USGS-NPS VEGETATION MAPPING
Jewel Cave National Monument, South Dakota

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EXECUTIVE SUMMARY

A vegetation association classification, vegetation map, and thematic accuracy assessment is presented for the area in and around Jewel Cave National Monument. This report is presented in two volumes: The Nature Conservancy report which presents the vegetation classification and this report which presents the methods and results of the mapping portion of this project.

The vegetation associations were developed by analysis of 28 vegetation plots and 37 observation points within the park boundaries. The classification system developed uses and augments the National Vegetation Classification System (NVCS). Twelve vegetation associations within 3 major physiognomic groups are defined and described. Included are discussions of range, environmental variables, common species, diagnostic species, local and global descriptions, and various comments. A diagnostic key is provided for field identification of association types based on indicator plant species.

The vegetation map was developed by photographic interpretation of 1993, 1:16,000 scale color infrared photography. Two separate classification systems were used to develop the mapping units. Cultural, disturbed, or unsampled vegetation types used the Anderson Level II classification system. All other vegetation within the mapping boundary used map units derived from the NVCS. A total of 7 Anderson Level II classes and 12 NVCS classes were used. The NVCS classes were combined to form 5 vegetation mapping classes.

As part of the mapping effort, we have included an accuracy assessment for the overall mapping effort as well as for individual class accuracies. These data include reporting for both errors of omission and commission. Overall map accuracy is 80.8% within a 90% confidence interval. A few map units do not meet the 80% accuracy level but do fall within a 90% confidence interval around the 80% accuracy stipulation.

Final products developed by this mapping effort include the following:

- vegetation classification system
- vegetation key
- ACCESS database with all field data
- digital and paper vegetation map
- digital coverage with all vegetation plots
- digital coverage with all observation plots
- digital coverage with all accuracy assessment points
- graphic files (*.tif) of all digital coverages
- accuracy assessment
- metadata for all digital files
- scanned aerial photography
- annotated field photographs/slides
- all products on Computer Disk (CD)

INTRODUCTION

This mapping effort originates from a long-term vegetation monitoring program that is part of a larger Inventory and Monitoring (I&M) program started by the National Park Service (NPS). I&M goals are, among others, to map the vegetation of all national parks and monuments and provide a baseline inventory of vegetation. The I&M program currently works in close cooperation with the Biological Resources Division (BRD) of the United States Geological Survey (USGS). The USGS/BRD continues overall management and oversight of all ongoing mapping efforts in close cooperation with the NPS. Contractors for each park vary. For Jewel Cave National Monument the principal contractor is the U.S. Bureau of Reclamation (BOR), Denver Technical Center, Remote Sensing and Geographic Information Group (D-8260). The primary subcontractor is The Nature Conservancy (TNC) who also works closely with the Wyoming Natural Heritage Program.

Objectives and Scope

The purposes of the mapping effort are varied and include the following:

- Provides support for NPS Resources Management
- Promotes vegetation-related research for both NPS and USGS/BRD
- Provides support for NPS Planning and Compliance
- Adds to the information base for NPS Interpretation
- Assists in NPS Operations

PROJECT AREA

Location: Jewel Cave National Monument is in Custer County and is part of the south western Black Hills (Figure 1). The Monument lies 11 miles west of the town of Custer, South Dakota.

Geology: The geology of the mapping area is in the Pahasapa (Madison) Limestone of Mississippian age which was deposited approximately 330 million years ago. This area is part of the Limestone Plateau that surrounds the Central Crystalline region of the Black Hills.

Soils: The soils in and around the park are described as Vanocker-Sawdust-Paunsaugunt association. These soils are generally deep to shallow, well drained, and gently sloping to very steep. The soils are formed in material weathered from limestone and calcareous sandstone (Ensz 1990).

Topography: The topography varies across the mapping area from gently sloping in the Pleasant Creek area (southeast and east) to steep canyon walls in Hell Canyon (central mapping area). The topography within the park varies from moderate to steep. The elevation range is moderate ranging from a low of 1663 m (5455 ft) in the Pleasant Creek area to 1837 m (6028 ft) in the northern portion of the mapping area (north of Hell Canyon).

