation inventory work (Batt 1991 and Butler and Batt 1995).

Map Validation

Before the accuracy assessment, verification or map validation trips were taken in June and August 1998 to refine and assess the initial mapping effort. These trips 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 photo-interpretation. The area heavily impacted by a 1997 hailstorm was reviewed during the June verification trip to determine the distribution of grass species such as green needlegrass (*Stipa viridula*), Kentucky bluegrass (*Poa pratensis*), smooth brome (*Bromopsis inermis*), and crested wheatgrass (*Agropyron cristatum*) within the otherwise western wheatgrass (*Pascopyrum smithii*) dominated prairie. Aerial photo signatures that were not identifiable during interpretation, such as large four-wing saltbush (*Atriplex canescens*) clumps growing on badlands complex soils (initially thought to be greasewood (*Sarcobatus vermiculatus*) shrubland) were also examined.

Digital Transfer

An ArcInfoJ (ESRI) GIS database was designed for BADL using the National Park GIS Database Design, Layout, and Procedures created by RSGIG (Appendix 9). 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 and on-screen digitizing. Both techniques required the use of 176, 1995 digital black-and-white orthophoto quarter quadrangles (DOQQ's) supplied by USGS and covering the study area.

The scanning technique used for BADL involved a multi-step process whereby mylar overlays, with 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 DOQQ's. 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 technicians. Any remaining map units that were not already scanned were quickly transferred through on-screen digitizing. This process entered interpreted line work from aerial 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 was connected to produce a digital coverage.

Adjacent transferred coverages were joined and edge-matched to create vegetation polygon coverages corresponding to each BADL DOQQ. Ancillary linear coverages (*i.e.* secondary roads and trails and linear wetland features) and attribute information including vegetation map unit, location, and aerial photo number was subsequently entered for all DOQQ's. Completed DOQQ's were also edge-matched creating a contiguous vegetation coverage and corresponding spatial database for the entire BADL project area. All spatial data for BADL and the processes used are described in the BADL Metadata (Appendix 10).

8. Accuracy Assessment

The accuracy assessment (AA) for the BADL vegetation mapping project consisted of preliminary planning and discussion, logistical planning, fieldwork, analysis of fieldwork, and computation of final results. Preliminary planning involved BOR/RSGIG and Dr. Jack Butler (a plant ecologist contracted to collect the field AA data). Following detailed discussion, a modified accuracy assessment procedure dubbed Afront-loading@ (Owens 1998) was selected using protocols outlined in the Accuracy Assessment Procedures (TNC 1994).

The following guidelines for the AA 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 plant association/map class would vary depending on abundance of the class upon the landscape.
- No maximum number of points was assigned so that the Park could be sampled as completely as possible.

Logistical planning for the AA revolved around coordination of work schedules and finding reasonable work areas within the Park. Collection of AA points was confined to within Park boundaries but not limited to the previously described gradsects. Instead, AA's were based on availability of access and to a lesser extent, time constraints. The actual assessment was begun prior to completion of preliminary vegetation maps for the Park, thus the need for the front-loading of the sample points. Selecting random AA sampling sites beforehand was deemed unnecessary due to familiarity of the principal researcher with vegetation types and distribution at BADL. The final point chosen for assessment was selected to be as representative as possible of the vegetation in the immediate area, well away from stand boundaries, and in a stand larger than the minimum mapping unit (exceptions were made for wetland and some shrub classes which rarely exceeded 0.5 hectares in size). Field ecologists were supplied with a vegetation key, to be used to determine plant associations/map classes entered on field forms (Appendix 8).

AA data, including limited habitat and vegetation data, was recorded on field forms to document the classification decision made by the investigator (Appendix 11). 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 error.

465 AA data points were collected during August 1998 (Figure 12). The weather at this time was unusually warm and vegetation readily identifiable unless heavily grazed. In the Park=s North Unit, an extremely heavy growth of yellow sweetclover was present over most grassland and shrub communities. While noted during the AA sampling, very little yellow sweetclover was present during the previous year (1997), the year of aerial photography acquisition and interpretation. AA points were collected in proportion to the size of the plant association/map class within the Park; *e.g.* more points were collected within extensive types.

Accuracy assessment of the BADL project area was conducted in September 1999. This involved entering all accuracy data points into a digital coverage and overlaying these electronically onto final vegetation maps (by DOQQ). AA identification 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 in the field) 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 methods shown in Table 2. depending on the normality and size of the data.

Overall total accuracy for BADL 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.

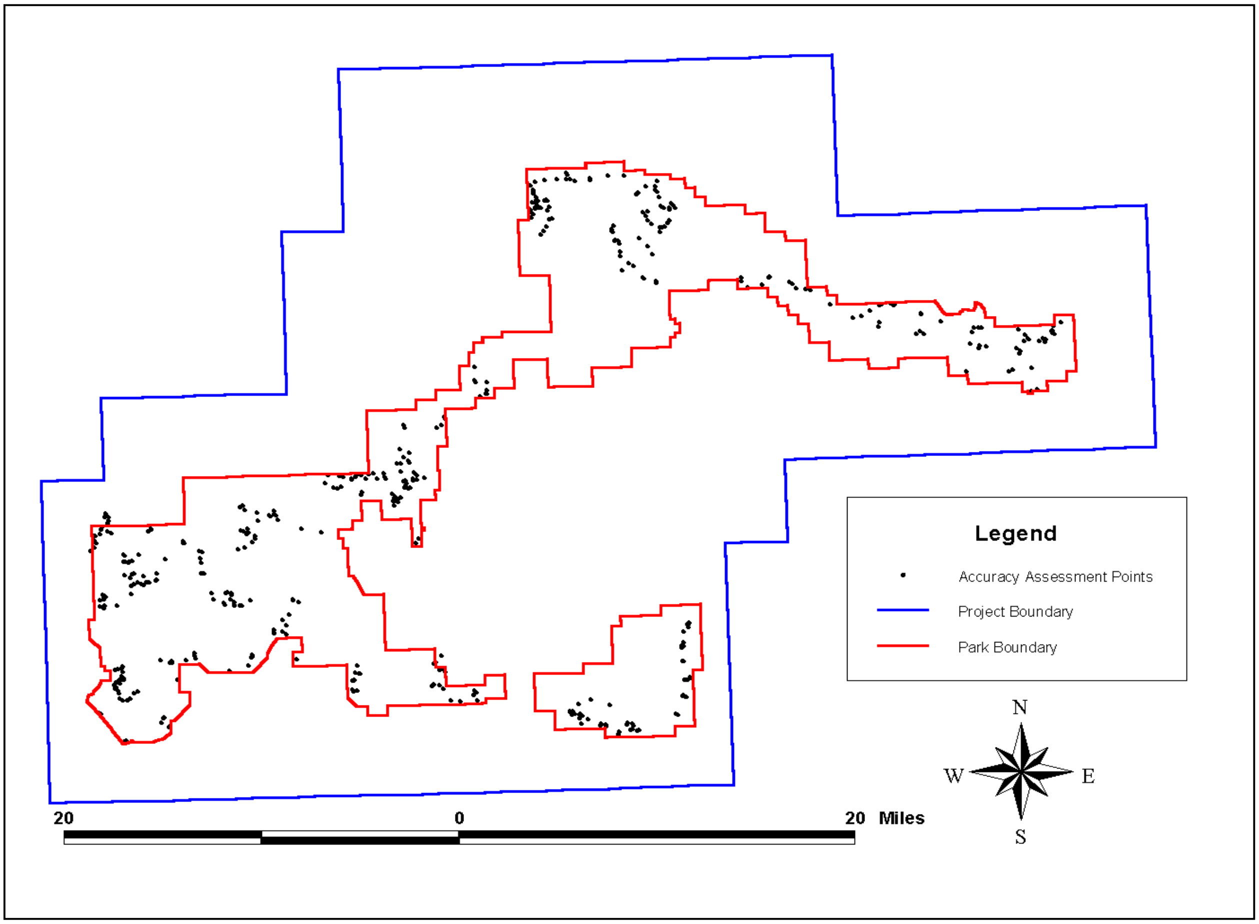


Figure 12. Map of accuracy assessment locations sampled during summer and fall of 1998.

Table 2. Summarized procedure and equations used to calculate 90% confidence intervals for the BADL Accuracy Assessment.

- For large sample sizes ($n > 30$), a normal distribution was assumed when
  1) $np \geq 5$ and $n(1-p) \geq 5$, and
  2) $0.2 < p < 0.8$
  where n = sample size and p = (number of correct samples / total number of samples) (Zar 1984, Hay 1979).

- For normally distributed map classes the confidence intervals were calculated using the equations provided by Snedecor and Cochran (1976) 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 ($n \leq 30$), calculated tables of probabilities based on the underlying binomial distribution (Natrella 1963) were referenced for the upper and lower confidence limits.

RESULTS

Vegetation Classification and Characterization

The NVCS for the BADL study area includes 28 natural and semi-natural associations and two complexes. The natural associations are comprised of four woodland, ten shrubland, six upland herbaceous/grassland, four wetland and four sparse vegetation types. The semi-natural associations are comprised of one woodland and three grassland types. The final classification is presented in Table 3. A field key and detailed type descriptions are included in Appendices 8 and 12, respectively. As expected, many of the vegetation types are representative of the mixed-grass prairie found throughout the Great Plains physiographic region and sparse vegetation associated with badland formations.

Woodlands are minor components of the regional vegetation, covering approximately 1.8% of the project area. These are generally restricted to floodplains, drainage bottoms, toeslopes of sandhills, draws associated with eroding buttes, and slumps on butte and cliff faces. Rocky Mountain juniper (*Juniperus scopulorum*) forms the most common woodland in the project area, occurring as its purest form on drier slopes, along butte edges, and in upper draws. It likely hybridizes with eastern red cedar (*J. virginiana*), as characteristics of both species were observed in the field, often on the same tree. A special habitat occupied by Rocky Mountain juniper is the side-slope slump, where additional moisture collects following the landslide. Juniper trees are often knocked sideways, or felled during this movement, some of these were even observed to be rooting along the trunk with each major branch becoming a new tree.

Rocky Mountain juniper often intergrades with other woodlands, especially ponderosa pine (*Pinus ponderosa*) and green ash (*Fraxinus pennsylvanica*). Ponderosa pine woodlands occur in the upper elevations of the South Unit, where cover values for ponderosa pine and Rocky Mountain juniper are often nearly equal (Figure 13). Throughout the Park's lower elevations, Rocky Mountain juniper and hardwood trees also intermix along a broad gradient, with hardwoods occupying more mesic sites. Green ash and American elm (*Ulmus americana*) are the most common hardwood trees present, occupying bottoms of draws, river floodplains, and toeslopes of sand hills. The upper portion of hardwood draws is commonly dominated by various shrub species, particularly American plum (*Prunus americana*) and western snowberry (*Symphoricarpos occidentalis*).

Extremely mesic sites within the project area support stands of Eastern or plains cottonwood (*Populus deltoides*) trees. Along with peachleaf willow (*Salix amygdaloides*), these typically occur within the Park as small clumps along minor streams, around seeps and springs, and around ponds. Immediately adjacent to BADL, Eastern or plains cottonwood trees form riparian woodlands within floodplains of the White and Cheyenne Rivers. These riparian woodlands tend to be separated into different age classes relative to year of establishment and position within the floodplain. Young trees establish from seed on newly scoured point bars and islands, while mature trees occupy deeper sediment deposits of river meanders or oxbows and higher, more permanent islands (Figure 14). Green ash and Rocky Mountain juniper are usually present as co-dominants or as principal understory species.

Table 3. Summary of the National Vegetation Classification System (NVCS) for BADL, with types grouped into physiognomic and ecological categories. (Note: for some of the Herbaceous types, part of the name, "Herbaceous Vegetation", has been abbreviated to "H.V." to retain the names on a single line.)

NVCS Associations and Complexes	Common Name
FORESTS AND WOODLANDS	
Dry Coniferous Forests and Woodlands	
• *Juniperus scopulorum* / *Oryzopsis micrantha* Woodland	Rocky Mountain juniper / Little-seed ricegrass Woodland
• *Pinus ponderosa* / *Juniperus scopulorum* Woodland	Ponderosa pine / Rocky Mountain juniper Woodland
Riparian Deciduous Forests and Woodlands	
• *Fraxinus pennsylvanica* - (*Ulmus americana*) / *Prunus virginiana* Woodland	Green ash - (American elm) / Chokecherry Woodland
• *Populus deltoides* - (*Salix amygdaloides)* / *Salix exigua* Woodland	Eastern cottonwood - (Peachleaf willow) / Sandbar willow Woodland
• *Elaeagnus angustifolia* Semi-natural Woodland	Russian-olive Semi-natural Woodland
SHRUBLANDS	
Dry Plains Shrublands	
• *Artemisia filifolia* / *Calamovilfa longifolia* Shrubland	Sand sagebrush / Prairie sandreed Shrubland
• *Chrysothamnus nauseosus / Pseudoroegneria spicata* Shrubland	Rubber rabbitbrush Shrubland
• *Rhus trilobata* / *Carex filifolia* Shrub Herbaceous Vegetation	Three-leaved Sumac / Threadlead Sedge Shrub Herbaceous Vegetation
• *Yucca glauca / Calamovilfa longifolia* Shrub Herbaceous Vegetation	Soapweed Yucca / Prairie sandreed Shrub Herbaceous Vegetation
Mesic Plains Shrublands	
• *Artemisia cana / Pascopyrum smithii* Shrubland	Silver sagebrush / Western wheatgrass Shrubland
• *Prunus virginiana - (Prunus americana)* Shrubland	Chokecherry - (American plum) Shrubland
• *Sarcobatus vermiculatus* / *Pascopyrum smithii* Shrubland	Greasewood / Western wheatgrass Shrubland
• *Shepherdia argentea* Shrubland	Silver buffaloberry Shrubland
• *Symphoricarpos occidentalis* Shrubland	Western snowberry Shrubland
Riparian Shrublands	
• *Salix exigua* Temporarily Flooded Shrubland	Sandbar willow Temporarily Flooded Shrubland

Table 3. (continued)

HERBACEOUS VEGETATION	
• Prairie Dog Town Complex	Prairie dog town Complex
Dry Mixedgrass Prairies	
• *Bouteloua gracilis - Buchloe dactyloides* Xeric Soil Herbaceous Vegetation	Blue grama - Buffalo grass Xeric Soil Herbaceous Vegetation
• *Calamovilfa longifolia - Carex inops ssp. heliophila* Herbaceous Vegetation	Prairie sandreed - Long-stolon sedge Herbaceous Vegetation
• *Pascopyrum smithi - Bouteloua gracilis - Carex filifolia* Herbaceous Vegetation	Western wheatgrass - Blue grama - Threadleaf sedge H. V.
• *Schizachyrium scoparium - Bouteloua* (*curtipendula, gracilis*) - *Carex filifolia* Herbaceous Vegetation.	Little bluestem - (Sideoats grama, Blue grama) -Threadleaf sedge H.V.
• *Stipa comata - Bouteloua gracilis - Carex filifolia* Herbaceous Vegetation	Needle-and-thread - Blue grama - Threadleaf sedge H.V.
Mesic Mixedgrass Prairies	
• *Pascopyrum smithii - Nassella viridula* Herbaceous Vegetation	Western wheatgrass - Green needlegrass Herbaceous Vegetation
Introduced Grasslands	
• *Agropyron cristatum - (Pascopyrum smithii) Semi-natural* Herbaceous Vegetation	Crested wheatgrass - (Western wheatgrass) Semi-natural H.V.
• *Bromus inermis - (Pascopyrum smithii) Semi-natural* Herbaceous Vegetation	Smooth brome - (Western wheatgrass) Semi-natural H.V.
• *Poa pratensis - (Pascopyrum smithii) Semi-natural* Herbaceous Vegetation	Kentucky bluegrass - (Western wheatgrass) Semi-natural H.V.
Riparian/Wet Meadows	
• *Eleocharis palustris* Herbaceous Vegetation	Pale spikerush Herbaceous Vegetation
• *Panicum virgatum* Herbaceous Vegetation	Switchgrass Herbaceous Vegetation
• *Spartina pectinata - Carex* spp. Herbaceous Vegetation	Prairie cordgrass - Sedge species Herbaceous Vegetation
• *Typha* spp. - *Scirpus* spp. - Mixed Herbs Great Plains Herbaceous Vegetation	Cattail species - Bulrush species - Mixed herbs Great Plains H.V.
SPARSE VEGETATION	
• Badlands Sparse Vegetation Complex	Badlands Sparse Vegetation Complex
• *Artemisia longifolia* Badlands Sparse Vegetation	Long-leaf sagebrush Badlands Sparse Vegetation
• *Eriogonum pauciflorum - Gutierrezia sarothrae* Sparse Vegetation	Small-flowered wild buckwheat - Snakeweed Sparse Vegetation
• Eroding Great Plains Badlands Sparse Vegetation	Eroding Great Plains Badlands Sparse Vegetation
• Shale Barren Slopes Sparse Vegetation	Shale barren slopes Sparse Vegetation

photo by D. Cogan

Figure 13. Woodland in the South Unit of BADL containing a near equal mix of ponderosa pine and Rocky Mountain juniper.

Shrublands make up approximately 6.6% of the BADL study area and occur mainly along river and creek floodplains, and on sand deposits, mesic slopes, and draws. The most widespread of all shrublands is silver sagebrush (*Artemisia cana*), which occurs regularly on floodplains and adjacent slopes. Silver sagebrush is usually found sparsely scattered throughout western wheatgrass (*Pascopyrum smithii*) grasslands, although in certain areas it may become quite dense or intermingle with other shrubs. For example, silver sagebrush commingles with greasewood (*Sarcobatus vermiculatus*) near Plenty Star Table and with western snowberry in drainages throughout the Park.

Sand hills support extensive stands of sand sagebrush shrubland (*Artemisia filifolia*), particularly in the southern half of the Park and project area. Where sand hills are reduced to sandy ridges or flats, stands of yucca (*Yucca glauca*) may replace or intermingle with sand sagebrush. Most yucca stands are located along the margins of buttes, on low sandy ridges, and on dry canyonsides. Where broad valleys lie adjacent to sand hills, as along the Cedar Creek/Blind Man Table interface, silver sagebrush may also intermix with yucca along the upper slopes.

Mesic draws, swales, slopes, and drainages all through the study area provide enough moisture to sustain patches of various broad-leaved shrubs, in addition to the silver sagebrush described above. Among the more common are western snowberry, American plum, and occasional three-leaved sumac (*Rhus trilobata*). Western snowberry is the most prevalent, occurring as relatively small stands or clones at the heads of draws or covering low swales. American plum often occurs adjacent to western snowberry or within openings of green ash. American plum typically grows in clumps that produce almost impenetrable thickets. Three-leaved sumac is present at BADL as both very dense (moist conditions) and very sparse (dry conditions) shrubland types. Typically, this shrubland occurs as sparse stands along the rims of buttes. Outside the Park, there are dense stands of three-leaved sumac, particularly in the Cheyenne River drainage, where they dominate exposures of Pierre shale or clay soils derived from Pierre shale.

photos by D. Cogan

Figure 14. Plains cottonwood riparian woodlands occurring in the floodplain of the Cheyenne River. Demonstrating (from left) the young, medium, and old age classes.

The remaining shrublands represent relatively rare types found only in a few locations in and around BADL. Sandbar willow shrublands grow in saturated ox-bows or cut-banks of Sage Creek in the North Unit and Fog Creek in the South Unit (Figure 15). One very large stand is located along the Conata Basin Road just outside of the Park boundary. Habitat similar to and slightly drier than that of sandbar willow may contain clumps of silver buffaloberry (*Shepherdia argentea*). These are typically distributed along drainages and streams and seem to be more common in the South Unit along the White River. Greasewood shrublands are known only from two small patches on Cuny Table in the South Unit and a small hilltop in the Sage Creek Wilderness of the North Unit. Finally, rabbitbrush (*Chyrsomthamnus nauseosus*) shrubs become dominant in disturbed sites throughout the project area, such as areas of road-construction. The largest of these communities occurs along the Cuny Table Road and the road-cut on the southern edge of Red Shirt Table (both in the environs adjacent to the South Unit), while smaller patches occur along the main Park road in the North Unit.

Grassland and sparse vegetation communities cover the majority of area in and around BADL. Four associations were found in the sparsely vegetated badlands (approximately 19.2% of the project area) ranging from completely barren slopes to vegetated erosion fans (Table 3). Badlands sparse vegetation develops on siltstone, volcanic ash, and claystone eroded to form pinnacle, cliff, mound, outwash fan, and intermittent drainage habitats. Also, a relatively unique badlands formation occurs on large expanses of low hills covered by chalcedony, a flat, crystalline rock with properties similar to quartz. Drought-tolerant shrubs such as silverscale saltbush (*Atriplex argentea*) and broom snakeweed (*Gutierrezia sarothrae*) and annual forbs can be found dispersed throughout variable badlands environments/habitats.

Sparse vegetation can also be found within areas of established prairie dog towns (approximately 2% of the project area). Prairie dog towns occupy deeper soils on large flats dissected by many drainages, such as in the Conata Basin. Prairie dogs may alter grassland vegetation types over time through their cycle of burrow establishment, grazing, and burrow abandonment. This constant use causes the native vegetation to revert back to an early successional state, *i.e.* a weedy, forb-dominated community. For the purpose of this study, an attempt was made to separate the older, forb-dominated towns from the newer or less heavily grazed towns dominated by grass species. However, the various associations that may be present in a prairie dog town have not been described by the NVCS for BADL, rather they are simply treated as a Prairie Dog Town Complex.

Grasslands of the project area are directly influenced by many natural and anthropogenic factors such as soil depth, soil composition, landscape position, moisture levels, lack of fire, past disturbance, and grazing. This has resulted in a diverse grassland mixture that intermingles in small units across the landscape. Western wheatgrass is the predominant grass occurring in the project area. This sod-forming grass thrives on clayey soils were it ranges from almost pure, monotypic stands on clay to a true mixed grass prairie on silty/sandy clays or loamy clays. Common associated species include various forbs and grasses such as prairie coneflower (*Ratibida columnifera*), white milkwort (*Polygala alba*), needle-and-thread (*Stipa comata*), and prairie dropseed (*Sporobolus heterolepis*). The heterogeneous species composition of western wheatgrass made it difficult, if not impossible to consistently identify and separate unique associations. Consequently, these associations were mapped at the alliance level, except where stands of western wheatgrass - green needlegrass (*Nassella viridula*) could be distinguished.

Two non-native annual grasses, Japanese brome (*Bromus japonicus*) and downy brome (*B. tectorum*) are also usually present to some degree in all grassland associations, especially western wheatgrass stands. Western wheatgrass also tends to be replaced in drier areas or places with increased grazing by blue grama. This shorter grass often grows in association with needle-and-thread and threadleaf sedge (*Carex filifolia*), especially around the extremely dry edges of buttes and small tables. On gravelly soils, side draws, and broad swales, little bluestem becomes dominant, often in association with side-oats grama (*Bouteloua curtipendula*). These areas are quite small in the North Unit even though they appear relatively widespread in the fall due to the bright coloration of the grass. In the South Unit and along the Cheyenne River in the northwest corner of the study area, little bluestem is common on gravelly soils of side slopes, draws, breaks, and drainages.

Unique and predictable grassland associations for this project include switchgrass, which occurs in very wet, shallow basins, and western wheatgrass / green needlegrass, which is present on selected hills, slopes, and buttes. Switchgrass is a facultative wetland species restricted to temporarily flooded areas such as the upland drainage just north of the main Park access Road in the North Unit (Figure 15). In this area and a few others scattered through the North Unit, switchgrass grows as a fairly homogenous stand surrounded by western wheatgrass and little bluestem on slightly higher ground. The Western Wheatgrass / Green Needlegrass Association is present on small rises and slopes of the North Unit and in somewhat flat mesic sites on buttes (such as Stronghold Table) in the South Unit. Typically, this vegetation association contains thick clumps of green needlegrass characterized by 1m tall seed heads amongst solid mats of western wheatgrass.

Regions throughout the project area that were disturbed historically by agricultural or transportation activity are primarily re-vegetated by non-native grass species. Representative locations include road corridors in the Park seeded with smooth brome (*Bromus inermis*), old fields in the North Unit seeded with crested wheatgrass (*Agropyron cristatum*), and old pastures on Sheep Mountain Table grazed by sheep and invaded by Kentucky bluegrass (*Poa pratensis*). These three grasses form large enough mono-dominant stands that they were treated as separate associations, though they were mapped as a unit. Other relatively common non-native species found in various disturbed sites include alfalfa (*Medicago sativa*), Canada thistle (*Cirsium arvense*), and giant ragweed (*Ambrosia trifida*). A biennial, yellow sweetclover (*Melilotus officianalis*) is an exotic that is widespread within the North Unit of the Park. During peak growing years, yellow sweetclover can cover native grasslands growing over 2 meters tall.

photos by D. Cogan and J. Von Loh

Figure 15. Switchgrass (left) and sandbar willow (right), two rare wetland associations found within the North Unit of BADL.

Besides the switchgrass and sandbar willow associations, other riparian or wet meadow associations comprise approximately 0.7% of the project area. These include both naturally occurring wetlands along basins, depressions, and on seeps and springs and introduced wetlands, created indirectly as a result of sedimentation into man-made ponds and dugouts. Introduced wetlands are typically dominated by broad- and/or narrow-leaved cattail (*Typha angustifolia* and *T. latifolia*) and soft-stem bulrush (*Scirpus validus*), while naturally occurring wetlands support species of spikerush (*Eleocharis* spp.), foxtail barley (*Hordeum jubatum*), and true rushes (*Juncus* spp.). Another common wetland species found in small, linear strips in BADL is prairie cordgrass (*Spartina pectinata*). Due to its limited size and patchy distribution it was difficult to separate from the other wetland types in this study.

Vegetation Map Production

Map Units

Thirty-three map classes or units were recognized and used for BADL (Table 4). These were divided into 23 vegetation units and ten Anderson Level II (Anderson *et al.* 1976) land use classes. Map units were developed through a combination of fieldwork, preliminary photo-interpretation, and the NVCS for BADL. Deviations from the NVCS occurred when distinct photo signatures could not be discerned from aerial photography, such as some of the grassland and badlands types. Also, some map units did not directly correspond to the USGS-NPS vegetation-mapping program but were included to aid with BADL's management needs.

Various minor grassland associations within the Western Wheatgrass Alliance could not be differentiated well in the field or from aerial photographs. These common grasslands were so finely intertwined that only at the alliance level could they be consistently recognized and delineated. However, the Western Wheatgrass / Green Needlegrass Association was clearly identifiable in the field and marginally recognizable on the photos. It was agreed that when this class met the minimum-mapping unit (mmu) of 0.5 hectares, an attempt would be made to interpret it and enter the polygon in the database on an as-known or as-observed basis.

A relatively high concentration and large expanse of black-tailed prairie dogs has made BADL a very important and successful site for the re-introduction of black-footed ferrets (an endangered species). In order to monitor and maintain the current population of ferrets and possibly increase the number of released individuals, park managers are interested in the location, size, and edge identification of prairie dog towns within the Park (Plumb 1997; Appendix 13). Typically, wildlife habitats would not be candidates for mapping under this program, however prairie dogs do alter the vegetation around them to the point of creating and sustaining predictable vegetation types. Largely from similar work conducted at nearby Wind Cave National Park, prairie dog towns have been designated as belonging to the Purple Threeawn-Fetid Marigold Herbaceous Vegetation Association (Cogan, *et al.* 1999). It was determined during fieldwork and from the aerial photos, that similar prairie dog towns at BADL did not always change the grassland type in which they occurred. To address this situation, the prairie dog town classification was only applied to core town areas where the vegetation was seriously altered. In lesser-disturbed areas, prairie dog towns were still delineated but classified as the native grassland type. In this manner, two separate areas could be calculated, one for the native grasslands pertaining to this study and one for prairie dog towns necessary for the Park. This distinction is represented on the final maps as stippled overlay patterns.

Three map classes routinely occur within the study area below the mmu even though they could be consistently identified on the photos. These include emergent wetlands, western snowberry shrublands, and silver buffaloberry shrublands. Partially based on the importance of these types for wildlife habitat, the ability to easily discern them on the photography, and the need to adequately represent shrubs in an otherwise grassland/badlands environment a decision was made to map all three regardless of size. This included the use of a line coverage for long, linear wetlands.

Table 4. Vegetation map units for BADL and corresponding NVCS classes. Map units are ordered by map code. All map classes are at the association level if they end in Woodland, Shrubland, or Grassland. Other units (*i.e.* Complex, Introduced Grasslands, Emergent Wetlands, and Alliances) are various groupings of associations that were more amenable units for mapping.

Map Code	Map Unit	NVCS Association or Complex
1	Prairie Dog Town Complex	- Prairie Dog Town Complex
2	Badlands Sparse Vegetation Complex	- *Artemisia longifolia* Badlands Sparse Vegetation - *Eriogonum pauciflorum - Gutierrezia sarothrae* Badlands SparseVegetation - Eroding Great Plains Badlands Sparse Vegetation - Shale Barren Slopes Sparse Vegetation
12	Switchgrass Grassland	- *Panicum virgatum* Herbaceous Vegetation
14	Emergent Wetlands	- *Typha* spp. - *Scirpus* spp. - Mixed Herbs Great Plains Herbaceous Vegetation - *Eleocharis palustris* Herbaceous Vegetation - *Spartina pectinata - Carex* spp. Herbaceous Vegetation
15	Little bluestem - Grama grasses - Threadleaf sedge Grassland	- *Schizachyrium scoparium - Bouteloua* (*curtipendula, gracilis*) - *Carex filifolia* Herbaceous Vegetation
16	Western wheatgrass Grassland Alliance	- *Pascopyrum smithi - Bouteloua gracilis - Carex filifolia* H.V. - *Pascopyrum smithii - Nasella viridula* Herbaceous Vegetation - *Calamovilfa longifolia - Carex filifolia* Herbaceous Vegetation
17	Introduced Grassland (Smooth brome, Kentucky bluegrass, Crested wheatgrass)	- *Agropyron cristatum - (Pascopyrum smithii) Semi-natural* H.V. - *Bromus inermis - (Pascopyrum smithii) Semi-natural* Herbaceous Vegetation - *Poa pratensis - (Pascopyrum smithii) Semi-natural* Herbaceous Vegetation

Table 4. (continued)

18	Blue grama Grassland	- *Bouteloua gracilis - Buchloe dactyloides* Xeric Soil H. V. - *Stipa comata-Bouteloua gracilis - Carex filifolia* Herbaceous Vegetation
19	Western wheatgrass - Green needlegrass Grassland	- *Pascopyrum smithii - Nassella viridula* H.V. (where possible)
21	Soapweed yucca / Prairie sandreed Shrub Grassland	- *Yucca glauca* / *Calamovilfa longifolia* Shrub Herbaceous Vegetation
25	Silver buffaloberry Shrubland	- *Shepherdia argentea* Shrubland
31	Silver sagebrush / Western wheatgrass Shrubland	- *Artemisia cana / Pascopyrum smithii* Shrubland
32	Sand sagebrush / Prairie sandreed Shrubland	- *Artemisia filifolia* / *Calamovilfa longifolia* Shrubland - *Calamovilfa longifolia* - *Carex filifolia* Shrubland (in part)
33	Rabbitbrush Shrubland	- *Chrysothamnus nauseosus / Pseudoroegneria spicata* Shrubland
34	Chokecherry - (American plum) Shrubland	- *Prunus virginiana* - (*Prunus americana)* Shrubland
35	Three-leaved sumac / Threadleaf sedge Shrub Grassland	-*Rhus trilobata* / *Carex filifolia* Shrub Herbaceous Vegetation
37	Western snowberry Shrubland	-*Symphoricarpos occidentalis* Shrubland
38	Sandbar willow Temporarily Flooded Shrubland	-*Salix exigua* Temporarily Flooded Shrubland
39	Greasewood / Western wheatgrass Shrubland	-*Sarcobatus vermiculatus* / *Pascopyrum smithii* Shrubland

Table 4. (continued)

41	Eastern cottonwood - (Peachleaf willow) / Sandbar willow Woodland	- *Populus deltoides* - (*Salix amygdaloides) / Salix exigua* Woodland - *Elaeagnus angustifolia* Semi-natural Woodland
42	Green ash - (American elm) / Chokecherry Woodland	- *Fraxinus pennsylvanica* - (*Ulmus americana*) / *Prunus virginiana* Woodland
43	Ponderosa pine / Rocky Mountain juniper Woodland	- *Pinus ponderosa* / *Juniperus scopulorum* Woodland
44	Rocky Mountain juniper/ Little-seed ricegrass Woodland	- *Juniperus scopulorum* / *Oryzopsis micrantha* Woodland

Aerial Photograph Interpretation

A brief description of each map class (plant association, alliance, or complex), its location in the project area, and photo signature characteristics is presented as follows:

Prairie Dog Town Complex (1). This vegetation class occupies broad drainages, swales, terraces, and gentle slopes within the project region. It contains high forb cover versus low graminoid cover. The aerial photo signature consists of small, white stipples (prairie dog burrows), usually somewhat interconnected by narrow trails and lying within bright red, pink, and green colors. The class is delineated to the edge of the obviously grazed zone (Plumb 1997)(Figure 16A).

Badlands Sparse Vegetation Complex (2). This geologic feature and sparse vegetation class provides the Park's aesthetic focus and consists of barren to sparsely vegetated walls, cliffs, bluffs, pinnacles, mounds or haystacks, table lands, escarpments, erosion fans, alkaline flats, overflows, and drainages. Siltstone, claystone, sandstone, volcanic ash, and sediments contribute to a bright white photographic signature, often with some shadowing which may appear as black. Layers of chalcedony over the white sediments create a gray signature, making it difficult to discern from light gray-green grassland signatures (Figure 16B).

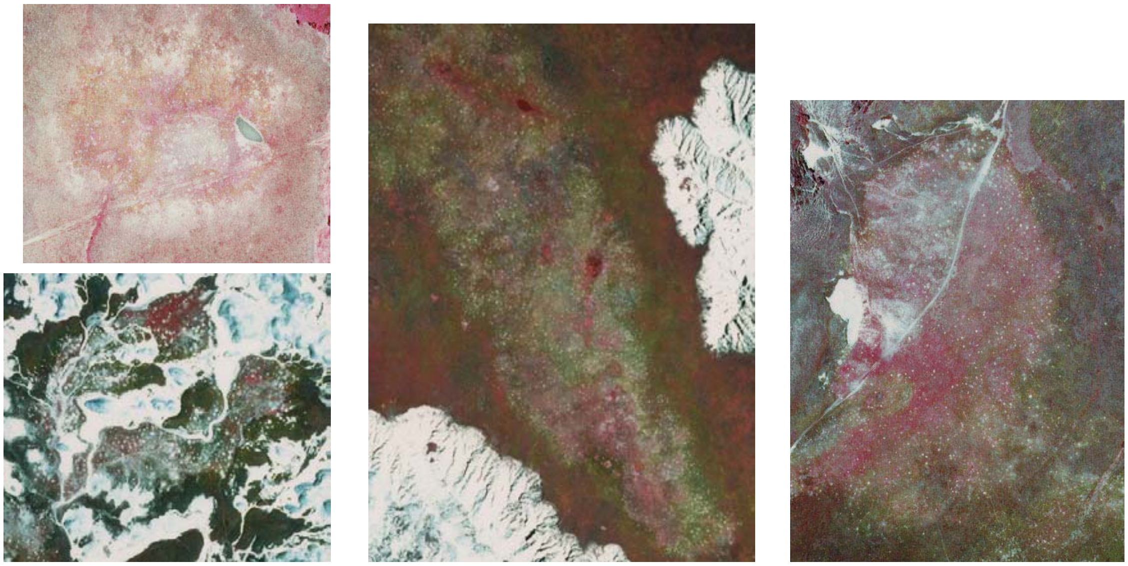
Switchgrass Grassland (12). This vegetation class occupies a basin with a high ground water table, adjacent to the North Unit access road and a few broad drainages, all associated with the North Unit. Some individual cottonwood trees dot the associated drainages. Aerial photo signatures include dark brown to maroon in color, a smooth texture, and a brush stroke appearance (Figure 17A).

Emergent Wetland (14). This vegetation class occurs on saturated and inundated soils, where water depths do not exceed about one meter. Wetland vegetation is found along drainages, in swales and closed basins, and around dugouts, ponds, and reservoirs. All wetlands are delineated for this study, whether or not they meet the mmu. Linear wetlands of swales are delineated in a line coverage. Aerial photo signatures range from dark brown for spikerush wetlands, to pink for prairie cordgrass wetlands, to bright red for wetlands dominated by cattail and bulrush. Small pockets of open water are often present, usually black in color (Figure 17B).

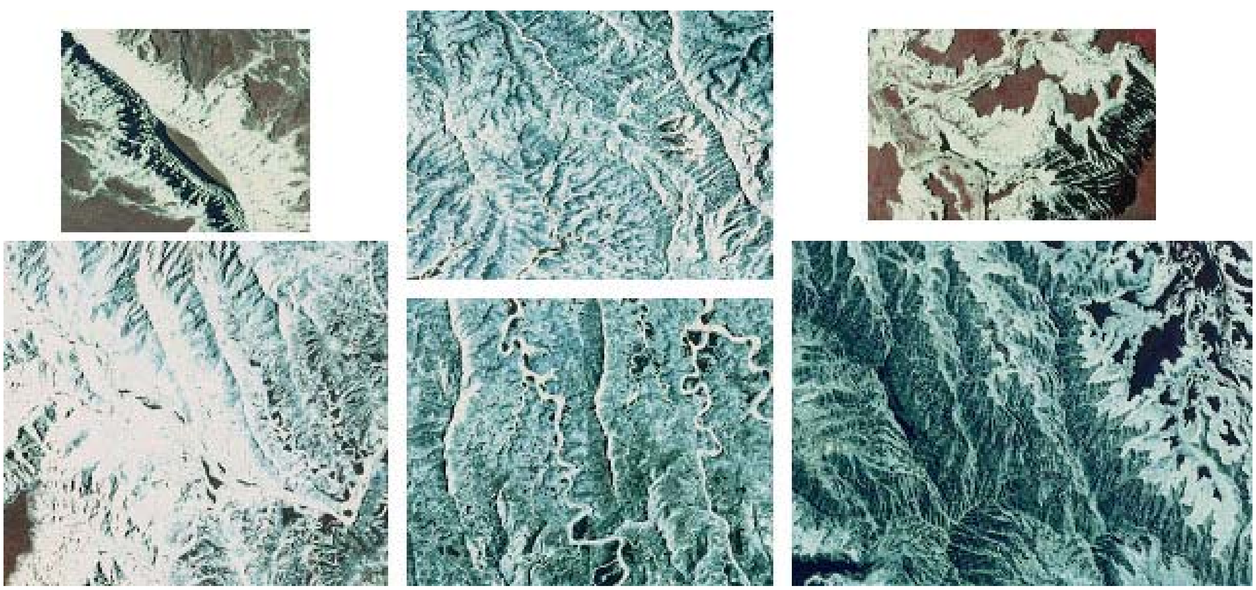
Little Bluestem - Grama Grasses - Threadleaf Sedge Grassland (15). This vegetation class occurs on gravelly hillsides, ridges, and in drainages, more so in the South Unit of the Park and the northwestern environs outside the Park. Aerial photo signatures range from a stippled pattern of white dots on slopes and ridges to a brushed, blood red appearance in drainages (Figure 17C). This vegetation type sometimes supports sparse yucca and three-leaved sumac and may be delineated under Classes 21 or 35, as well.

Western Wheatgrass Grassland Alliance (16). This vegetation class is widespread throughout the Park and region, particularly on clay and silt soils. Ungrazed western wheatgrass may be 0.5 m tall and screen all associated species in aerial view, the exotic annual Japanese brome is common in this vegetation type and has a strong influence on photo signatures. Aerial photo signatures are typically a smooth gray-green to dark green color or brownish maroon for this grassland.

Figure 16. Photo-interpretive key to the prairie dog town and badlands sparse vegetation classes (all photography by Horizons, Inc. 1997).