Climate: The area is characterized by generally warm to hot during the summer to cold punctuated with occasional milder weather during the winter. Average summer temperatures are 17 degrees C (62 degrees F) and may reach temperatures of over 38 degrees C (100 degrees F). Average winter temperatures are about -5 degrees C (25 degrees F) but may reach temperatures as low as -42 degrees C (-43 degrees F). Total annual precipitation is about 46 cm (18 inches) with most of that falling between April and September. Average snowfall is about 114 cm (45 inches) (Ensz 1990).

METHODS

Development of Programmatic and Technical Team: This project required the combined expertise and oversight of several organizations. Oversight and programmatic considerations are managed by the Center for Biological Informatics of the Biological Resources Division of the U.S. Geological Survey. The National Park Service provided additional guidance.

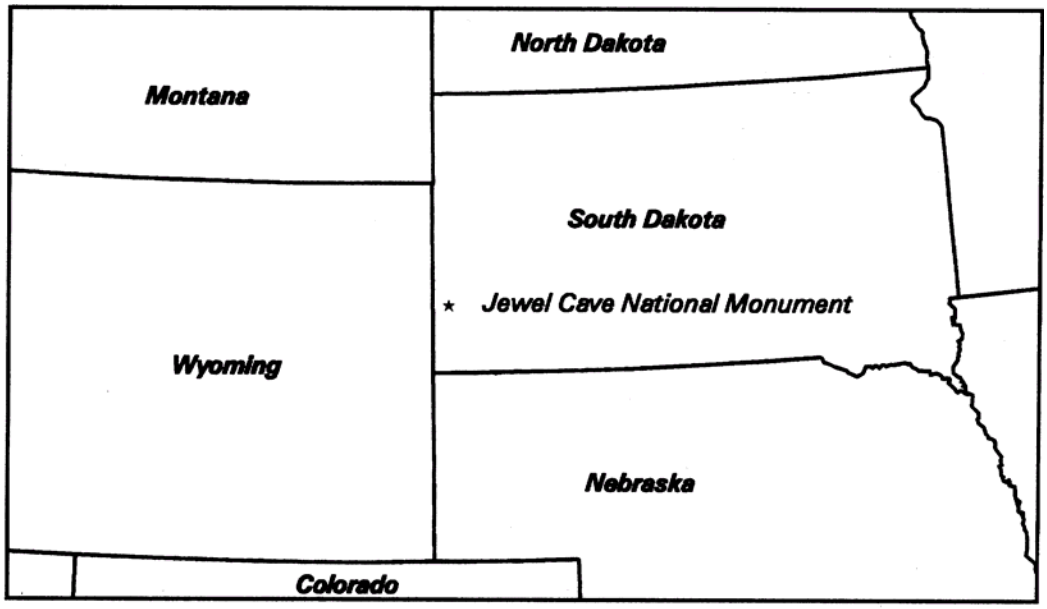

Figure 1. Location map for Jewel Cave National Monument

The technical responsibilities for the mapping effort were divided between TNC and BOR.

TNC responsibilities and deliverables included the following:

- Create a vegetation classification system based upon field species level data and consistent with the Standard National Classification System at the Alliance or Community Element level.
- Provide documentation that describes the national classes at the local and global levels, with field keys, and field data in a *.dbf format.

- Provide technical opinion to BOR as the mapping portion of the project proceeds.
- Provide field notes and site descriptions

BOR responsibilities and deliverables included the following:

- Digital files of vegetation on Compact (CD); including topology and labeling for height, density, and pattern subclasses; location of field sample sites; and locations of sites used for accuracy assessment in Arc/Info format
- Any ancillary digital files developed during the mapping process
- Digital FGDC compliant metadata file for each digital file delivered
- Annotated field site photographs
- Original mylar overlays of interpreted photographs
- Hard copy vegetation map
- Accuracy assessment
- Final report describing all procedures used in developing the final map and accuracy assessment

Planning and Review Meeting

An initial meeting was held with all interested parties to discuss several aspects of the mapping effort. Foremost among these was the mapping extent. Figure 2 shows the Monument boundary and the area outside the Monument to be included in the map. Vegetation issues particular to the park were addressed. Jewel Cave National Monument was responsible for obtaining permission from adjacent land owners for property access for sampling purposes. Most of the private lands were under some form of grazing or farming. Consequently, sampling on these lands was not necessary. The remainder of the lands within the mapping area are U.S. Forest Service Lands so permission was not necessary.