A) Prairie Dog Town Complex



B) Badlands Sparse Vegetation Complex

When exotic annuals are abundant, or the grassland is regularly grazed, reducing the overstory, a pink to light red signature is common (Figure 17D).

Introduced Grassland (17). This vegetation class occurs along roadways, on historic agricultural fields, and in pastures where exotic species have escaped or been inter-seeded. Notable examples occur on Sheep Mountain Table, the northern boundary of the North Unit, and on the Cuny/Stronghold Table interface. Aerial photo signatures vary by species and condition: smooth brome is dark brown and circular when undisturbed, but bright red when burned, mown, or grazed; Kentucky bluegrass is light gray to green-gray when not mown or grazed, but light pink to bright pink when it is grazed; and crested wheatgrass is lime green to gray-green (Figure 17E).

Blue Grama Grassland (18). This vegetation class is common in the South Unit on sandy and sandy loam soils, and in grazed areas outside the Park. On the predominantly clay and silt soils in the vicinity of the North Unit, this class is restricted to hilltops and ridges and the dry edges of buttes. Under the influence of heavy grazing, western wheatgrass can be reduced and replaced by blue grama, even on clay and silt soils, as observed on the northwestern portion of the Palmer Creek Unit of Pine Ridge Reservation. Aerial photo signatures for this short-grass type are olive-brown to greenish-brown on sandy soils, reddish-gray color along the dry edges of buttes, and a pinkish, cloudy signature on regularly grazed sites (Figure 17F).

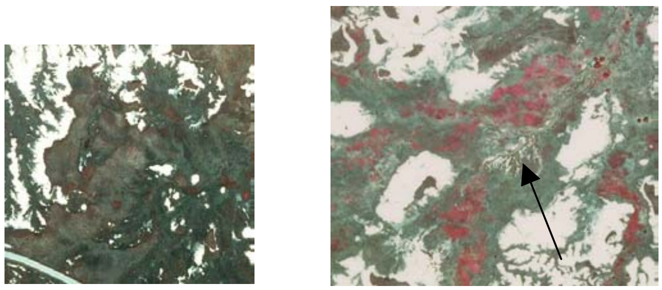
Western Wheatgrass - Green Needlegrass Grassland (19). This vegetation class has a patchy distribution in the Park, and is only delineated on a when-observed basis. Unless green needlegrass is the truly dominant species, the aerial photo signature is that of Class 16, described above. Large patches of dense green needlegrass produce a reddish-maroon splotch within the gray-green western wheatgrass signature (Figure 17G).

Soapweed Yucca / Prairie Sandreed Shrub Grassland (21). This shrub grassland type occupies low, sandy ridges and the edges of some buttes. It is also a component of Class 32 on sand hills and can be difficult to interpret separately. Aerial photo signatures include a yellow-green to medium green color associated with an olive-green to dull brown background color, coupled with a texture like that of coarse sandpaper (Figure 18A).

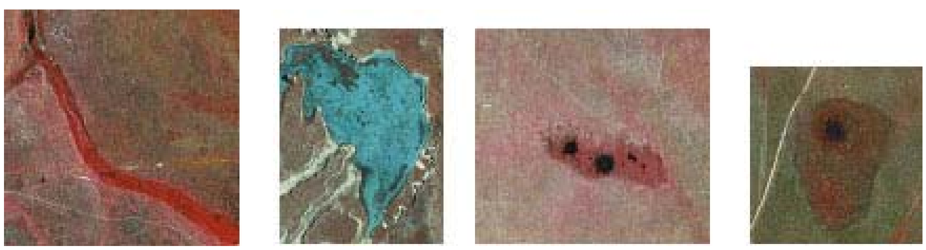
Silver Buffaloberry Shrubland (25). This shrub class occurs as small patches along several creeks and the White River, typically outside Park boundaries. The patches usually occur below the mmu, but are delineated for overall vegetation mapping accuracy. Aerial photo signatures include a large, pebbly texture and a gray to light pink color (Figure 18B).

Silver Sagebrush / Western Wheatgrass Shrubland (31). This shrub class occupies broad drainages, creek beds, and gentle slopes of creek and river valleys within the project area. Typical habitat is the oxbow bends of meandering creeks draining the project area lands. Photo signatures vary, ranging from black dots against a white background in recently flooded drainages, to maroon dots against a green background on well-vegetated drainages. The texture appears rough as on medium-grit sandpaper (Figure 18C).

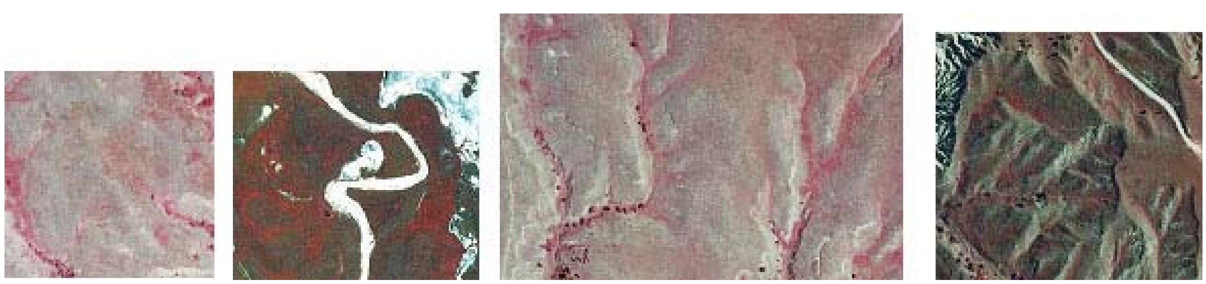
Figure 17. Representative photo-signatures for the grassland / herbaceous map units. (all photography by Horizons, Inc. 1997).



A) Switchgrass Grassland

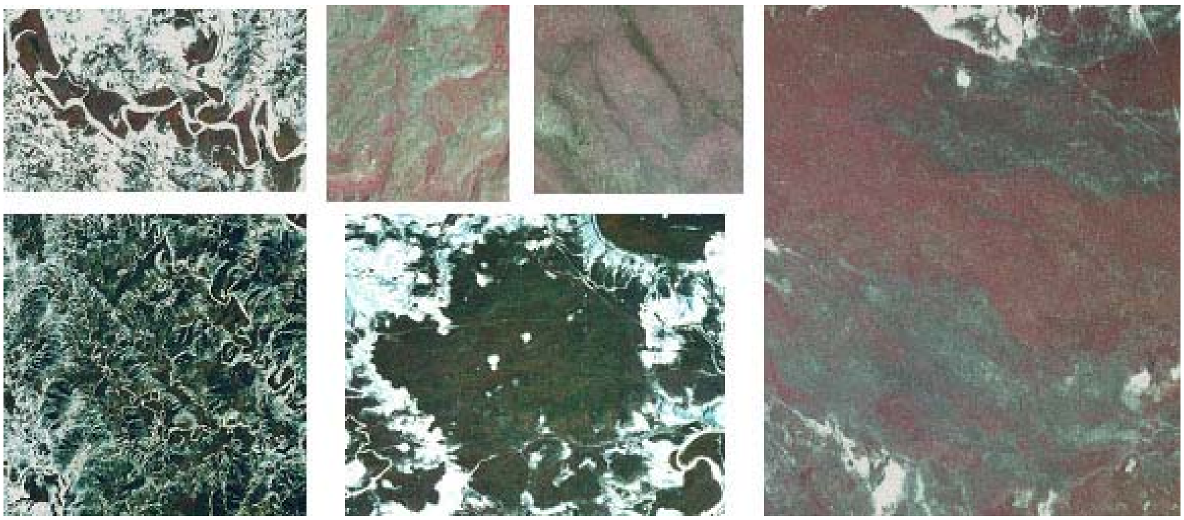


B) Emergent Wetland

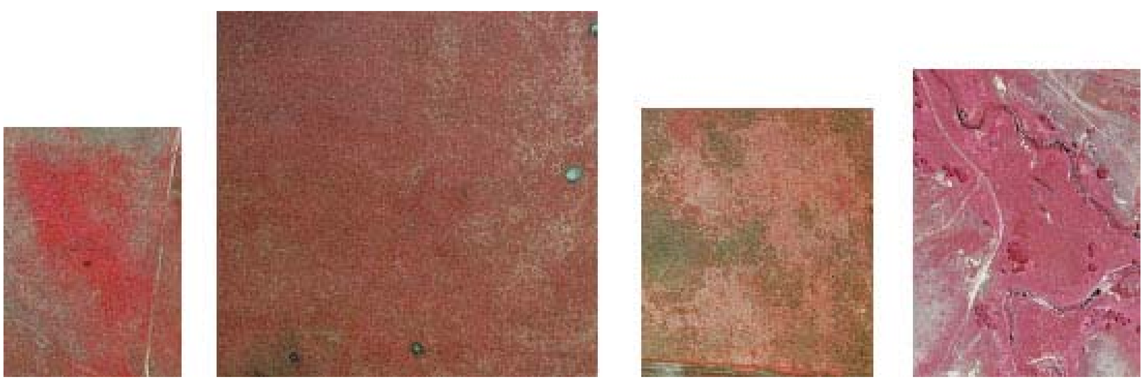


C) Little Bluestem - Grama Grasses -Threadleaf Sedge Grassland

Figure 17. (continued)

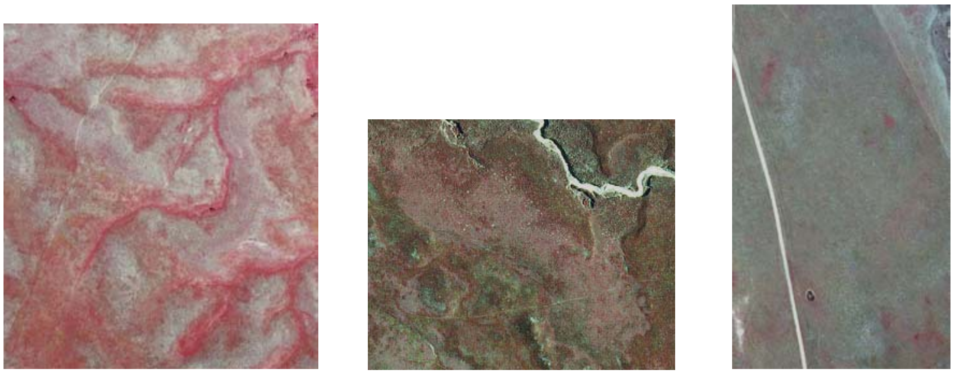


D) Western Wheatgrass Grassland Alliance

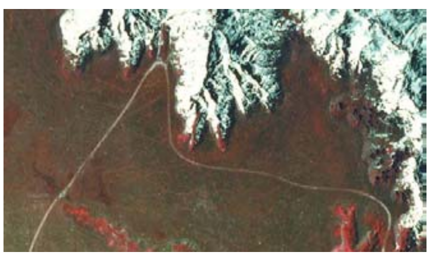


E) Introduced Grassland

Figure 17. (continued)



F) Blue Grama Grassland



G) Western Wheatgrass - Green Needlegrass Grassland

Sand Sagebrush / Prairie Sandreed Shrubland (32). This shrub class occupies sand hills and ridges deposited along the White River drainage, mostly in the South Unit of the Park. Typical examples of these sand hill complexes include Blind Man Table, a portion of Red Shirt Table, and the complex just north of Imlay. Occasional pure stands of prairie sandreed may be included in this map unit. Aerial photo signatures include the crescent-shaped blowouts and swirls of dune sand, over which a grayish to flesh-tone colored, pebbly texture is observed (Figure 18D).

Rabbitbrush Shrubland (33). This shrub class was only observed on slopes disturbed during road construction activities. Stands bigger than the mmu occur along the North Unit access road and along Cuny Table Road and Red Shirt Road in the South Unit. Aerial photo signatures include very small individual bumps that are gray to maroon in color (Figure 18E).

Chokecherry - (American Plum) Shrubland (34). This shrub class commonly occurs in mesic draws, slumps, along the edge of sand hills, and on some slopes where mesic conditions persist. Often, this class mixes with western snowberry, making them difficult to separate during interpretation. Aerial photo signatures include a rank, brushy texture with orange, red, or pink colors (Figure 18F).

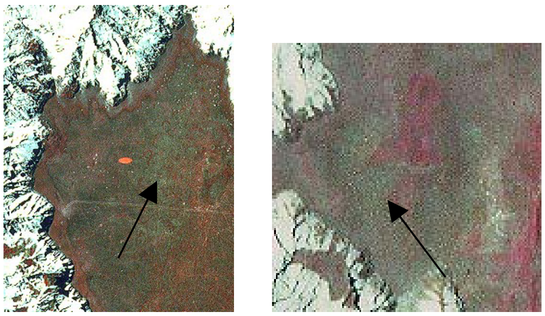
Three-leaved Sumac / Threadleaf sedge Shrub Grassland (35). This shrub class includes a sparse component when it grows along the upper edge of buttes and cliffs and a denser component when observed on low ridges and swales of Pierre Shale derived soils. More dense stands are common in the project environs of the Cheyenne River drainage, while less dense stands are more common to the South Unit. Aerial photo signatures include a regular distribution of rounded shrubs that are dull red, orange-red, or brown in color (Figure 18G).

Western snowberry Shrubland (37). This shrub class is distributed throughout the project area, but occurs as larger patches in the swales and draws of the southern portion of the South Unit. Within the Park, western snowberry patches usually occur below the mmu, so delineation included relatively small inclusions for overall vegetation mapping accuracy. Aerial photo signatures range from bright pink to bright orange in color, but sometimes a dull brown was noted; the margins are smooth and clones are oval (Figure 18H).

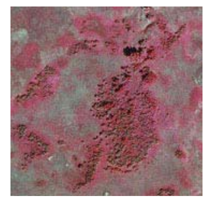
Sandbar Willow Temporarily Flooded Shrubland (38). This wetland shrub class is rare and usually occurs below the mmu on point bars and creek/river shorelines. Good examples were observed along Sage and Fog Creeks within the Park and along the White and Cheyenne Rivers and Wounded Knee Creek in the environs. Signatures include brushy, bright orange to dull red color (Figure 18I).

Greasewood / Western Wheatgrass Shrubland (39). This shrub grassland vegetation class is rare, observed only on one small hilltop in the Sage Creek Wilderness and on small flats on Cuny Table. A few small greasewood shrubs grow on badlands formations and are delineated as part of Class 2. Photo signatures for greasewood shrubs are black dots over a gray-white to whitish-green background color (Figure 18J).

Figure 18. Representative photo-signatures for the shrubland map units.
(all photography by Horizons, Inc. 1997).



A) Soapweed Yucca / Prairie Sandreed Shrub Grassland

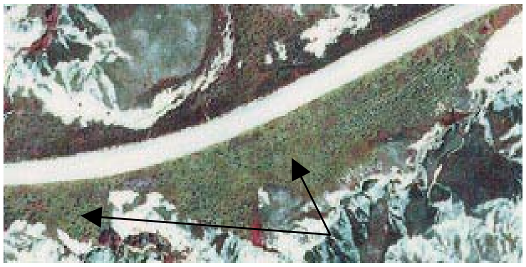


B) Silver Buffaloberry Shrubland

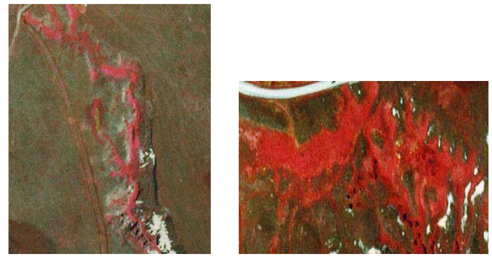
C) Silver Sagebrush / Western Wheatgrass Shrubland

D) Sand Sagebrush / Prairie Sandreed Shrubland

Figure 18. (continued)

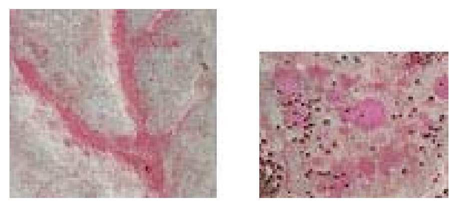


E) Rabbitbrush Shrubland



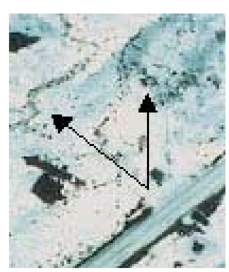
F) Chokecherry - (American Plum) Shrubland

G) Three-leaved Sumac / Threadleaf Sedge Shrub Grassland



H) Western Snowberry Shrubland

I) Sandbar Willow Temporarily Flooded Shrubland



J) Greasewood / Western Wheatgrass Shrubland

Eastern Cottonwood - (Peachleaf Willow) / Sandbar Willow Woodland (41). This woodland class grows primarily along the White and Cheyenne Rivers and Wounded Knee Creek all outside Park boundaries. Within the Park, riparian woodland species are limited to small clumps of trees growing in creek meanders, toeslopes of sandhills, around seeps and springs, and along the perimeter of ponds and lakes. Along river courses, as many as four age classes were observed for riparian woodlands dominated by plains cottonwood. Aerial photo signatures include large-crowned trees to brushy thick stands of young trees that are dull orange to brownish in color (Figure 19A).

Green Ash - (American Elm) / Chokecherry Woodland (42). This woodland class occupies mesic draws, drainages, and outer edges of river floodplains. It is short-statured with denser crown cover than plains cottonwood (mature stands) and it tends to intermix with both cottonwood and Rocky Mountain juniper stands. Aerial photo signatures include dense, rounded tree canopies that appear brushy and bright orange and red in color (Figure 19B).

Ponderosa Pine / Rocky Mountain Juniper Woodland (43). This woodland class is distributed entirely within the South Unit, beginning in the vicinity of Sheep Mountain Table (Cedar Butte - north) and Red Shirt Table. It is most noticeable on the two Cedar Buttes (Cedar Butte - south is near the Cuny Table Road) and on the ridge along the eastern Palmer Creek sub-unit. It occupies ridge and butte tops within the Park and some drainages in the southern environs. Aerial photo signatures include extremely large canopied trees, pebbly or brushy in texture, and medium-orange to dark green in color (Figure 19C).

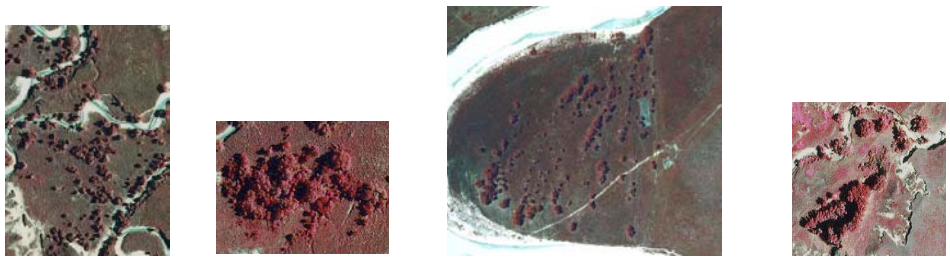
Rocky Mountain Juniper / Littleseed Ricegrass Woodland (44). This woodland class occupies drier draws, ridge and butte tops, and slumps on side-slopes. It often intermixes with Class 42 and is the understory canopy for Class 43. Aerial photo signatures include a dull, dusty-gray to gray-green color, and tight, pebbly canopy (Figure 19D).

Perennial Drainages (50). Few drainages carry water most or all of the year in and around BADL. The White and Cheyenne Rivers and Sage and Wounded Knee Creeks fall into this category with a few others. Photo signatures range from pure white for turbid water filled with sediment to black for deep water reaches; clear, shallow water reflects a light blue to medium blue color (Figure 20A).

Transportation, Communications, and Utilities (51). This land use class represents Federal, state, NPS, USFS, BIA and other paved highways, disturbed powerline rights-of-way, electrical substations, missile silos, sewage lagoons, and railroad rights-of-way. These are interpreted between the right-of-way or facility fences since they are often disturbed by mowing and during other maintenance activities. Photo signatures are typically a linear, square, or rectangular stark white color when compared with adjacent vegetation (Figure 20B).

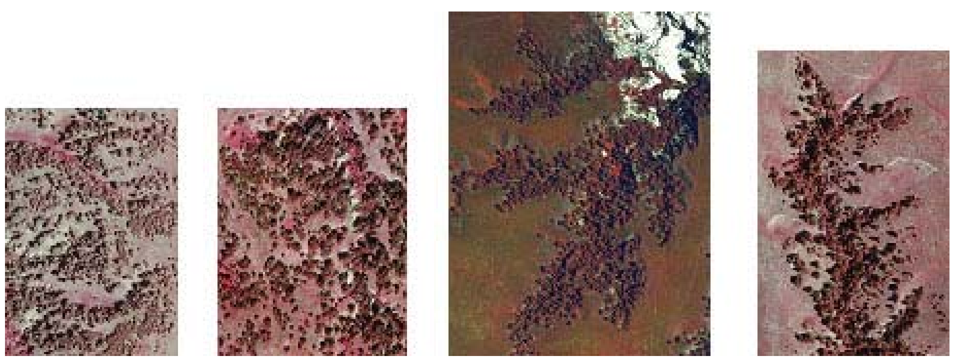
Mixed Urban or Built-up Land (52). This land use class represents small towns and villages such as Wall, Interior, Scenic, Red Shirt, etc., BADL facilities, and other developed land. The aerial photo signature ranges from white or gray on non-vegetated surfaces to pink and orange

Figure 19. Representative photo-signatures for the woodland map units.
(all photography by Horizons, Inc. 1997).

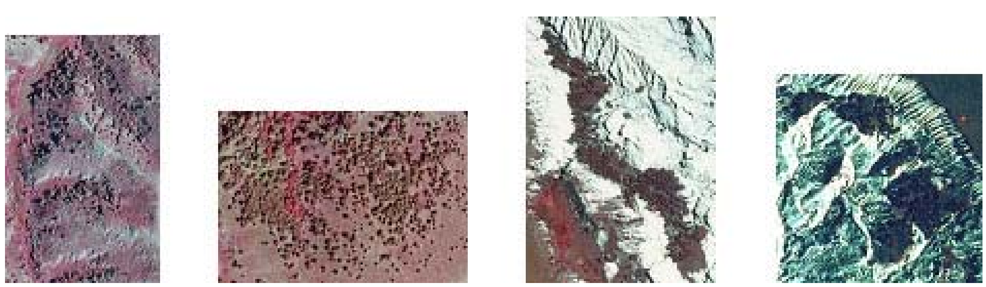


A) Eastern Cottonwood - (Peachleaf Willow) / Sandbar Willow Woodland

B) Green Ash - (American Elm) / Chokecherry Woodland



C) Ponderosa Pine / Rocky Mountain Juniper Woodland



D) Rocky Mountain Juniper / Little-seed Ricegrass Woodland for lawns and tree and shrub plantings. This class generally has a very rough texture because of all the various land uses and plantings (Figure 20C).

Croplands and Pasture (53). This land use class includes dry-farmed and irrigated fields, introduced pastures, and intensively used winter pastures. Aerial photo signatures include a striped or tilled pattern ranging from dull gray to gray-green for fallow land, to bright pink, orange, and red for cropped land. The texture for this class is smooth, often showing mowing lines, windrows of mown hay, hay bales, etc. (Figure 20D).

Seeded Mixed Grass Prairie (54). This land use class represents agricultural fields placed under the Conservation Reserve Program of the NRCS. To comply with program goals, restoration of these fields is typically undertaken using mid- to tall grass species. The aerial photo signature is that of a farmed field (53), except it is muted to a pink, red or dull brown color (Figure 20E).

Other Agricultural Land (55). This land use class includes farmsteads, ranch headquarters, corrals, equipment storage areas, windbreak and shelterbelt plantings, and more remote windmill structures. Aerial photo signatures range from white for barren ground to pink, orange, and/or bright red depending on the vegetation present (Figure 20F).

Intermittent Drainages (56). This land use class includes numerous small and medium-sized drainages that flow periodically throughout the region. These drainages meander along large oxbow bends and occasionally support scattered trees or patches of shrubs. This map class includes both the drainage channel and the adjacent scoured terraces, which are typically dry, except during flash floods. The drainages reflect bright white, unless they are carrying water that reflects from white to black depending on depth and clarity/turbidity. Tree and shrub patches are usually bright orange to pink in color, while silver sagebrush shrubs are a dull maroon (Figure 20G).

Reservoirs (57). This land use class ranges in size from small holes dug into the ground water table (dugouts), to large ponds and small lakes backed up behind earth-fill dams. Aerial photo signatures range from white for turbid, sediment-laden water, blue for water of medium depths, and black for deep water bodies. Emergent wetlands (14) are almost always associated with reservoir margins, and often grow into the shallower waters present (Figure 20H).

Beaches and Sandy Areas Other Than Beaches (58). This land use class represents point bars and islands along and within perennial drainage channels. These mostly unvegetated soils reflect pure white on aerial photos and are interpreted using their landscape position (Figure 20I).

Strip Mines, Quarries, and Gravel Pits (59). This land use class represents areas where the surface soils or geologic formations have been removed or drastically disturbed by heavy equipment. Check dams used to pond water in support of livestock grazing and irrigation are also included in this class. The photo signature is typically bright white, with a corresponding haul road, and often piles or mounds of material are present. In some instances, this excavation exposes ground water and by their nature, check dams pond water, which may appear as white, blue, or black depending on depth and clarity/turbidity (Figure 20J).

Figure 20. Photo-interpretative key for land-use map units.
(all photography by Horizons, Inc. 1997.)

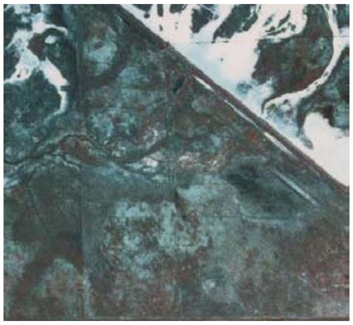
A) Perennial Drainages

B) Transportation, Communications, &Utilities

C) Mixed Urban or Built-up Land

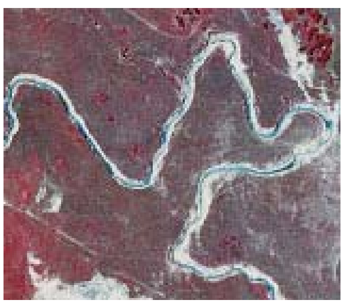
D) Croplands and Pastures

Figure 20. (continued)

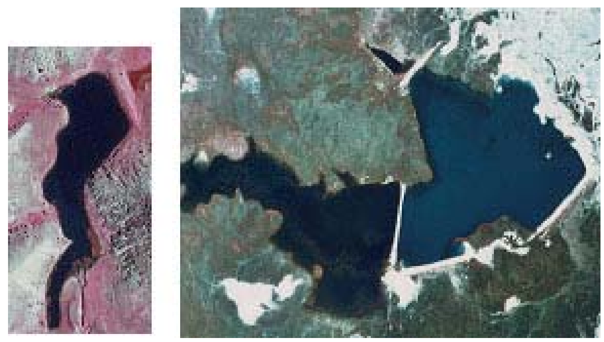


E) Seeded Mixed Grass Prairie

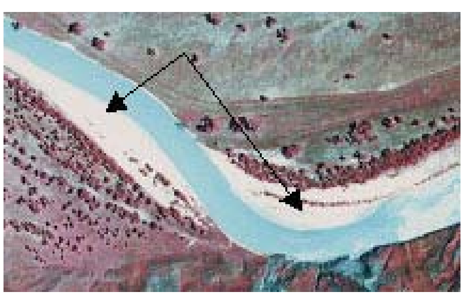
F) Other Agricultural



G) Intermittent Drainages



H) Reservoirs



I) Beaches & Sandy Areas Other Than Beaches

J) Strip Mines, Quarries, and Gravel Pits

Digital Transfer

Vegetation coverages were created in ArcInfo™ (ESRI, Inc.) corresponding to each quarter quadrangle in the BADL vegetation mapping project area. Quarter quadrangles were numbered 1-4 per quad, starting in the northwest corner and working clockwise. A list of USGS quadrangles for this project can be found in Appendix 4. Total area and number of polygons for each map unit were generated for each quarter quadrangle. The final total of polygons and area for the entire study is summarized in Table 5.

Accuracy Assessment

A total of 458 accuracy assessment points were used to assess the accuracy of the BADL vegetation map by:

- using AA points collected during the summer of 1998 (front-loading method);
- entering AA point coordinates into an electronic format to overlay on the vegetation map;
- comparing map vegetation classification (transferred from photo interpretation) with field assessment of vegetation type to determine errors of omission and commission;
- resolving questions by referring to original data forms, so that Dr. Butler could make the final determination;
- recording all information on the attached AA matrix (Table 7).

Overall, initial accuracy of the vegetation map is 80.6% for all vegetation classes and the Kappa Index is 78.2%. Results for each vegetation class are discussed here, and recommendations are made relative to creating a more accurate vegetation map, as desired.

The specific results are presented in Tables 5 and 6 below. In general, the percentage of the Park that an individual map class covered is reflected in the number of AA points collected for that type. For example, map class 16-19 (Western Wheatgrass Alliance / Western Wheatgrass - Green Needlegrass Grassland) covers approximately 38% of the Park, and is represented by 29% of the AA points, and map Class 1 (Prairie Dog Town Complex) occupies approximately 2% of the Park and is represented by 3% of the AA points. An exception for this is map class 2 (Badlands Sparse Vegetation Complex), which covers approximately 46% of the Park but is represented by only 14% of the AA points.

Two rare shrub classes were either not assessed or lightly assessed, due to their lack of abundance within the Park. These include map class 33 (Rabbitbrush Shrubland), which was not assessed and map class 38 (Sandbar Willow Temporarily Flooded Shrubland), which had one AA point but the polygon was attributed with a land use type; map class 56 (intermittent stream).

Table 5. 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 14.

Map Unit	BADL Hectares	BADL Polygons	Environs Hectares	Environs Polygons	Total Hectares	Total Polygons
1	1964.0	259	5343.9	704	7307.9	963
2	44,400.9	5364	26,910.3	10,266	71,311.2	15,630
12	179.4	28	15.2	21	194.6	49
14	239.1	902	2671.4	7280	2910.5	8182
15	2051.0	273	17,259.2	2677	19,310.2	2950
16	35,715.3	8186	136,781.5	8602	172,496.8	16,788
17	2064.1	208	1301.2	547	3365.3	755
18	3290.7	342	15,772.5	4022	19,063.2	4364
19	599.1	84	41.6	4	640.7	88
21	525.4	249	765.7	438	1291.1	687
25	6.7	26	82.5	396	89.2	422
31	1541.1	982	2591.3	1562	4132.4	2544
32	599.2	106	13,530.5	422	14,129.7	528
33	7.0	20	1.4	4	8.4	24
34	183.9	511	222.9	860	406.8	1371
35	750.7	685	2179.6	2277	2930.3	2962
37	451.7	2225	804.1	4668	1255.8	6893
38	5.3	18	251.1	327	256.4	345
39	5.4	7	0.2	1	5.6	8
41	52.7	261	1778.5	4248	1831.2	4509
42	188.3	315	1007.1	1155	1195.4	1470
43	140.9	82	121.0	108	261.9	190
44	1061.0	1385	2143.2	3042	3204.2	4427
50	20.5	5	840.8	60	861.3	65
51	185.1	43	1990.2	103	2175.3	146
52	36.2	33	366.8	86	403.0	119
53	268.3	29	31,046.7	685	31,315.0	714
54	0	0	2312.8	57	2312.8	57
55	28.5	17	1381.9	518	1410.4	535
56	899.1	191	2214.2	590	3113.3	781
57	49.9	114	933.7	1528	983.6	1642
58	13.5	33	430.6	504	444.1	537
59	12.1	67	251.5	1128	263.6	1195
Totals	97,536.1	23,050	273,345.1	58,890	370,881.2	81,940

Table 6. Summary of AA Results for Badlands National Park, by map class.

Map Class	Discussion
1-Prairie Dog Town Complex	This map class assessed at 93% / 93% (omission / commission) accurate and is considered to be adequate as mapped.
2-Badlands Sparse Vegetation Complex	This map class assessed at 100% / 94% accurate and is considered to be adequate as mapped.
12-Switchgrass Grassland	This map class assessed at 40% / 100%, the photo signature representing the cool-season dominant (western wheatgrass) instead of the warm-season class dominant (switchgrass). This class is very rare in the park, except for one large occurrence sampled in 1997, and is considered to be adequate as mapped.
14- Emergent Wetland	This map class assessed at 88% / 85%, with 5 points identified as ponds from photo signatures in Spring 1997 determined to be accurate as wetlands in Summer 1998. The class is considered to be adequate as mapped.
15-Little Bluestem - Grama Grasses - Threadleaf Sedge Grassland	This map class assessed at 78% / 56%, with most error falling under map class 16 and occurring in the Palmer Creek subunit.
16/19-Western Wheatgrass Alliance / Western Wheatgrass - Green Needlegrass Grassland	This map class combination assessed at 78% / 75% with most error falling under map class 18. Map class 19 is "Park special" with no conclusive photo signature to separate it from map class 16. This mixed grassland type became very confusing in the Palmer Creek subunit of the Park.
17-Introduced Grassland	This map class assessed at 65% / 71%, with most error falling under map class 16. Much of the error associated with grasslands in the Palmer Creek subunit (map classes 15 and 16) could probably be resolved by placing them in this map class.

Table 6. (continued)

18-Blue Grama Grassland	This map class assessed at 55% / 65%, with most error falling under map classes 16 and 17. Some error may be expected from Spring aerial photography enhancing cool season grass (western wheatgrass and Kentucky bluegrass) signatures over the warm season grass (blue grama).
21-Soapweed Yucca / Prairie Sandreed Shrub Grassland	This map class assessed at 56% / 90%, with most error falling under map class 16. This error likely results from an interpretation for grassland rather than very sparse shrubland.
25-Silver Buffaloberry Shrubland	This map class assessed at 60% / 75%, with most error related to the very mixed nature of shrublands and this class being included in larger mapping units with other shrub types.
31-Silver Sagebrush / Western Wheatgrass Shrubland	This map class assessed at 100% / 82%, and is considered adequate as mapped.
32-Sand Sagebrush / Prairie Sandreed Shrubland	This map class assessed at 89% / 89% and is considered adequate as mapped.
33-Rabbitbrush Shrubland	This small map class was not sampled due to very limited distribution in the study area.
34-Chokechery (American Plum) Shrubland	This map class assessed at 56% / 83% accuracy, reflecting the very mixed nature of shrublands and this class being included in larger mapping units with other shrub and small tree types.
35-Three-leaved Sumac / Threadleaf Sedge Shrub Grassland	This map class assessed at 78% / 54% accuracy, reflecting the very mixed nature of shrublands and this class being included with other shrub types.
37-Western Snowberry Shrubland	This map class assessed at 63% / 71% accuracy, reflecting the very mixed nature of shrublands and this class being included with other shrub types.

Table 6. (continued)

38-Sandbar Willow Temporarily Flooded Shrubland	Only one site was sampled for this map class and it had been mapped as a land use class (56) that includes small drainages.
39- Greasewood / Western Wheatgrass Shrubland	Only three sites were sampled for this map class and it was included in the silver sagebrush (31) type and three-leaved sumac (35) type. This reflects the very mixed nature of shrublands in the park.
41-Eastern Cottonwood - (Peachleaf Willow) / Sandbar Willow Woodland	This map class was assessed at 50% / 100% accuracy, with no clear alternative map class chosen. This is partly due to different age classes of trees resembling shrub communities.
42-Green Ash - (American Elm) / Chokecherry Woodland	This map class was assessed at 100% / 79% accuracy and is considered to be adequate as mapped. Minor errors resulted where this class was confused with tall, mixed shrubs or with short cottonwood woodlands.
43/44-Ponderosa Pine / Rocky Mountain Juniper Woodland - Rocky Mountain Juniper / Little-seed Ricegrass Woodland	This map class combination assessed at 100% / 98% accuracy. Map class 43 is considered a "Park special" since the majority of ponderosa pine in the study area are short and appear as mature Rocky mountain junipers on the photos.

Table 7. Contingency table (error matrix) for BADL vegetation mapping accuracy assessment.

		Reference Data (Accuracy Assessment Class)																					Total	Comission	90% Confidence	
	Map Unit Code	1	2	12	14	15	16-19	17	18	21	25	31	32	33	34	35	37	38	39	41	42	43-44	N	Error % Correct	Interval -	Interval +
S	1	13					1																14	92.9	73.9	99.3
a	2		64			1	1						1			1							68	94.1	97.0	91.2
m	12			2																			2	100	31.6	100
p	14				22		2										1			1			26	84.6	70.1	93.1
l	15					14	8		3														25	56.0	38.9	74.5
e	16-19	1		3	2	3	102	5	10	4					1								131	75.0	78.7	71.3
	17						8	15	1	1													25	60.0	39.0	75.4
D	18						7	1	17	1													26	65.4	46.0	79.1
a	21									9						1							10	90.0	64.8	99.0
t	25										3									1			4	75.0	32.0	97.4
a	31											14							2	1			17	82.4	63.6	93.3
	32						1						8										9	88.9	60.9	98.8
(M	33																						0	NA	-	-
a	34									1					5								6	83.3	45.8	98.3
p	35						1				2					7	2		1				13	53.8	27.6	75.4
	37				1										1		5						7	71.4	31.6	92.1
C	38																						0	NA	-	-
l	39																						0	NA	-	-
a	41																			6			6	100	65.5	100
s	42														2					2	15		19	78.9	61.3	90.5
s)	43-44																			1		48	49	98.0	95.8	100
	Total N	14	64	5	25	18	131	21	31	16	5	14	9	0	9	9	8	1*	3	12	15	48	458			

	1	2	12	14	15	16-19	17	18	21	25	31	32	33	34	35	37	38	39	41	42	43-44
Omission Error % Correct	92.9	100	40.0	88.0	77.8	77.9	71.4	54.8	56.3	60.0	100	88.9	NA	55.6	77.8	62.5	0*	0	50.0	100	100
90% Confidence Interval -	73.9	92.0	11.2	74.5	58.1	82.0	54.2	63.7	30.5	24.7	83.7	60.9	-	23.2	48.5	25.5	0	0	27.1	84.6	85.5
+	99.3	100	75.3	95.5	89.9	73.8	87.0	45.9	76.5	88.8	100	98.8	-	79.0	93.9	85.3	90.0	53.6	72.9	100	100

Total Correct = 369

OVERALL TOTAL ACCURACY = 80.6 %

OVERALL KAPPA INDEX = 78.2%

OVERALL TOTAL ACCURACY 90% UPPER AND LOWER CONFIDENCE INTERVAL = + 82.4 % - 78.8 %

* Represents 1 AA point taken for class 38. This point was mapped incorrectly as a land-use class (reservior). This point is included in the total sample size (N) and is used to calculate Overall Total Accuracy.

(Map unit combinations of 16 -19 and 43-44 were used for the A.A. since classes 19 and 43 were only seperated as a Park management concern, on a "where known basis".)

(Omission and Commision errors were calculated using total accuracy)

DISCUSSION

Badlands National Park lies within the Northern Great Plains grasslands between and adjacent to the White and Cheyenne River drainages. The Park occupies relatively level plains from the eastern and central portions of this study area continuing to Red Shirt Table on the west. Here the Plains grasslands merge into the lower elevations of the Black Hills escarpment. The geology and topography of this region creates an interesting landscape mosaic of plant associations. This complexity is compounded by the land use differences between the North (protected and lightly grazed by bison in the Sage Creek Wilderness Area) and South (grazed by livestock) Units of the Park and the introduction of exotic, perennial grasses. Together, these presented unique challenges in terms of vegetation classification, photographic interpretation, and digital transfer that had to be met and addressed in the USGS-NPS National Park vegetation mapping effort. Final accuracy for the vegetation map reflects the time and effort required and given by researchers to understand and appreciate the complex nature of BADL vegetation.