Preliminary Data Collection and Review of Existing Information

To reduce duplicating previous work and to help in our effort we collected existing vegetation reports and maps from the staff at Jewel Cave National Monument. These materials were referenced during the mapping process and the information contained in them was incorporated where it was deemed useful. Because soils also affect the distribution of vegetation, soil maps and soil descriptions were also obtained as reference (Ensz 1990). These were not converted to a digital file.

Digital elevation models (DEM) were obtained to create slope and aspect maps that helped in determining vegetation community distribution.

Vegetation Sampling

The sampling approach used in this mapping effort was typical of small park sampling, where all polygons within the park boundary are sampled.

Two levels of field data gathering were conducted in this park; plots and observations. Plots represented the most intensive sampling of the landscape and used TNC's 'Plot Form'.

Observations consisted of brief descriptions and were designed to obtain a quick overview of the landscape without spending a large amount of time at each sample site. Observation points used the 'Observation Form' data sheet. Examples of both 'Plot' and 'Observation' forms are included in the companion report by TNC.

Initially, plots were used to describe the vegetation of the park. A total of 28 plots were obtained from July 29 through August 1, 1996. These plots were used by TNC to describe the vegetation associations found within the park. These descriptions are in the companion report by TNC.

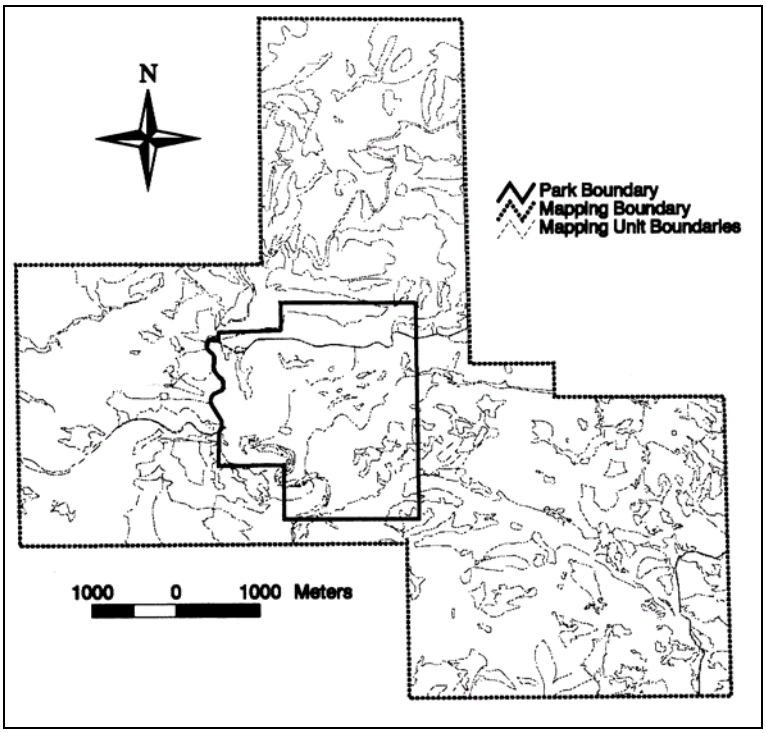

Figure 2. Monument Boundary and Mapping Area.

Before the accuracy assessment, we conducted a verification trip to assess the preliminary mapping effort. The verification used the observation forms described above. The verification data were then used to refine both the final map and the final vegetation description. Thirty-seven observation points were collected on May 27 through May 30, 1997. Figure 3 shows the locations of all plot and observation points.

Plot locations: The location of each vegetation plot or observation point was based upon several factors. These factors included the preliminary photo signature and other physiographic variables such as slope, aspect, soils, and geology. We attempted to sample the vegetation in a way that recorded the greatest amount of variability across the landscape. Plots were placed subjectively in areas that best represented the immediate landscape.

The geographic coordinates of the plot locations were determined by marking our approximate position on a mylar overlay on aerial photographs with ink. These positions were

later transferred to a digital file using the digital orthophoto quad (DOQ) as a base map. Observation points were located by a global positioning system (GPS) using a Precision Light Weight GPS Receiver (PLGR) device. Plot locations in dense canopies are estimated to be within 10 to 20 meters of their actual location. Observation points are generally within 10 meters of their actual location.