The importance of developing this database should not be underestimated; during the 2 ½-year course of this study, the following data requests and ideas were received by RSGIG:

- draft vegetation plots to be used by the Park Interpretive Coordinator;
- aerial photographs to search for potential ordinance sites for the Badlands Bombing Range Project;
- aerial photographs to review habitat for lambing by bighorn sheep ewes;
- draft vegetation plots to correlate with information on soils appropriate for emergency take-off and landing by military aircraft;
- aerial photographs and draft vegetation plots to examine prairie dog town mapping protocols and proper photograph scale on Northern Cheyenne Tribal lands;
- black-footed ferret introduction program requests for aerial photographs and draft vegetation plots;
- draft vegetation plots and aerial photographs for a burrowing owl distribution study,
- draft vegetation database for fire management program development; and
- a proposal to cross-match this vegetation database with a 1990 vegetation study prepared by Batt, 1991 and Butler and Batt, 1995.

Vegetation Classification and Characterization

Most of the vegetation found in the Badlands study area was classified using existing community types for the Northern Great Plains. In a few cases, new types were described and created which also occur outside the study area but were not identified and/or described prior to this project. For example, the work with prairie dog town disturbed community vegetation at BADL supported similar work being conducted simultaneously at WICA. As a result, the Purple three-awn / Fetid marigold Disturbed Vegetation type was created for WICA, and could now be used to describe similar vegetation at BADL.

The ponderosa pine type for BADL is not typical when compared to those found at higher elevations in the Black Hills and further south on the Pine Ridge Reservation. The stands in the Park can then be thought of as representing the northernmost extension of ponderosa pine in this region of the country. At BADL, ponderosa pines either provide a canopy layer over Rocky Mountain juniper or simply intersperse among Rocky Mountain juniper trees. It was never found in any abundance as a separate type devoid of Rocky Mountain juniper. In fact, the pine trees tended to be short statured with round crowns, similar to the growth form of mature junipers. Based on these observations and the difficulty in interpreting ponderosa pine trees into a separate map class with accuracy, this type at BADL was viewed as a variation of the Rocky Mountain juniper woodland type but retained as a mapping unit.

Several shrub types occur within the BADL study area occurring in relatively low abundance, but are recognizable during on-ground surveys. However, to map these types from one another often requires interpreting below the mmu requirement of 0.5 hectares. Although it is useful for park managers to know the amount and location of different shrub types, these types are often intermixed in a mosaic of dominant species. A case could be made for having only five shrub classes at BADL instead of the current ten. The five would be silver sagebrush shrubland, sand sagebrush shrubland, yucca sparse shrubland, western snowberry shrubland, and a mixed shrub vegetation complex or mosaic. The mixed class would combine shrub dominants, including American plum, rabbitbrush, three-leaved sumac, and greasewood. Finally, sandbar willow could be combined with either cottonwood - willow woodlands or with wetlands map classes since they all grow in similar habitat. For the purposes of this study, all ten shrub classes regardless of their accuracy were mapped and retained in the final database.

Grasslands within BADL can be extremely simple to interpret and map, such as the western wheatgrass alliance encompassing the lower elevations of the North Unit, or they can be extremely confusing. Particularly puzzling grassland types occur where exotic grass species intermix with native grassland species, as on the uplands of the Palmer Creek sub-unit of the South Unit. Here, the soils suggest typical habitat for little bluestem and sideoats grama with western wheatgrass occupying swales and playas and the area was so interpreted. However, with heavy, annual grazing and the introduction of exotic grasses this area actually supports a very mixed grassland of Kentucky bluegrass, Japanese brome, western wheatgrass, green needlegrass, little bluestem, and sideoats grama. This mixture of species led researchers to place the grasslands under the western wheatgrass alliance, resulting in a rather large error determined during accuracy assessment for this area. Future studies of the vegetation in the Palmer Creek sub-unit should focus on the species composition and how it changes over time with respect to grazing pressures. In this way, an appropriate NVCS association and corresponding map class can be applied that better describe the actual long-term dominant grasses as recognized in the field.

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 classes based on complex signatures. Vegetation characteristics that can be seen on aerial photography are not necessarily the same as those apparent on the ground and vice versa. Effective fieldwork and map verification work aided enormously in developing the map units and discerning the inherent variability of each photographic signature.

The final mapping scheme for BADL contains 5 basic elements:

- NVCS associations represented by an unique photo-signature, *e.g.,* silver sagebrush / western wheatgrass shrubland;
- multiple NVCS associations that together are represented by unique signature, *e.g.,* western wheatgrass grassland alliance;
- NVCS associations that could not be consistently recognized on the aerial photography, but were mapped at known locations for the benefit of the park's management *e.g.,* western wheatgrass - green needlegrass grasslands and ponderosa pine / rocky mountain juniper woodlands.
- wildlife habitat units that were also identified as management concerns, *e.g.,* prairie dog town complex; and
- geologic formations and land-use classes that were not addressed by the NVCS.

At the time of aerial overflight (Spring 1997), large rainfall events had occurred which influenced several photo signatures. Small reservoirs and dugouts were completely full of water and were interpreted under map class 57. Instead of the typical blue to black range of color signatures for water, signatures ranged from milky white to black, because of white sediments washed into some reservoirs and dugouts. During the accuracy assessment (Summer 1998), data points taken in five of these reservoirs and dugouts indicated cattail - bulrush wetland species were present instead of open water. Also, as a result of this heavy rainfall in Spring 1997, intermittent drainages (map class 56) in some areas were scoured into wide channels (or new sediments were deposited over existing vegetation) resulting in very wide drainage bottoms when interpreted using the pure white photo signature. These drainages appeared to be much wider than the perennial rivers flowing near the park, causing some concerns among vegetation map users at the Park.

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 South Unit and all environs), moisture gradients, presence and density of annual grasses, forbs, and shrubs, and soil diversity result in several photographic signatures for each grassland class. It was apparent early in this study, that western wheatgrass / green needlegrass could not be easily separated from other western wheatgrass associations. This is largely because green needlegrass varies greatly in density from one site to another. An agreement to map western wheatgrass /

green needlegrass where it was observed during fieldwork was accepted. However, the class required accuracy assessment within the larger western wheatgrass alliance to insure adequate coverage and to avoid error related to incomplete coverage.

Another grassland type that presented similar challenges is the blue grama grassland association. This type is confined to a few dry plateaus, edges of buttes, sandhills, and ridges within BADL and on some grazed areas in the environs. Here the photo signature is very similar to that of the western wheatgrass alliance, but appearing Adrier@. Rather than combining the two types into a complex, the blue grama association was primarily interpreted from the aerial photography based on a combination of landscape position, location and signature.

Seasonal changes from the time of the aerial photography (June 1997) to the collection of accuracy assessment data (August 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 B brown stems in the fall. The aerial photography records spring phenology where western wheatgrass and Kentucky bluegrass are the dominant 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. This may in part explain some of the error associated between map class 15 and map class 16\19. A similar seasonal phenomenon was also witnessed with respect to the vegetation occurring on badlands formations. In the spring, exotic annuals, particularly kochia (*Kochia scoparia*) and Russian thistle (*Salsola iberica*), were absent but gradually became quite prominent in the summer.

Livestock grazing in the environs and South Unit of the Park influenced not only the grassland composition but also exotic species distribution. Whereas some non-native species may actually increase under grazing pressure (*e.g.* Canada thistle), yellow sweetclover was clearly controlled by cattle grazing. For example, yellow sweetclover dominated the vegetation cover of the North Unit during 1998, with some individual plants and stands of plants exceeding 1.5m tall. However, all grazed lands of the South Unit and adjacent U. S. Forest Service and private lands had no noticeable cover by yellow sweetclover. It was fortuitous that aerial photography was flown during 1997 for this project, when there was little contribution to vegetative cover by yellow sweetclover, because most of the vegetation signatures for the North Unit would have been concealed by this species in the 1998 growing season. As it was, collection of accuracy assessment points during 1998 was made more challenging by hiking through dense stands of yellow sweetclover, while assessing the understory beneath this rank cover.

Digital transfer and registration of information from aerial photographs to a spatial database proved to be a challenging task for BADL. 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.

Comparison of the AA points collected for BADL and the areas covered by individual map units reveal that nine classes represent approximately 90% of the vegetated surface within the Park. These classes (Map Classes 1, 2, 14, 16/19, 17, 32, 42, and 43-44) are considered accurate near or above the desired 80% minimum accuracy level for the program. One rare vegetation type was not sampled for this effort (Map Class 33) due to lack of abundance. Subsequently, the remaining thirteen map classes lend themselves to be further considered to improve map accuracy. These considerations include:

- Combine map classes 25, 33, 34, 35, 37, and 39 into a single Mixed Shrub type, increasing accuracy by 6 additional correct assessment points.
- Consider 4 additional points accurate for Western Wheatgrass Herbaceous Alliance Grassland, mapped as the Yucca Sparse Shrubland Alliance, because of the marginal shrub cover.
- Combine map classes 16 and 18 into a Western Wheatgrass/Blue Grama Herbaceous Alliance type, increasing accuracy by 17 additional correct assessment points.

Two changes were incorporated into the final products for this project. First, map classes 43 and 44 were combined for the accuracy assessment but were retained as separate map units in the vegetation database. On any hardcopy maps produced directly from this data, one color will be used for both classes and a pattern will be placed over map class 43 polygons to distinguish them. 2) Five sparse silver sagebrush accuracy assessment points originally considered incorrect due to lack of silver sagebrush cover were subsequently changed to accurate upon further review of the data.

Recommendations for Future Projects

Several recommendations for future mapping projects have come out of the experience gained at BADL. Determining the size of the project environs in relation to the Park size, layout, and management needs must be examined closely for each vegetation mapping project. In the case of BADL, nearly 80% of the interpretive effort was focused outside the Park, while about 60% of the data transfer was so directed. The percentages differ because interpretation was performed for the entire 1.3 million-acre area project area proposed initially while data transfer occurred over about 920,000 acres.

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 and sampled using 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 Badlands, but at other Parks in South Dakota, as well. It is important for users of the vegetation map that the two classifications be as similar as possible. At the beginning of this project, emphasis was 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 for a portion of the study area was available early so compatibility problems could be addressed.

BIBLIOGRAPHY

Anderson, J.R., E.E. Hardy, J.T. Roach, R.E. Witmer. 1976. A land use and land cover classification system for use with remote sensor data. Geological Survey Professional Paper 964. U.S. Government Printing Office, Washington. 28pp.

Austin, M.P. and P.C. Heyligers. 1989. Vegetation survey design for conservation: gradsect sampling of forests in northeastern New South Wales, Biological Conservation. **50**: 13-32.

Batt, J. E. 1991. *Grassland Community Types of The Sage Creek Wilderness Area, Badlands National Park, South Dakota*. Master=s Thesis Submitted to: Biology Department, The University of South Dakota. Vermillion, SD. 152 pp.

Bessken, 1999. Personal Communication with Jim Von Loh concerning natural resource topics at Badlands National Park.

Butler, J. L. and J. E. Batt. 1995. Final Report: *Grassland Community Types of Badlands National Park, South Dakota*. University of South Dakota. Vermillion, SD. 133 pp.

Cogan, D., H. Marriott, J. Von Loh, and M. Pucherelli. 1999 *USGS-NPS Vegtation Mapping Program, Wind Cave National Park (Final Report)*. Technical Memorandum No. 8260-99-03. U.S. Bureau of Reclamation Technical Service Center. Denver, Colorado.

Daubenmire R. 1959. *A canopy-coverage method of vegetational analysis*. Northwest Science. **23**: 69-82.

DeLorme, 1997. South Dakota Atlas and Gazetteer. DeLorme. Yarmouth, Maine.

Ensz, Edgar H. 1990. Soil Survey of Custer and Pennington Counties, Black Hills Parts, South Dakota. U.S. Dept. of Agriculture, Soil Conservation Service.

Faber-Langendoen, D. and Midwest State Natural Heritage Program Ecologists. 1996. Terrestrial vegetation of the Midwestern United States. From, International Classification of Ecological Communities: Terrestrial Vegetation of the United States, The Nature Conservancy, Arlington, VA, USA. 33 pp. (+ tables).

Federal Geographic Data Committee. 1996. *FGDC Vegetation Classification and Information Standards*. Reston, VA. 35 pp.

Foody, G.M. 1992. *On the compensation for chance agreement in image classification accuracy assessment.* Photogrammetric Engineering and Remote Sensing. **58** (10): 1459-1460.

Gillison, A.N. and K.R.W. Brewer. 1985. The use of gradient directed transects or gradsescts in natural resource survey. Journal of Environmental Management. **20**: 103-127.

Gries, J. P. 1996. *Roadside Geology of South Dakota.* Mountain Press Publishing Company. Missoula, MT. 358 pp.

Hay, A.M. 1979. Sampling designs to test land-use map accuracy, Photogrammetric Engineering and Remote Sensing. **45** (4): 529-533.

McCune, B.and M.J.Mefford. 1997. PC-ORD. Multivariate Analysis of Ecological Data, Version 3.0. MjM Software Design, Gleneden Beach, OR.

Mc Gregor, R., T. Barkley, R. Brooks, and E. Schofield. 1986. *Flora of the Great Plains*. The Great Plains Flora Association. University Press of Kansas. Lawrence, KS. 1392 pp.

Mueller-Dombois, D. and H. Ellenberg. 1974. Aims and Methods of Vegetation Ecology. Wiley. New York.

Natrella, M.G. 1963 *Experimental Statistics*, National Bureau of Standards Handbook 91. U.S. Government Printing Office, Washingtion, DC.

O=Harra, C. C. 1920, revised 1976. *The White River Badlands.* South Dakota School of Mines, Bulletin Number 13, Department of Geology. Argus Printers. Stickney, SD. 277 pp.

Owens, T. 1998. Comments and forms for front-loading accuracy assessment methodology.

Plumb, G. 1997. Badlands National Park and Wall District 1997 Prairie Dog Aerial Photo Interpretation U.S. Government Memorandum.

Snedecor, G.W. and W.G. Cochran. 1976. Statistical Methods. Ames, Iowa: The Iowa State University Press.

Stephens, H. 1973. *Woody Plants of the North Central Plains*. University Press of Kansas. Lawrence, KS. 530 pp.

Story, M. 1999. Facsimile Illustrating New Badlands Project Area Boundary. (Facsimile Communication between NPS-USGS/BRD and US BOR).

The Nature Conservancy and Environmental Research Systems Institute. 1994. *NBS/NPS Vegetation Mapping Program: Accuracy Assessment Procedures.* Arlington, VA.

_____. 1994. *NBS/NPS Vegetation Mapping Program: Field Methods for Vegetation Mapping*. Arlington, VA.

_____. 1994. *NBS/NPS Vegetation Mapping Program: Standardized National Vegetation Classification System*. Arlington, VA.

USDA Soil Conservation Service. 1971. *Soil Survey: Bennett County, South Dakota*. Washington, D. C. 78 pp, plus maps.

_____. 1996. *Soil Survey of Custer and Pennington Counties, Prairie Parts, South Dakota*. Washington, D. C. 288 pp, plus maps.

_____. 1987. *Soil Survey: Jackson County, Northern Part, South Dakota*. Washington, D. C. 216 pp, plus maps.

_____. 1980. *Soil Survey of Fall River County, South Dakota*. Washington, D. C. 192 pp, plus maps.

_____. 1971. *Soil Survey: Shannon County, South Dakota*. Washington, D. C. 92 pp, plus maps.

Van Bruggen, T. 1983. *Wildflowers, Grasses & Other Plants of the Northern Plains and Black Hills*. Badlands Natural History Association. Interior, SD. 97 pp.

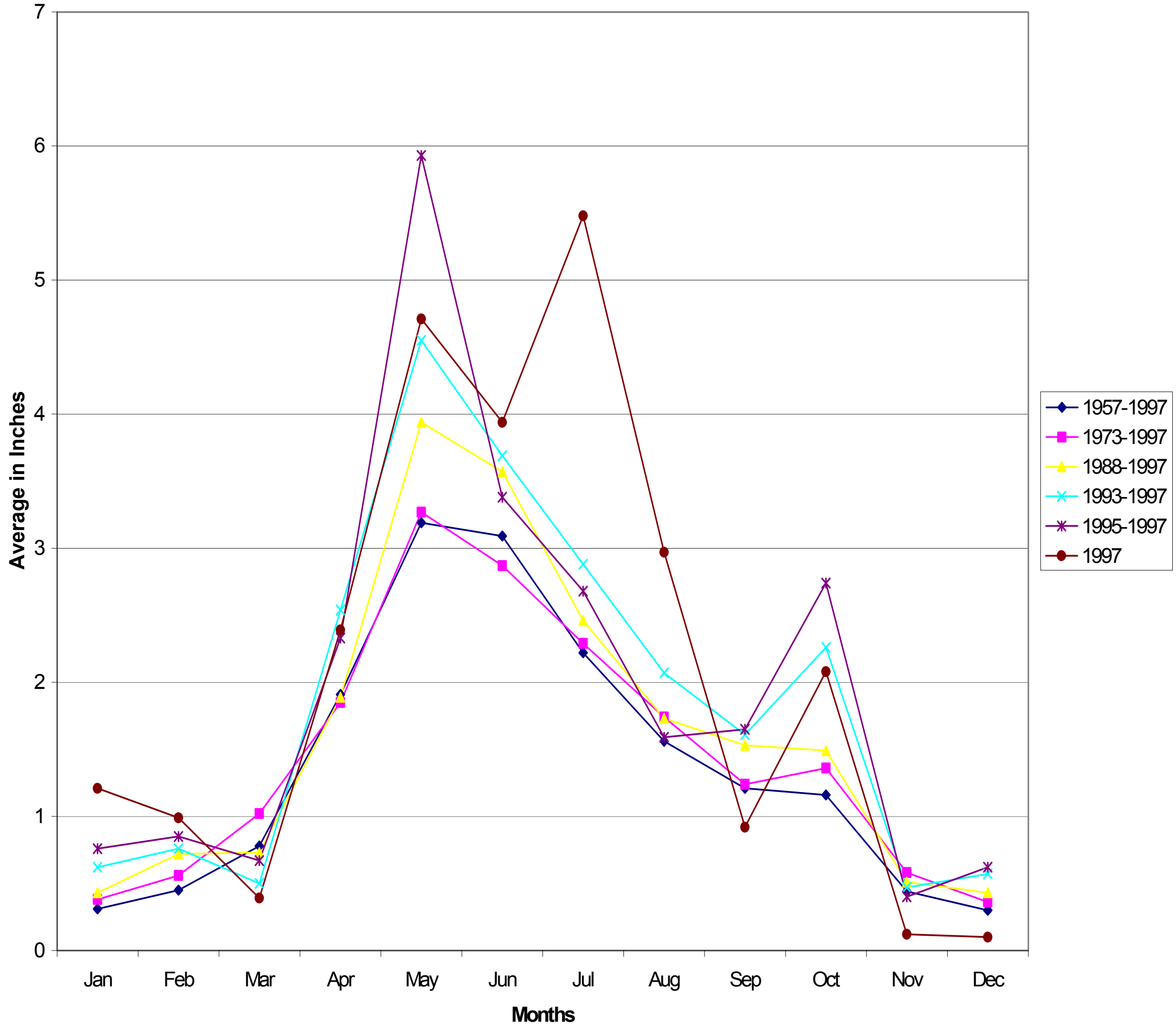
_____. 1976. *Vascular Plants of South Dakota*. Iowa State Press. Ames, IA.

Zar, J.H. 1984. *Biostatistical Analysis*, second edition. Prentice-Hall, Inc., New Jersey, 718.

Appendix 1.

Average Monthly Precipitation Values for Interior, SD.
Comparisons of 1997 values with the last 3, 5, 10, 15, and 40 year averages.