Vegetation and Map Classification

This mapping effort includes a description of vegetation at two levels. The primary and most informative level is that of the vegetation classification at the association level. Because many plant associations cannot be mapped from the photography at this level, we also include a mapping classification. The map classification may be the same as the vegetation association but is usually a combination of associations in either a complex or mosaic of associations.

Vegetation Classification: The association descriptions for the vegetation and methods used to derive those descriptions are included in the TNC companion report. (See Table 1 for a summary of the associations. The methods used by TNC and this office (Bureau of Reclamation, D-8260) for collecting and processing these data are also described in *Field Methods for Vegetation Mapping* (The Nature Conservancy 1994).

Mapping Classification: The final map contains elements of two separate classification systems. All vegetation sampled and described by this project use the NVCS. All other land cover types within the mapping area use the Anderson Level II classification system (Anderson et al. 1976).

Map classes were derived from the vegetation classification and modified such that the photo-interpreted classes represented at least one vegetation class. Because many vegetation classes did not have a distinct photo signature, some vegetation classes were combined to make a map class. For example, many Ponderosa Pine types were not distinguishable by photo signature and had to be combined into ‘complexes’. Other communities may have been visually distinguishable but were so mixed that separating the communities by individual polygons was not feasible. These areas were designated ‘mosaics’. Mosaics were typically grassland or shrub communities. Before combining and producing the final map classes, we worked with preliminary map classes. The preliminary map classes were typically equivalent to the association descriptions. The accuracy assessment was done on the original map classes. Information derived from the accuracy assessment helped us in developing the final map classification. Table 2 describes the map classes and the component community types.