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

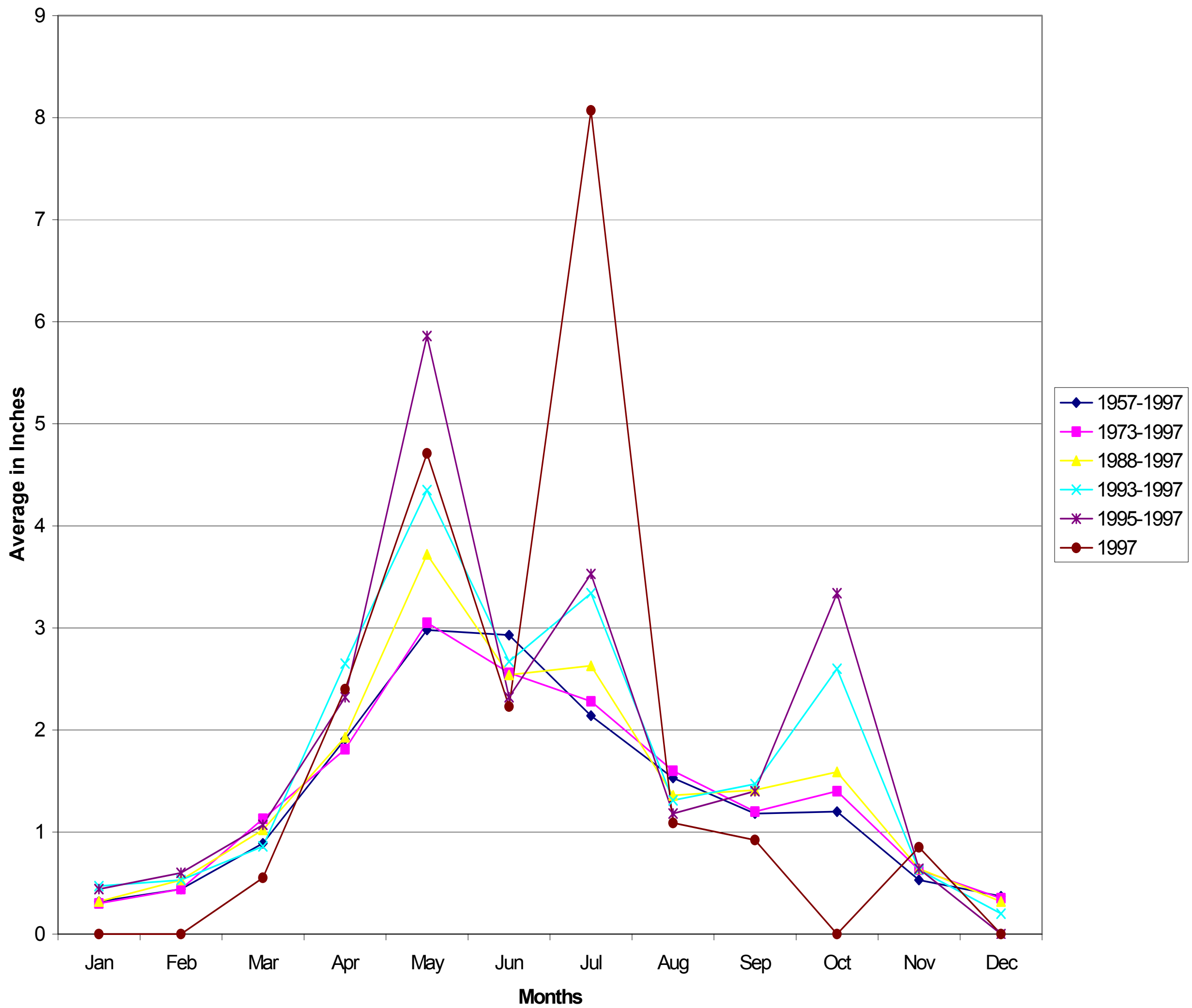


	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1957-1997	0.31	0.45	0.78	1.91	3.19	3.09	2.22	1.56	1.21	1.16	0.44	0.30
1973-1997	0.38	0.56	1.02	1.85	3.27	2.87	2.29	1.74	1.24	1.36	0.58	0.36
1988-1997	0.43	0.72	0.73	1.89	3.94	3.57	2.46	1.73	1.53	1.49	0.51	0.43
1993-1997	0.62	0.76	0.50	2.54	4.55	3.69	2.88	2.07	1.61	2.26	0.47	0.57
1995-1997	0.76	0.85	0.67	2.33	5.93	3.38	2.68	1.59	1.65	2.74	0.40	0.62
1997	1.21	0.99	0.39	2.39	4.71	3.94	5.48	2.97	0.92	2.08	0.12	0.10

Appendix 2.

Average Monthly Precipitation Values for Wasta, SD.
Comparisons of 1997 values with the last 3, 5, 10, 15, and 40 year averages.

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



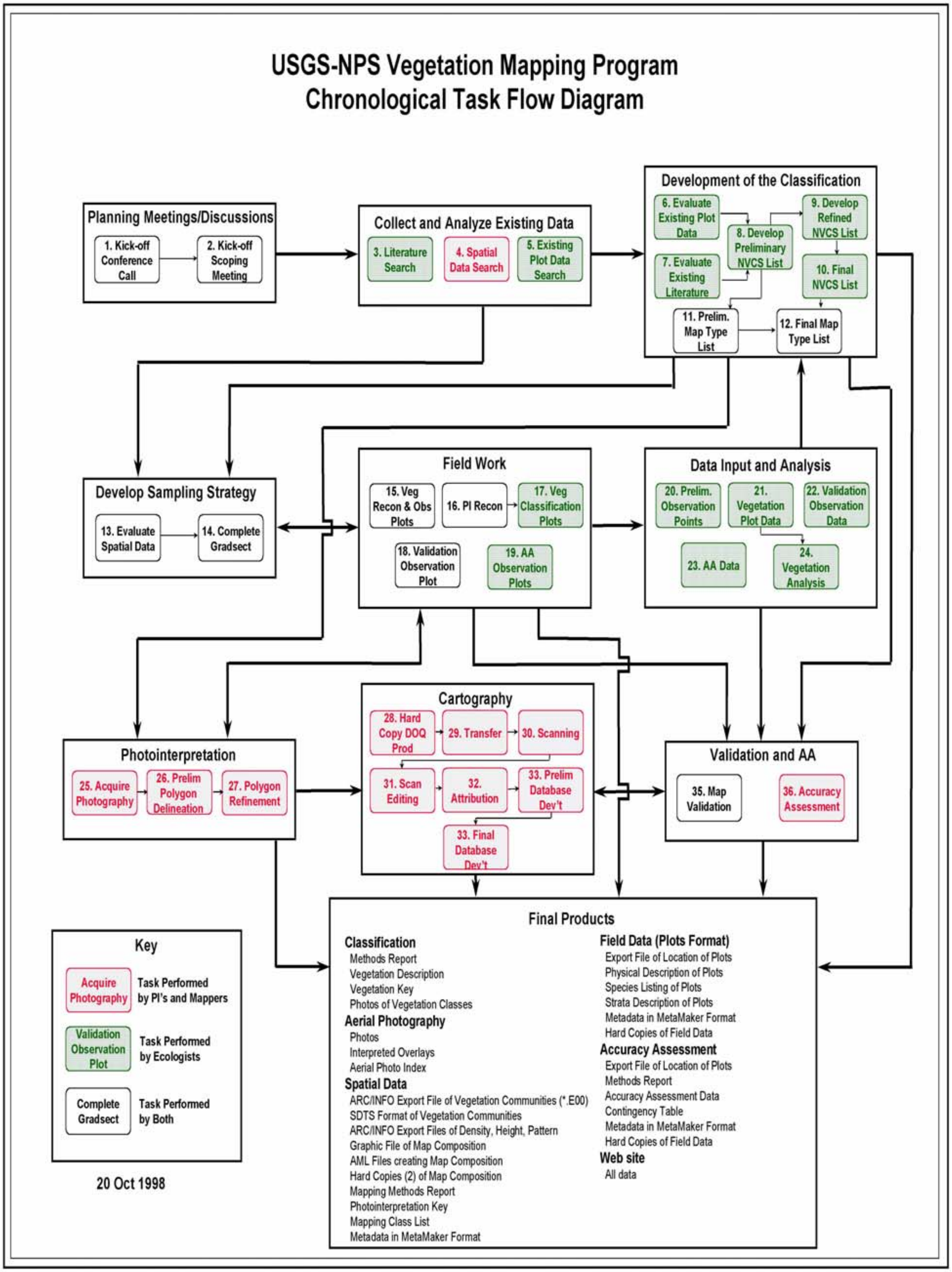
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1957-1997	0.32	0.44	0.89	1.91	2.98	2.93	2.14	1.53	1.18	1.20	0.53	0.37
1973-1997	0.30	0.44	1.13	1.81	3.05	2.56	2.28	1.60	1.20	1.40	0.63	0.35
1988-1997	0.32	0.53	1.02	1.93	3.72	2.54	2.63	1.36	1.41	1.59	0.64	0.32
1993-1997	0.47	0.53	0.86	2.65	4.35	2.67	3.34	1.31	1.47	2.60	0.63	0.20
1995-1997	0.44	0.60	1.07	2.32	5.86	2.32	3.53	1.18	1.40	3.34	0.64	0
1997	-	-	0.55	2.40	4.71	2.23	8.07	1.09	0.92	-	0.85	0

“- ” indicates no average recorded for that month

Appendix 3.

Flowchart of USGS-NPS National Parks Vegetation Program

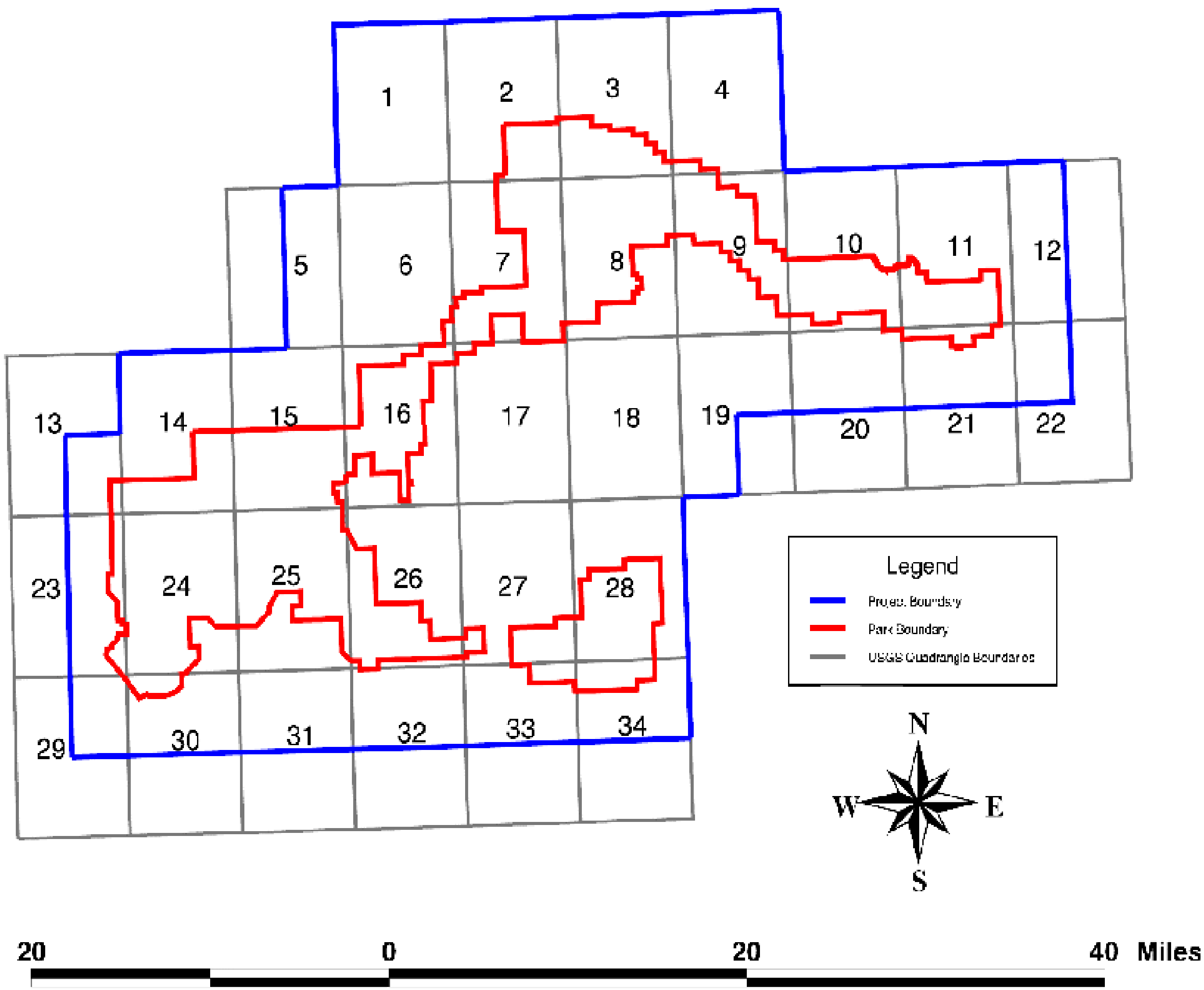
(created by Tom Owens USGS/BRD)


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

Appendix 4.

USGS 7.5-minute topographic quadrangle maps for Badlands National Park and project mapping area.

Map of Badlands National Park, project mapping area, and corresponding USGS quadrangles.



Index to USGS 1:24K Quadrangle Maps:

1 Brennan Flat
2 Quinn Table
3 Quinn Table NE
4 Wall
5 Scenic SW
6 Scenic
7 Quinn Table SW
8 Quinn Table SE
9 Wall SW
10 Wall SE
11 Cottonwood SW
12 Cottonwood SE
13 Red Shirt
14 Red Shirt NE
15 Heutmacher Table
16 Sheep Mountain Table
17 Imlay
18 Bouquet Table
19 Conata
20 Conata NE
21 Interior
22 School Section Butte
23 Red Shirt SW
24 Cuny Table West
25 Cuny Table East
26 Stirk Table
27 Imlay SW
28 Imlay SE
29 Willow Creek NW
30 Willow Creek NW
31 Rockyford NW
32 Rockyford
33 Sharps Corner
34 Evergreen NE

Appendix 5.

Index to 1997, 9x9-inch, color infrared aerial photographs used for vegetation interpretation. Sorted by flight line number and USGS quadrangle.

Aerial photos sorted by flight line number (starting with flight line #3).

Quad Name	Quarter Quad	Flight line and Photos							
Willow Creek NW	ne	3	09 to 15	4	9 to 15	5	9 to 15		
Red Shirt SW	se	3	15 to 22	4	15 to 22	5	15 to 22		
Red Shirt SW	ne	3	22 to 28	4	22 to 28	5	22 to 28		
Red Shirt	se	3	28 to 35	4	28 to 35	5	29 to 35		
Willow Creek NE	nw	5	09 to 15	6	9 to 15	7	9 to 15		
Cuny Table West	sw	5	15 to 22	6	15 to 22	7	15 to 22		
Cuny Table West	nw	5	22 to 28	6	22 to 28	7	22 to 28		
Red Shirt NE	sw	5	29 to 35	6	28 to 35	7	28 to 35		
Red Shirt NE	nw	5	35 to 42	6	35 to 42	7	35 to 42		
Willow Creek NE	ne	7	09 to 15	8	9 to 15	9	9 to 15	10	9 to 15
Cuny Table West	se	7	15 to 22	8	15 to 22	9	15 to 22	10	15 to 22
Cuny Table West	ne	7	22 to 28	8	22 to 28	9	22 to 28	10	22 to 28
Red Shirt NE	se	7	29 to 35	8	28 to 35	9	28 to 35	10	28 to 35
Red Shirt NE	ne	8	35 to 42	9	35 to 42	10	35 to 42		
Rocky Ford NW	nw	10	09 to 15	11	9 to 15	12	9 to 15		
Cuny Table East	sw	10	15 to 22	11	15 to 22	12	15 to 22		
Cuny Table East	nw	10	22 to 28	11	22 to 28	12	22 to 28		
Heutmacher Table	sw	10	29 to 35	11	29 to 35	12	29 to 35		
Heutmacher Table	nw	10	35 to 42	11	35 to 42	12	35 to 42		
Rocky Ford NW	ne	12	09 to 15	13	09 to 15	14	09 to 15		
Cuny Table East	se	12	15 to 22	13	15 to 22	14	15 to 22		
Cuny Table East	ne	12	22 to 28	13	22 to 28	14	22 to 28		
Heutmacher Table	se	12	29 to 35	13	29 to 35	14	29 to 35		
Heutmacher Table	ne	12	35 to 42	13	35 to 42	14	35 to 42		
Scenic SW	se	12	42 to 48	13	42 to 49	14	42 to 48		
Scenic SW	ne	12	48 to 55	13	49 to 55	14	48 to 55		
Rocky Ford	nw	14	09 to 15	15	9 to 15	16	9 to 15	17	9 to 15
Stirk Table	sw	14	15 to 22	15	15 to 22	16	15 to 22	17	15 to 20
Stirk Table	nw	14	22 to 28	15	22 to 28	16	22 to 28	17	22 to 28
Sheep Mt Table	sw	14	29 to 35	15	29 to 35	16	28 to 35	17	29 to 35
Sheep Mt Table	nw	14	35 to 42	15	35 to 42	16	35 to 42	17	35 to 41
Scenic	sw	14	42 to 48	15	42 to 48	16	42 to 48	17	42 to 48
Scenic	nw	14	48 to 55	15	48 to 55	16	49 to 55	17	49 to 55
Sheep Mt Table	sw	14	55 to 57	15	55 to 62	16	55 to 62	17	55 to 62
Brennan Flat	nw	15	62 to 68	16	62 to 68	17	62 to 68		
Rocky Ford	ne	17	09 to 15	18	9 to 15	19	9 to 15		
Stirk Table	se	17	15 to 22	18	15 to 22	19	16 to 23		
Stirk Table	ne	17	22 to 28	18	22 to 28	19	22 to 29		
Sheep Mt Table	se	17	29 to 35	18	29 to 35	19	29 to 35		
Sheep Mt Table	ne	17	35 to 42	18	35 to 42	19	35 to 42		
Scenic	se	17	42 to 48	18	42 to 48	19	42 to 48		
Scenic	ne	17	49 to 55	18	49 to 55	19	49 to 55		
Sheep Mt Table	se	17	55 to 62	18	55 to 62	19	55 to 62		
Sheep Mt Table	ne	17	62 to 68	18	62 to 68	19	62 to 68		
Sharpes Corner	nw	19	09 to 15	20	9 to 15	21	9 to 15		
Imlay SW	sw	19	15 to 22	20	15 to 22	21	15 to 22		
Imlay SW	nw	19	22 to 28	20	22 to 28	21	22 to 28		
Imlay	sw	19	29 to 35	20	29 to 35	21	29 to 35		
Imlay	nw	19	35 to 42	20	35 to 42	21	35 to 42		
Quinn Table SW	sw	19	42 to 48	20	42 to 48	21	42 to 48		
Quinn Table SW	nw	19	49 to 55	20	48 to 55	21	48 to 55		

Quinn Table	sw	19	55 to 62	20	55 to 62	21	55 to 61		
Quinn Table	nw	19	62 to 68	20	62 to 68	21	62 to 68		
Sharpes Corner	ne	21	09 to 15	22	9 to 15	23	9 to 15		
Imlay SW	se	21	15 to 22	22	15 to 22	23	15 to 22		
Imlay SW	ne	21	22 to 28	22	22 to 28	23	22 to 29	24	22,23
Imlay	se	21	29 to 35	22	29 to 35	23	29 to 35		
Imlay	ne	21	35 to 41	22	35 to 42	23	35 to 42		
Quinn Table SW	se	21	42 to 48	22	42 to 48	23	42 to 48		
Quinn Table SW	ne	21	48 to 55	22	48 to 55	23	48 to 55		
Quinn Table	se	21	55 to 61	22	55 to 61	23	55 to 61		
Quinn Table	ne	21	62 to 68	22	62 to 68	23	62 to 68		
Quinn Table NE	nw	23	63 to 68	24	62 to 68	25	62 to 68	26	62 to 68
Evergreen NE	nw	24	09 to 15	25	9 to 15	26	9 to 15		
Imlay SE	sw	24	15 to 22	25	15 to 22	26	15 to 22		
Imlay SE	nw	24	22 to 28	25	22 to 29	26	22 to 28		
Bouguet Table	sw	24	29 to 35	25	29 to 35	26	29 to 35		
Bouguet Table	nw	24	35 to 42	25	35 to 42	26	35 to 42		
Quinn Table SE	sw	24	42 to 48	25	42 to 48	26	42 to 48		
Quinn Table SE	nw	24	48 to 55	25	48 to 55	26	48 to 55		
Quinn Table NE	sw	24	55 to 61	25	55 to 61	26	55 to 61		
Evergreen NE	ne	26	09 to 15	27	9 to 15	28	9 to 15		
Imlay SE	se	26	15 to 22	27	15 to 22	28	15 to 22		
Imlay SE	ne	26	22 to 28	27	22 to 28	28	22 to 29		
Bouguet Table	se	26	28 to 35	27	28 to 35	28	29 to 35		
Bouguet Table	ne	26	35 to 42	27	35 to 42	28	35 to 42		
Quinn Table SE	se	26	42 to 48	27	42 to 48	28	42 to 48		
Quinn Table SE	ne	26	48 to 55	27	48 to 55	28	48 to 55		
Quinn Table NE	se	26	55 to 61	27	55 to 61	28	55 to 61		
Quinn Table NE	ne	26	62 to 68	27	61 to 68	28	62 to 68		
Conata	sw	28	29 to 35	29	29 to 35	30	29 to 35		
Conata	nw	28	35 to 41	29	21 to 28	30	21 to 28		
Wall SW	sw	28	42 to 48	29	28 to 35	30	29 to 35		
Wall SW	nw	28	48 to 55	29	35 to 42	30	35 to 42		
Wall	sw	28	55 to 61	29	42 to 48	30	42 to 48		
Wall	nw	28	62 to 68	29	48 to 55	30	49 to 55		
Conata	ne	30	22 to 28	31	22 to 38	32	22 to 28	33	22 to 28
Wall SW	se	30	29 to 35	31	29 to 35	32	28 to 35	33	29 to 33
Wall SW	ne	30	35 to 42	31	35 to 42	32	35 to 42		
Wall	se	30	42 to 48	31	42 to 48	32	42 to 48		
Wall	ne	30	49 to 55	31	48 to 55	32	48 to 55		
Conata NE	nw	33	22 to 29	34	9 to 15	35	9 to 15		
Wall SE	sw	33	29 to 35	34	15 to 22	35	15 to 22		
Wall SE	nw	33	36 to 42	34	22 to 28	35	22 to 28		
Conata NE	ne	35	09 to 15	36	9 to 15	37	9 to 15		
Wall SE	se	35	15 to 22	36	15 to 22	37	15 to 22		
Wall SE	ne	35	22 to 28	36	22 to 28	37	22 to 28		
Interior	nw	37	09 to 15	38	9 to 15	39	9 to 15		
Cottonwood SW	sw	37	15 to 22	38	15 to 22	39	15 to 22		
Cottonwood SW	nw	37	22 to 28	38	22 to 28	39	22 to 28		
Interior	ne	39	09 to 15	40	9 to 15	41	9 to 15	42	9 to 15
Cottonwood SW	se	39	16 to 22	40	15 to 22	41	15 to 22	42	15 to 22
Cottonwood SW	ne	39	22 to 28	40	22 to 29	41	22 to 28	42	22 to 28
Cottonwood SE	sw	42	15 to 22	43	15 to 22	44	15 to 22		
Cottonwood SE	nw	42	22 to 28	43	22 to 28	44	22 to 28		
School Section Butte	nw	42	9 to 15	43	9 to 15	44	9 to 15		

(R&C: Reviewed and Corrected)

Aerial photos sorted by USGS Quadrangle Name

Quad Name	QQ	Photos							
Bouguet Table	nw	24	35 to 42	25	35 to 42	26	35 to 42		
Bouguet Table	ne	26	35 to 42	27	35 to 42	28	35 to 42		
Bouguet Table	se	26	28 to 35	27	28 to 35	28	29 to 35		
Bouguet Table	sw	24	29 to 35	25	29 to 35	26	29 to 35		
Brennan Flat	nw	15	62 to 68	16	62 to 68	17	62 to 68		
Bouguet Table	ne	17	62 to 68	18	62 to 68	19	62 to 68		
Bouguet Table	se	17	55 to 62	18	55 to 62	19	55 to 62		
Bouguet Table	sw	14	55 to 57	15	55 to 62	16	55 to 62	17	55 to 62
Conata	nw	28	35 to 41	29	21 to 28	30	21 to 28		
Conata	ne	30	22 to 28	31	22 to 38	32	22 to 28	33	22 to 28
Conata	sw	28	29 to 35	29	29 to 35	30	29 to 35		
Conata NE	nw	33	22 to 29	34	9 to 15	35	9 to 15		
Conata NE	ne	35	9 to 15	36	9 to 15	37	9 to 15		
Cottonwood SE	nw	42	22 to 28	43	22 to 28	44	22 to 28		
Cottonwood SE	sw	42	15 to 22	43	15 to 22	44	15 to 22		
Cottonwood SW	nw	37	22 to 28	38	22 to 28	39	22 to 28		
Cottonwood SW	ne	39	22 to 28	40	22 to 29	41	22 to 28	42	22 to 28
Cottonwood SW	se	39	16 to 22	40	15 to 22	41	15 to 22	42	15 to 22
Cottonwood SW	sw	37	15 to 22	38	15 to 22	39	15 to 22		
Cuny Table East	nw	10	22 to 28	11	22 to 28	12	22 to 28		
Cuny Table East	ne	12	22 to 28	13	22 to 28	14	22 to 28		
Cuny Table East	se	12	15 to 22	13	15 to 22	14	15 to 22		
Cuny Table East	sw	10	15 to 22	11	15 to 22	12	15 to 22		
Cuny Table West	nw	5	22 to 28	6	22 to 28	7	22 to 28		
Cuny Table West	ne	7	22 to 28	8	22 to 28	9	22 to 28	10	22 to 28
Cuny Table West	se	7	15 to 22	8	15 to 22	9	15 to 22	10	15 to 22
Cuny Table West	sw	5	15 to 22	6	15 to 22	7	15 to 22		
Evergreen NE	nw	24	9 to 15	25	9 to 15	26	9 to 15		
Evergreen NE	ne	26	9 to 15	27	9 to 15	28	9 to 15		
Heutmacher Table	nw	10	35 to 42	11	35 to 42	12	35 to 42		
Heutmacher Table	ne	12	35 to 42	13	35 to 42	14	35 to 42		
Heutmacher Table	se	12	29 to 35	13	29 to 35	14	29 to 35		
Heutmacher Table	sw	10	29 to 35	11	29 to 35	12	29 to 35		
Imlay	nw	19	35 to 42	20	35 to 42	21	35 to 42		
Imlay	ne	21	35 to 41	22	35 to 42	23	35 to 42		
Imlay	se	21	29 to 35	22	29 to 35	23	29 to 35		
Imlay	sw	19	29 to 35	20	29 to 35	21	29 to 35		
Imlay SE	nw	24	22 to 28	25	22 to 29	26	22 to 28		
Imlay SE	ne	26	22 to 28	27	22 to 28	28	22 to 29		
Imlay SE	se	26	15 to 22	27	15 to 22	28	15 to 22		
Imlay SE	sw	24	15 to 22	25	15 to 22	26	15 to 22		
Imlay SW	nw	19	22 to 28	20	22 to 28	21	22 to 28		
Imlay SW	ne	21	22 to 28	22	22 to 28	23	22 to 29	24	22,23
Imlay SW	se	21	15 to 22	22	15 to 22	23	15 to 22		
Imlay SW	sw	19	15 to 22	20	15 to 22	21	15 to 22		
Interior	nw	37	9 to 15	38	9 to 15	39	9 to 15		
Interior	ne	39	9 to 15	40	9 to 15	41	9 to 15	42	9 to 15
Quinn Table	nw	19	62 to 68	20	62 to 68	21	62 to 68		
Quinn Table	ne	21	62 to 68	22	62 to 68	23	62 to 68		
Quinn Table	se	21	55 to 61	22	55 to 61	23	55 to 61		
Quinn Table	sw	19	55 to 62	20	55 to 62	21	55 to 61		
Quinn Table NE	nw	23	63 to 68	24	62 to 68	25	62 to 68	26	62 to 68

Quinn Table NE	ne	26 62 to 68	27 61 to 68	28 62 to 68	
Quinn Table NE	se	26 55 to 61	27 55 to 61	28 55 to 61	
Quinn Table NE	sw	24 55 to 61	25 55 to 61	26 55 to 61	
Quinn Table SE	nw	24 48 to 55	25 48 to 55	26 48 to 55	
Quinn Table SE	ne	26 48 to 55	27 48 to 55	28 48 to 55	
Quinn Table SE	se	26 42 to 48	27 42 to 48	28 42 to 48	
Quinn Table SE	sw	24 42 to 48	25 42 to 48	26 42 to 48	
Quinn Table SW	nw	19 49 to 55	20 48 to 55	21 48 to 55	
Quinn Table SW	ne	21 48 to 55	22 48 to 55	23 48 to 55	
Quinn Table SW	se	21 42 to 48	22 42 to 48	23 42 to 48	
Quinn Table SW	sw	19 42 to 48	20 42 to 48	21 42 to 48	
Red Shirt	SE	3 28 to 35	4 28 to 35	5 29 to 35	
Red Shirt NE	nw	5 35 to 42	6 35 to 42	7 35 to 42	
Red Shirt NE	ne	8 35 to 42	9 35 to 42	10 35 to 42	
Red Shirt NE	se	7 29 to 35	8 28 to 35	9 28 to 35	10 28 to 35
Red Shirt NE	sw	5 29 to 35	6 28 to 35	7 28 to 35	
Red Shirt SW	ne	3 22 to 28	4 22 to 28	5 22 to 28	
Red Shirt SW	se	3 15 to 22	4 15 to 22	5 15 to 22	
Rocky Ford	nw	14 9 to 15	15 9 to 15	16 9 to 15	17 9 to 15
Rocky Ford	ne	17 9 to 15	18 9 to 15	19 9 to 15	
Rocky Ford NW	nw	10 9 to 15	11 9 to 15	12 9 to 15	
Rocky Ford NW	ne	12 9 to 15	13 9 to 15	14 9 to 15	
Scenic	nw	14 48 to 55	15 48 to 55	16 49 to 55	17 49 to 55
Scenic	ne	17 49 to 55	18 49 to 55	19 49 to 55	
Scenic	se	17 42 to 48	18 42 to 48	19 42 to 48	
Scenic	sw	14 42 to 48	15 42 to 48	16 42 to 48	17 42 to 48
Scenic SW	ne	12 48 to 55	13 49 to 55	14 48 to 55	
Scenic SW	se	12 42 to 48	13 42 to 49	14 42 to 48	
School Section Butte	nw	42 9 to 15	43 9 to 15	44 9 to 15	
Sharpes Corner	nw	19 9 to 15	20 9 to 15	21 9 to 15	
Sharpes Corner	ne	21 9 to 15	22 9 to 15	23 9 to 15	
Sheep Mt Table	nw	14 35 to 42	15 35 to 42	16 35 to 42	17 35 to 41
Sheep Mt Table	ne	17 35 to 42	18 35 to 42	19 35 to 42	
Sheep Mt Table	se	17 29 to 35	18 29 to 35	19 29 to 35	
Sheep Mt Table	sw	14 29 to 35	15 29 to 35	16 28 to 35	17 29 to 35
Stirk Table	nw	14 22 to 28	15 22 to 28	16 22 to 28	17 22 to 28
Stirk Table	ne	17 22 to 28	18 22 to 28	19 22 to 29	
Stirk Table	se	17 15 to 22	18 15 to 22	19 16 to 23	
Stirk Table	sw	14 15 to 22	15 15 to 22	16 15 to 22	17 15 to 20
Wall	nw	28 62 to 68	29 48 to 55	30 49 to 55	
Wall	ne	30 49 to 55	31 48 to 55	32 48 to 55	
Wall	se	30 42 to 48	31 42 to 48	32 42 to 48	
Wall	sw	28 55 to 61	29 42 to 48	30 42 to 48	
Wall SE	nw	33 36 to 42	34 22 to 28	35 22 to 28	
Wall SE	ne	35 22 to 28	36 22 to 28	37 22 to 28	
Wall SE	se	35 15 to 22	36 15 to 22	37 15 to 22	
Wall SE	sw	33 29 to 35	34 15 to 22	35 15 to 22	
Wall SW	nw	28 48 to 55	29 35 to 42	30 35 to 42	
Wall SW	ne	30 35 to 42	31 35 to 42	32 35 to 42	
Wall SW	se	30 29 to 35	31 29 to 35	32 28 to 35	33 29 to 33
Wall SW	sw	28 42 to 48	29 28 to 35	30 29 to 35	
Willow Creek NE	nw	5 9 to 15	6 9 to 15	7 9 to 15	
Willow Creek NE	ne	7 9 to 15	8 9 to 15	9 9 to 15	10 9 to 15
Willow Creek NW	ne	3 9 to 15	4 9 to 15	5 9 to 15	

R&C: Reviewed and Corrected

Appendix 6.

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			
	Tidal	Non-Tidal		Salinity/Halinity Modifiers
____Upland	____Irregularly Exposed	____Permanently Flooded	____Saturated	
____Riverine	____Regularly Flooded	____Semipermanetly Flooded	____Seasonally Flooded/Saturated	____Saltwaters
____Palustrine	____Irregularly Flooded	____Seasonally / Temporarily Flooded		____Brackish
____Lacustrine	____Unknown		____Intermittenly Flooded	____Freshwater

Environmental Comments:	Unvegetated Surface: *(please use the cover scale below)*
	____% Bedrock ____% Litter, duff ____% Wood (> 1 cm)
	____% Large rocks (cobbles, boulders > 10 cm)
	____% Small rocks (gravel, 0.2-10 cm)
	____% Sand (0.1-2 mm)
	____%
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	____Broad-leaved	____Forest	01 0 - 10%	01 < 0.5 m
____Evergreen	____Needle-leaved	____Woodland	02 10 - 25%	02 0.5 -1 m
____Cold-deciduous	____Microphyllous	____Shrubland	03 25 - 60%	03 1-2 m
____Drought-deciduous	____Graminoid	____Dwarf Shrubland	04 60 - 100%	04 2-5 m
____Mixed evergreen - cold-deciduous	____Forb	____Herbaceous		05 5-10 m
____Mixed evergreen - drought-deciduous	____Pteridophyte	____Nonvascular		06 10-15 m
		____Sparsely Vegetated		07 15-20 m
				08 20-35 m
				09 35-50 m
Herbs				10 > 50 m
____Annual				
____Perennial				

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 7.

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			
	Tidal	Non-Tidal		Salinity/Halinity Modifiers
____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 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 9.

Bureau of Reclamation's RSGIG National Parks GIS Database Design, Layout, and Procedures

(Created by Doug Crawford and Jay Carlson of the Bureau of Reclamation's RSGIG 1997)
(Revised 01-19-98)

Parks GIS Database
Design, Layout, and Procedures

I. Design and Layout

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. For example, if you need to designate different datum and zone, use suffix _z14d27. 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 (i.e.; for Badlands it is badl) or the workspace name (i.e.: 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 USGS quads.

Naming convention: biology/<quadname>/<quadname>_veg#
where # indicates the quarter quad 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 wich 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 (Gradsect 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 quarter quad 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 ArcInfo aml menus particular to its project. All menus associated with the shell menu are not located here - see 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 on screen digitizing 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) therefore 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 and 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 (e.g.: woodland) x-coord and y-coord added with addxy command

6. Special considerations:

6.1) Note, ArcInfo=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 were sometimes 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 AML's and MENU's. 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 if not all of your ArcInfo work. To use it, you must have shell.aml in your project directory and type &r shell from the arc prompt. Note, the database setup conventions mentioned under items 4. and 5. above must be maintained for shell.aml to function properly.

II. Digital Orthophoto Quarter Quads

The parks projects will be using doqqs as the basemap for transfer of information from the CIR photos to the GIS database. The images are stored on CD-ROM's As mentioned above, the naming convention for the doqqs 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-ROMs (from USGS) do not match this format and will need to be renamed. The CD-ROMs also do not contain the needed .hdr files. The shell menu has an Aux 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 ArcInfo:

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 yet made an executable file 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, therefore:

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 do not 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 line work onto a geo-registered map base. Three of those methods include: (1) heads-up digitizing, (2) use of a zoom transfer scope or 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 ortho-photo, 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-photo, in which case the operator must estimate the shape and location of the line work. 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 that projects the image of an air photo onto a map base (ortho-photo, 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 ortho-photo 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 ortho-photo can be dark and consequently the projected line to be traced is difficult to see. It can be difficult to set the scale precise enough to do all but a small area, and either the photo or the map must be shifted to the next small area. The tracing of one line with another introduces an additional, but small 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 ortho-photo. If the scale of the overlay can be adjusted to the scale of the ortho-photo, then the lines should match features of the ortho-photo 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 ortho-photo (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 ortho-photo map. 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 ortho-photo map, 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. 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.

<u>B. Procedures and Techniques</u>.

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 usually means 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.

<u>B.1 Manual Method</u>.

> B.1.1) Mark photo control points (i.e., road junctions, farmhouses, boulders, other identifiable small points that do not 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 Black and White 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 line work 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 ortho-photoquad 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 photo-control 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 scanned 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 so 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 ortho-photoquad 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 fine (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) ortho-photoquad features. You can use the multiple-select command in ArcEdit to select both the labels and the arcs simultaneously for movement/rotation. Do not forget to make your snap distance small so that lines do not snap together inappropriately.

B.1.8) Once things line up approximately (i.e., the best you can obtain from shift, rotate, and scale), add links from the label locations to the same feature locations on the (backdrop) ortho-photoquad. The more links, the better. Link any additional features you can make out (that are unlikely to have changed) between coverage and ortho-photoquad, 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 correct and you do not need 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

"editfeature link" and "add" 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 does not produce the desired result.
B.1.9) Use the adjust command in ArcEdit to rubber sheet. Make sure snap distance is very small. If the results are poor, 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 line work. Naming convention for this coverage should be:
p####_arcs where #### is the photo number.

<u>B.2 Automated Method using AML</u>.

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, i.e., 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, 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 line-work as needed to clean up dangles and unclosed polygons that may not have come through 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, i.e., is the RMS error acceptable. If the RMS value is not acceptable, you will need to stop and move the labels to more accurate locations or create new ones until an acceptable RMS error is reached. When completed, this step creates an 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/labels so this step adds links that will be used to adjust or rubber-sheet the line work according to the new (transformed) tic locations.

The edit cover is ***p####_2_xfrm*** and the back cover 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, i.e., how well does the line work match features on the doqq. If everything looks ok and only minor changes are needed to the line work, type &return and the program will 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 line work should be cleaned. 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 labels 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 proper 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 line work 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 than one _veg# coverage if the _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 doqqs 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 edit coverage and then reverse coverages so that the _veg# coverage is the editcover and _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. Move 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 obtain major snapping errors after the merge, check the PRECISION on your coverage as you may need to switch to double precision.

3. After all line work 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.

C. Attribute Polygons.

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 but also a prairie dog colony the polygon would be attributed 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 on which you are working. Once all the desired labels are selected you can attribute for photo number, location, and color ($symbol) all at once. Change the color of the labels so they stand out better, plus the color demotes recently attributed labels for photo_no and location.

2. Next, select labels randomly for veg_code. Notice that after you calculate (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.

D. Attribute Arcs

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 calculates arcs in the _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 typographic errors.

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 typographic erros. Note: this button is set for editfeature label so you can not 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 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, i.e., 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 11.

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 13.

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 14.