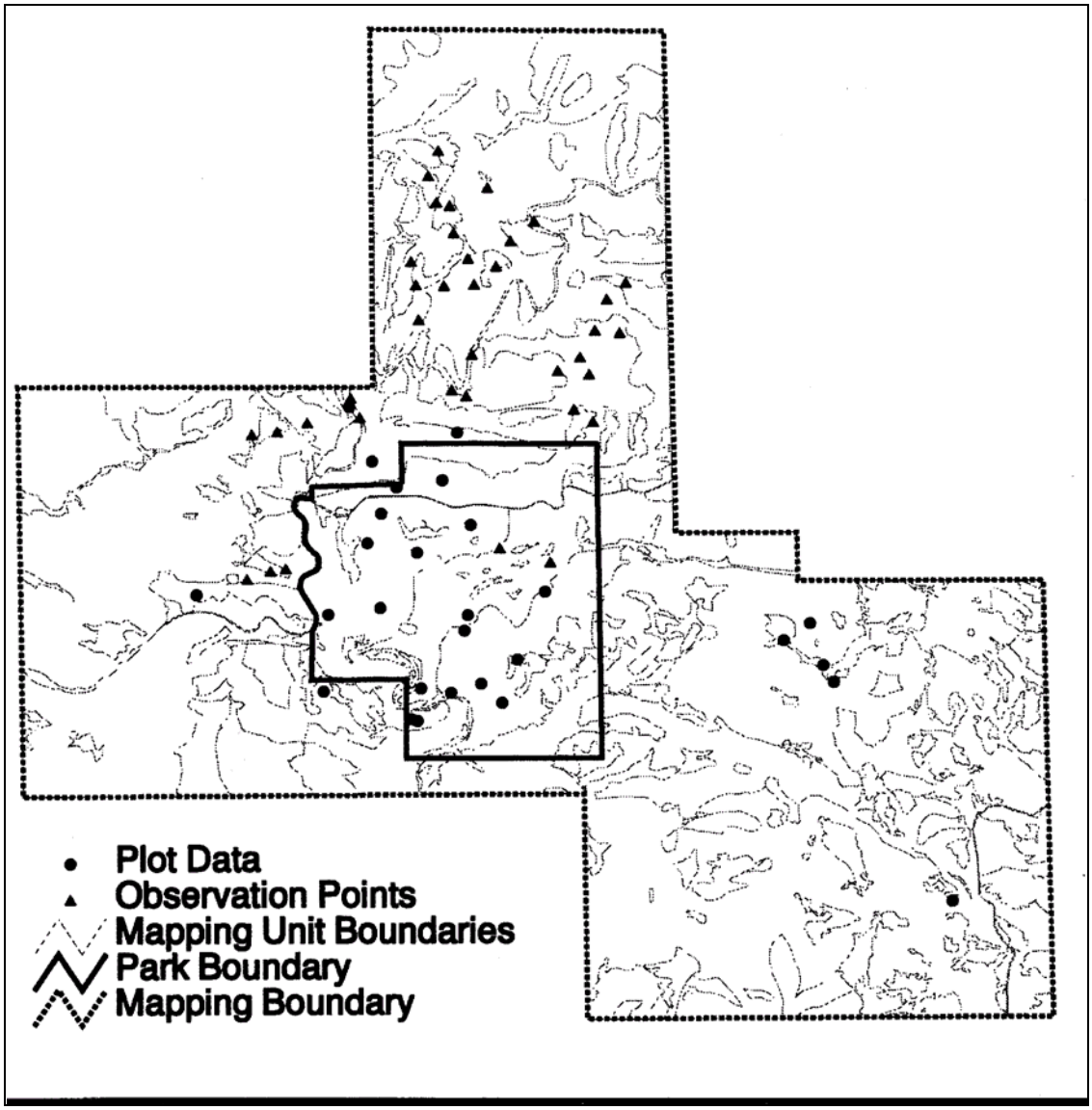

Figure 3. The Location of Observation Points and Plot Data in Jewel Cave National Monument and Vicinity.

Vegetation Association
Ponderosa Pine / Mountain Ninebark Forest
Ponderosa Pine / Common Snowberry Forest
Ponderosa Pine / Bearberry Woodland
Ponderosa Pine / Sun Sedge Woodland
Ponderosa Pine / Common Juniper Woodland
Quaking Aspen / Choke Cherry Forest
Ash Leaf maple / Choke Cherry Forest
Western Snowberry Shrubland
Little Bluestem - Grama (Side-Oats, Blue) - Threadleaf Sedge Herbaceous Vegetation
Western-Wheat Grass - Blue Grama - Threadleaf Sedge Herbaceous Vegetation
Kentucky Bluegrass Disturbed Community
Sedge Dominated Wetland Community (undefined alliance)

Table 1. Vegetation Associations Within Jewel Cave National Monument.

Air Photo Interpretation

All map classes were interpreted from existing 1:16,000 scale, color photography flown on August 17, 1993. The photographs were acquired from the U.S. Forest Service (USFS). Photointerpretation used the standard identification features such as tone, texture, color, pattern, topographic position, and shadow. In addition, field sample locations and their vegetation descriptions aided in assigning map class to each polygon. All photographs were examined using a stereoscope. Digital elevation models (DEM's) were processed and converted to slope and aspect coverages. These helped to provide additional perspectives of the landscape. Six photographs were interpreted for the entire mapping area. A photointerpretive key is provided in the appendix. Digital scans of these photographs are included as .tif files on the CD included with this report.

Map Validation

A field trip was conducted in May of 1997 to assess the initial mapping effort and to refine map classes. This trip included additional 'observation points' (see Vegetation Sampling above). Map classes were modified to reflect inadequacies in the initial photointerpretation.

Digital Files

All digital files were created with a standard format. All files are delivered with a UTM projection, zone 13, and a north American datum of 1983. Attributes and file format for each coverage are as follows:

Vegetation coverage: **jeca_veg**

Attributes

Item name	**width**	**output**	**type**	**n. dec**	
map_unit	3	5		C	-
anderson_code4	4		I	-	
height	4	4		I	-
density 4	4		I	-	
pattern 4	4		I	-	
hectares	10	10		N	2

Plot data coverage: **plot_data**

Attributes

Item name	**width**	**output**	**type**	**n. dec**	
plot_no	2	2		N	-
veg_code	10	10		C	-

Verification data coverage: **verif_data**

Attributes

Item name	**width**	**output**	**type**	**n. dec**	
plot_no	12	12		C	-
veg_code	10	10		C	-

Accuracy assessment coverage: **error_pts**

Attributes

Item name	**width**	**output**	**type**	**n. dec**	
veg_code	10	10		C	**-**
map_unit	4	4		C	-

Map Boundary Coverage: **map_boundary**

Attributes

Item name	**width**	**output**	**type**	**n. dec**	
hectares	10	10		N	-

Park Boundary Coverage: **park_boundary**

Attributes

Item name	**width**	**output**	**type**	**n. dec**	
hectares	10	10		N	-

Transfer to Digital Format

The digital products produced specifically for this mapping effort include a digital vegetation polygon coverage with labels and digital point coverages for plot, observation, and accuracy locations.