Badlands National Park Vegetation Mapping Classes and Map Codes

BADLANDS NATIONAL PARK
VEGETATION MAPPING CLASSES AND MAP CODES

Land Use

50	Rivers – Perennial
51	Transportation, Communications, and Utilities
52	Croplands and Pasture
53	Seeded Mixed Grass Prairie
54	Other Agricultural Land
55	Streams and Canals
56	Reservoirs
57	Beaches and Sandy Areas Other Than Beaches
58	Strip Mines, Quarries, and Gravel Pits

Vegetation

1	Prairie Dog Town Community
2	Badlands Sparse Vegetation Complex
12	Switchgrass Grassland
14	Emergent Wetland
15	Little Bluestem - Grama Grasses - Threadleaf Sedge Grassland
16	Western Wheatgrass Herbaceous Alliance
17	Introduced Grassland
18	Blue Grama Grassland
19	Western Wheatgrass - Green Needlegrass Grassland
21	Soapweed Yucca / Prairie Sandreed Shrub Grassland
25	Silver Buffaloberry Shrubland
31	Silver Sagebrush / Western Wheatgrass Shrubland
32	Sand Sagebrush / Prairie Sandreed Shrubland
33	Rabbitbrush Shrubland
34	Chokecherry - (American Plum) Shrubland
35	Three-leaved Sumac / Threadleaf Sedge Shrub Grassland
37	Western Snowberry Shrubland
38	Sandbar Willow Temporarily Flooded Shrubland
39	Greasewood / Western Wheatgrass Shrubland
41	Eastern Cottonwood - (Peachleaf Willow) / Sandbar Willow Woodland
42	Green Ash - (American Elm) / Chokecherry Woodland
43	Ponderosa Pine / Rocky Mountain Juniper Woodland
44	Rocky Mountain Juniper / Littleseed Ricegrass Woodland

Appendix 15.

Badlands National Park Species List

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

Family	Scientific Name	Common Name
Agavaceae	*Yucca glauca Nutt.*	small soapweed
Alismataceae	*Sagittaria cuneata Sheldon*	arumleaf arrowhead
Anacardiaceae	*Rhus trilobata Nutt.*	skunkbush sumac
	Toxicodendron rydbergii (Small ex Rydb.) Greene	western poison ivy
Apiaceae	*Musineon divaricatum (Pursh) Raf.*	leafy wildparsley
Apocynaceae	*Apocynum cannabinum L.*	Indianhemp
Asclepiadaceae	*Asclepias L.*	milkweed
	Asclepias speciosa Torr.	showy milkweed
	Asclepias viridiflora Raf.	green milkweed
Asteraceae	*Aster L.*	aster
	Achillea millefolium L.	common yarrow
	Ambrosia psilostachya DC.	Cuman ragweed
	Ambrosia trifida L.	great ragweed
	Antennaria Gaertn.	pussytoes
	Antennaria parvifolia Nutt.	smallleaf pussytoes
	Arctium minus Bernh.	lesser burdock
	Artemisia cana Pursh	silver sagebrush
	Artemisia dracunculus L.	wormwood
	Artemisia filifolia Torr.	sand sagebrush
	Artemisia frigida Willd.	fringed sagewort
	Artemisia longifolia Nutt.	longleaf sagebrush
	Artemisia ludoviciana Nutt.	Louisiana sagewort
	Aster ericoides L.	heath aster
	Aster laevis L.	smooth aster
	Aster oblongifolius Nutt.	aromatic aster
	Chrysopsis villosa (Pursh) Nutt. ex DC.	
	= Heterotheca villosa var. villosa	
	Chrysothamnus nauseosus (Pallas ex Pursh) Britt.	
	= Ericameria nauseosa ssp. nauseosa var. nauseosa	
	Cirsium arvense (L.) Scop.	Canada thistle
	Cirsium undulatum (Nutt.) Spreng.	wavyleaf thistle
	Conyza canadensis (L.) Cronq.	Canadian horseweed
	Conyza ramosissima Cronq.	dwarf horseweed
	Dyssodia papposa (Vent.) A.S. Hitchc.	fetid marigold
	Echinacea angustifolia DC.	blacksamson echinacea
	Erigeron L.	fleabane
	Erigeron bellidiastrum Nutt.	western daisy 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
	Haplopappus spinulosus (Pursh) DC.	
	= Machaeranthera pinnatifida ssp. pinnatifida var. pinnatifida	
	Helianthus L.	sunflower
	Helianthus annuus L.	common sunflower
	Helianthus maximiliani Schrad.	Maximilian sunflower

	Helianthus petiolaris Nutt.	prairie sunflower
	Hymenoxys acaulis (Pursh) Parker	
	= Tetraneuris acaulis var. acaulis	
	Kuhnia eupatorioides L.	
	= Brickellia eupatorioides var. eupatorioides	
	Lactuca oblongifolia Nutt.	
	= Lactuca tatarica var. pulchella	
	Lactuca serriola L.	prickly lettuce
	Liatris punctata Hook.	dotted gayfeather
	Liatris squarrosa (L.) Michx.	scaly gayfeather
	Lygodesmia juncea (Pursh) D. Don ex Hook.	rush skeletonplant
	Ratibida columnifera (Nutt.) Woot. & Standl.	upright prairie coneflower
	Senecio L.	groundsel
	Senecio integerrimus Nutt.	lambstongue groundsel
	Senecio riddellii Torr. & Gray	Riddell's ragwort
	Solidago L.	goldenrod
	Solidago canadensis L.	Canada goldenrod
	Solidago missouriensis Nutt.	Missouri goldenrod
	Solidago rigida L.	
	= Oligoneuron rigidum var. rigidum	
	Taraxacum officinale G.H. Weber ex Wiggers	common dandelion
	Thelesperma megapotamicum (Spreng.) Kuntze	Hopi tea greenthread
	Tragopogon dubius Scop.	yellow salsify
	Xanthium strumarium L.	rough cocklebur
Boraginaceae	*Cryptantha celosioides (Eastw.) Payson*	buttecandle
	Cryptantha thyrsiflora (Greene) Payson	calcareous catseye
	Lappula redowskii auct. non (Hornem.) Greene	
	= Lappula occidentalis var. occidentalis	
	Lithospermum incisum Lehm.	narrowleaf gromwell
	Onosmodium molle Michx.	smooth onosmodium
Brassicaceae	*Arabis hirsuta (L.) Scop.*	hairy rockcress
	Arabis holboellii Hornem.	Holboell's rockcress
	Camelina microcarpa DC.	littlepod falseflax
	Descurainia pinnata (Walt.) Britt.	western tansymustard
	Lepidium densiflorum Schrad.	common pepperweed
	Lesquerella ludoviciana (Nutt.) S. Wats.	foothill bladderpod
	Physaria brassicoides Rydb.	double twinpod
	Sisymbrium altissimum L.	tall tumblemustard
Cactaceae	*Coryphantha (Engelm.) Lem.*	coryphantha cactus
	Coryphantha vivipara (Nutt.) Britt. & Rose	
	= Escobaria vivipara var. vivipara	
	Opuntia fragilis (Nutt.) Haw.	brittle pricklypear
	Opuntia humifusa (Raf.) Raf.	pricklypear
	Opuntia macrantha Gibbes	
	= Opuntia stricta var. stricta	
	Opuntia macrorhiza Engelm.	twistspine pricklypear
	Opuntia polyacantha Haw.	plains pricklypear
Campanulaceae	*Triodanis perfoliata (L.) Nieuwl.*	clasping Venus' lookingglass

Capparaceae	*Cleome serrulata Pursh*	Rocky Mountain beeplant
	Polanisia dodecandra (L.) DC.	roughseed clammyweed
Caprifoliaceae	*Symphoricarpos occidentalis Hook.*	western snowberry
Caryophyllaceae	*Cerastium arvense L.*	field chickweed
Chenopodiaceae	*Atriplex argentea Nutt.*	silverscale saltbush
	Atriplex canescens (Pursh) Nutt.	fourwing saltbush
	Atriplex nuttallii S. Wats.	Nuttall's saltbush
	Chenopodium album L.	lambsquarters
	Chenopodium berlandieri Moq.	pitseed goosefoot
	Kochia scoparia (L.) Schrad.	common kochia
	Monolepis nuttalliana (J.A. Schultes) Greene	Nuttall's povertyweed
	Monolepis nuttalliana (J.A. Schultes) Greene	Nuttall's povertyweed
	Salsola iberica Sennen & Pau	
	= Salsola kali ssp. tragus	
	Sarcobatus vermiculatus (Hook.) Torr.	greasewood
Commelinaceae	*Tradescantia bracteata Small ex Britt.*	longbract spiderwort
Convolvulaceae	*Convolvulus arvensis L.*	field bindweed
	Evolvulus nuttallianus J.A. Schultes	shaggy dwarf morningglory
	Ipomoea leptophylla Torr.	bush morningglory
Cupressaceae	*Juniperus scopulorum Sarg.*	Rocky Mt. juniper
	Juniperus virginiana L.	eastern redcedar
Cyperaceae	*Carex L.*	sedge
	Carex brevior (Dewey) Mackenzie	fescue sedge
	Carex filifolia Nutt.	threadleaf sedge
	Carex heliophila Mackenzie	
	= Carex inops ssp. heliophila	
	Cyperus L.	flatsedge
	Eleocharis acicularis (L.) Roemer & J.A. Schultes	needle spikerush
	Eleocharis compressa Sullivant	flatstem spikerush
	Eleocharis palustris (L.) Roemer & J.A. Schultes	common spikerush
	Scirpus americanus Pers.	
	= Schoenoplectus americanus	
	Scirpus validus Vahl	
	= Schoenoplectus tabernaemontani	
Elaeagnaceae	*Elaeagnus angustifolia L.*	Russian olive
	Shepherdia argentea (Pursh) Nutt.	silver buffaloberry
Equisetaceae	*Equisetum laevigatum A. Braun*	smooth horsetail
Euphorbiaceae	*Euphorbia L.*	spurge
	Croton texensis (Klotzsch) Muell.-Arg.	Texas croton
	Euphorbia albomarginata Torr. & Gray	
	= Chamaesyce albomarginata	
	Euphorbia glyptosperma Engelm.	
	= Chamaesyce glyptosperma	

	Euphorbia marginata Pursh	snow on the mountain
	Euphorbia serpyllifolia Pers. *= Chamaesyce serpyllifolia ssp. serpyllifolia*	
Fabaceae	*Amorpha canescens Pursh*	leadplant
	Amorpha fruticosa L.	desert indigobush
	Astragalus L.	milkvetch
	Astragalus barrii Barneby	Barr's milkvetch
	Astragalus bisulcatus (Hook.) Gray	twogrooved milkvetch
	Astragalus gilviflorus Sheldon	plains milkvetch
	Astragalus lotiflorus Hook.	lotus milkvetch
	Astragalus missouriensis Nutt.	Missouri milkvetch
	Astragalus racemosus Pursh	alkali poisonvetch
	Dalea aurea Nutt. ex Pursh	golden prairieclover
	Dalea candida Willd.	slender white prairieclover
	Dalea enneandra Nutt.	nineanther prairieclover
	Dalea purpurea Vent.	purple prairieclover
	Glycyrrhiza lepidota Pursh	American licorice
	Lathyrus polymorphus Nutt.	manystem peavine
	Medicago lupulina L.	black medick
	Melilotus officinalis (L.) Lam.	yellow sweetclover
	Oxytropis lambertii Pursh	Lambert's crazyweed
	Oxytropis sericea Nutt.	silvery oxytrope
	Psoralea argophylla Pursh *= Pediomelum argophyllum*	silverleaf scurfpea
	Psoralea digitata Nutt. ex Torr. & Gray *= Pediomelum digitatum*	
	Psoralea esculenta Pursh *= Pediomelum esculentum*	breadfruit
	Psoralidium Rydb.	psoralidium
	Psoralidium lanceolatum (Pursh) Rydb.	lemon scurfpea
	Psoralidium tenuiflorum (Pursh) Rydb.	slimflower scurfpea
	Thermopsis rhombifolia (Nutt. ex Pursh) Nutt. ex Richards.	prairie thermopsis
	Vicia americana Muhl. ex Willd.	American vetch
Geraniaceae	*Geranium carolinianum L.*	Carolina geranium
Grossulariaceae	*Ribes odoratum H. Wendl.* *= Ribes aureum var. villosum*	Golden current
Juncaceae	*Juncus balticus Willd.*	Baltic rush
Lamiaceae	*Hedeoma hispida Pursh*	rough falsepennyroyal
	Lycopus americanus Muhl. ex W. Bart.	American waterhorehound
	Mentha arvensis L.	wild mint
	Monarda fistulosa L.	wildbergamot beebalm
	Nepeta cataria L.	catnip
Liliaceae	*Allium textile A. Nels. & J.F. Macbr.*	textile onion
	Maianthemum stellatum (L.) Link	starry false

		Solomon's seal
	Zigadenus venenosus S. Wats.	meadow deathcamas
Linaceae	*Linum rigidum Pursh*	stiffstem flax
Loasaceae	*Mentzelia decapetala (Pursh ex Sims) Urban & Gilg ex Gilg*	tenpetal blazingstar
	Mentzelia nuda (Pursh) Torr. & Gray	bractless blazingstar
Lythraceae	*Ammannia robusta Heer & Regel*	grand redstem
	Rotala ramosior (L.) Koehne	lowland rotala
Malvaceae	*Sphaeralcea coccinea (Nutt.) Rydb.*	scarlet globemallow
Nyctaginaceae	*Mirabilis linearis (Pursh) Heimerl*	narrowleaf 4 o'clock
	Mirabilis nyctaginea (Michx.) MacM.	heartleaf 4 o'clock
Oleaceae	*Fraxinus pennsylvanica Marsh.*	green ash
Onagraceae	*Calylophus serrulatus (Nutt.) Raven*	yellow sundrops
	Gaura coccinea Nutt. ex Pursh	scarlet beeblossom
	Gaura parviflora Dougl. ex Lehm.	velvetweed
	Oenothera biennis L.	common eveningprimrose
	Oenothera cespitosa Nutt.	tufted eveningprimrose
	Oenothera coronopifolia Torr. & Gray	crownleaf eveningprimrose
Orobanchaceae	*Orobanche ludoviciana Nutt.*	Louisiana broomrape
	Orobanche multiflora Nutt.	
	= Orobanche ludoviciana ssp. multiflora	
Oxalidaceae	*Oxalis stricta L.*	common yellow oxalis
Papaveraceae	*Argemone polyanthemos (Fedde) G.B. Ownbey*	crested pricklypoppy
Pinaceae	*Pinus ponderosa P.& C. Lawson*	ponderosa pine
Plantaginaceae	*Plantago aristata Michx.*	largebracted plantain
	Plantago major L.	common plantain
	Plantago patagonica Jacq.	woolly plantain
Poaceae	*Agropyron caninum (L.) Beauv.*	
	= Elymus caninus	
	Agropyron cristatum (L.) Gaertn.	crested wheatgrass
	Agropyron dasystachyum (Hook.) Scribn. & J.G. Sm.	
	= Elymus lanceolatus ssp. lanceolatus	
	Agropyron repens (L.) Beauv.	
	= Elytrigia repens var. repens	quack grass
	Agropyron spicatum Pursh	
	= Pseudoroegneria spicata ssp. spicata	
	Agropyron trachycaulum (Link) Malte ex H.F. Lewis	
	= Elymus trachycaulus ssp. trachycaulus	
	Andropogon gerardii Vitman	big bluestem
	Andropogon hallii Hack.	sand bluestem

	Aristida purpurea Nutt.	purple threeawn
	Bouteloua curtipendula (Michx.) Torr.	sideoats grama
	Bouteloua gracilis (Willd. ex Kunth) Lag. ex Griffiths	blue grama
	Bromus inermis Leyss.	smooth brome
	Bromus japonicus Thunb. ex Murr.	Japanese brome
	Bromus tectorum L.	cheatgrass
	Buchloe dactyloides (Nutt.) Engelm.	buffalograss
	Calamovilfa longifolia (Hook.) Scribn.	prairie sandreed
	Cenchrus longispinus (Hack.) Fern.	innocent-weed
	Dactylis glomerata L.	orchardgrass
	Echinochloa crus-galli (L.) Beauv.	barnyardgrass
	Elymus canadensis L.	Canada wildrye
	Elymus elymoides (Raf.) Swezey	bottlebrush squirreltail
	Elymus virginicus L.	Virginia wildrye
	Hordeum jubatum L.	foxtail barley
	Koeleria macrantha (Ledeb.) J.A. Schultes	prairie Junegrass
	Muhlenbergia cuspidata (Torr. ex Hook.) Rydb.	plains muhly
	Muhlenbergia racemosa (Michx.) B.S.P.	marsh muhly
	Nassella viridula (Trin.) Barkworth	green needlegrass
	Oryzopsis hymenoides (Roemer & J.A. Schultes) Ricker -ex Piper = Achnatherum hymenoides	ricegrass
	Oryzopsis micrantha (Trin. & Rupr.) Thurb. = Piptatherum micranthum	little seed ricegrass
	Panicum capillare L.	witchgrass
	Panicum virgatum L.	switchgrass
	Pascopyrum smithii (Rydb.) A. Love	western wheatgrass
	Poa compressa L.	Canada bluegrass
	Poa pratensis L.	Kentucky bluegrass
	Schedonnardus paniculatus (Nutt.) Trel.	tumblegrass
	Schizachyrium scoparium (Michx.) Nash	little bluestem
	Spartina pectinata Link	prairie cordgrass
	Sporobolus asper (Beauv.) Kunth = Sporobolus compositus var. compositus	
	Sporobolus cryptandrus (Torr.) Gray	sand dropseed
	Sporobolus heterolepis (Gray) Gray	prairie dropseed
	Stipa comata Trin. & Rupr. = Hesperostipa comata ssp. comata	needle-and-thread
	Vulpia octoflora (Walt.) Rydb.	sixweeks fescue
Polemoniaceae	*Phlox andicola E. Nels.*	prairie phlox
	Phlox hoodii Richards.	spiny phlox
Polygalaceae	*Polygala alba Nutt.*	white milkwort
	Polygala verticillata L.	whorled milkwort
Polygonaceae	*Eriogonum pauciflorum Pursh*	fewflower buckwheat
	Polygonatum biflorum (Walt.) Ell.	
	Polygonum amphibium L.	water knotweed
	Polygonum aviculare L.	prostrate knotweed
	Polygonum convolvulus L.	black bindweed
	Rumex L.	dock
	Rumex crispus L.	curly dock
Polypodiaceae	*Polypodium L.*	polypody

Ranunculaceae	*Anemone patens L.*	
	= Pulsatilla patens ssp. patens	anemone
	Clematis ligusticifolia Nutt.	W. white clematis
	Delphinium virescens Nutt.	
	= Delphinium carolinianum ssp. virescens	
	Thalictrum L.	meadowrue
Rosaceae	*Crataegus succulenta Schrad. ex Link*	fleshy hawthorn
	Prunus americana Marsh.	American plum
	Prunus pumila var. besseyi	
	Prunus virginiana L.	common chokecherry
	Rosa arkansana Porter	prairie rose
	Rosa woodsii Lindl.	Woods' rose
Rubiaceae	*Galium boreale L.*	northern bedstraw
Salicaceae	*Populus deltoides Bartr. ex Marsh.*	eastern cottonwood
	Salix amygdaloides Anderss.	peachleaf willow
	Salix exigua Nutt.	sandbar willow
Santalaceae	*Comandra umbellata (L.) Nutt.*	bastard toadflax
Scrophulariaceae	*Penstemon Schmidel*	penstemon
	Penstemon albidus Nutt.	white penstemon
	Penstemon angustifolius Nutt. ex Pursh	broadbeard beardtongue
	Penstemon gracilis Nutt.	lilac penstemon
	Verbascum thapsus L.	common mullein
Selaginellaceae	*Selaginella densa Rydb.*	lesser spikemoss
Solanaceae	*Physalis heterophylla Nees*	clammy groundcherry
	Physalis longifolia Nutt.	longleaf groundcherry
	Solanum ptychanthum Dunal	nightshade
	Solanum rostratum Dunal	buffalobur nightshade
	Solanum triflorum Nutt.	cutleaf nightshade
Typhaceae	*Typha angustifolia L.*	narrowleaf cattail
	Typha latifolia L.	broadleaf cattail
Ulmaceae	*Celtis occidentalis L.*	common hackberry
	Ulmus americana L.	American elm
Urticaceae	*Parietaria pensylvanica Muhl. ex Willd.*	Pennsylvania pellitory
Verbenaceae	*Verbena bracteata Lag. & Rodr.*	bigbract verbena
	Verbena stricta Vent.	hoary verbena
Vitaceae	*Parthenocissus quinquefolia (L.) Planch.*	Virginia creeper
	Vitis riparia Michx.	riverbank grape
(Various)	Bryophytes	
	Crytograms	