Photo-interpreted polygons and labels were transferred to a digital format using 'heads-up' digitizing on a digital orthophoto quad (DOQ). This process entails the visual transfer (digitizing) of line and label data directly to the computer screen with the DOQ as a backdrop/base map. The digital version of the ortho quad was created in-house by scanning and registering the Jewel Cave and Signal Hill orthophotographs. These scanned orthophotographs were then joined into one file. The original orthophotograph was produced from 1:80,000 scale aerial photographs taken October 13, 1977. The DOQ produced by this office is included on the CD accompanying this report.

The digital point coverages were created two different methods. 1.) The original plot data collected was done without the benefit of a GPS unit. Plot locations were noted on each photograph and later transferred to a digital file by using the DOQ base map as reference. 2.) Observation points and accuracy assessment points were collected in the field using a GPS unit. These data points were transferred directly from the GPS unit into a digital file and attributed in Arc/Info using the field data sheets as reference for the attribute. Coordinate system descriptions were added after creation of the digital files.

Data Description

Vegetation

Coverage name: **jeca_veg**

map_unit: This attribute refers to the vegetation map unit. The vegetation codes and map unit names are listed in Table 2. The map unit names can also be accessed using a lookup table (veg.lut) provided with the digital coverage.

anderson_code: This item refers to the map classification using the Anderson Level II classification. The classification codes and map unit names are listed in Table 3. The map unit names can also be accessed using a lookup table (anderson.lut) provided with the digital coverage.

The height, density, and pattern items are structural descriptions of each vegetation class described under the NVCS. Table 4 describes the structural categories and the codes associated with each. Figure 4 illustrates each category associated with each code. Height, density, and pattern look-up tables (height.lut, density.lut, pattern.lut) duplicate Table 4.

hectares: This item is simply a numeric figure representing the area covered by each polygon.

Plot Data

Coverage name: **plot_data**

plot_no: This item refers to the number assigned to each plot.

veg_code: This item refers to the association assigned to each plot location. Veg_code and descriptions are listed in Table 5.

map_unit	map unit name	associations included
BW	Ash Leaf Maple / Choke Cherry Forest	• Ash Leaf Maple / Choke Cherry Forest
GS	Grass / Shrub Complex	• Western Snowberry Shrubland • Little Bluestem - Grama (Side-Oats, Blue) - Threadleaf Sedge Herbaceous Vegetation • Western-Wheat Grass - Blue Grama - Threadleaf Sedge Herbaceous Vegetation • Kentucky Bluegrass Disturbed Community
P1	Ponderosa Pine Complex I	• Ponderosa Pine / Little Bluestem Woodland • Ponderosa Pine / Sun Sedge Woodland • Ponderosa Pine / Bearberry Woodland
P2	Ponderosa Pine Complex II	• Ponderosa Pine / Snowberry Forest • Ponderosa Pine / Common Juniper Woodland • Ponderosa Pine / Ninebark
PT	Quaking Aspen / Choke Cherry Forest	• Quaking Aspen / Choke Cherry Forest

Table 2. Map unit designations and component vegetation associations descriptions for Jewel Cave National Monument**.**

Verification Data
Coverage name: **verif_data**
plot_no: This item refers to the number assigned to each verification plot.
veg_code: This item refers to the association assigned to each verification plot location. Veg_code and descriptions are listed in Table 5.

Error Data
Coverage name: **error_pts**
veg_code: This item refers to the vegetation association assigned to each accuracy plot location. Veg_code and descriptions are listed in Table 5.
map_unit: This item refers to the map unit code

Ancillary Data
Coverage name: **map_boundary**
hectares: This item is simply a numeric figure representing the area covered by the mapping area.

Coverage name: **park_boundary**
hectares: This item is simply a numeric figure representing the area covered by the park.

anderson_code	description
11	Residential
12	Commercial and Services
14	Transportation, Communications, and Utilities
21	Cropland and Pasture
53	Reservoirs
62	Nonforested Wetland
75	Strip Mines, Quarries, and Gravel Pits

Table 3. Anderson Level II Codes and Descriptions

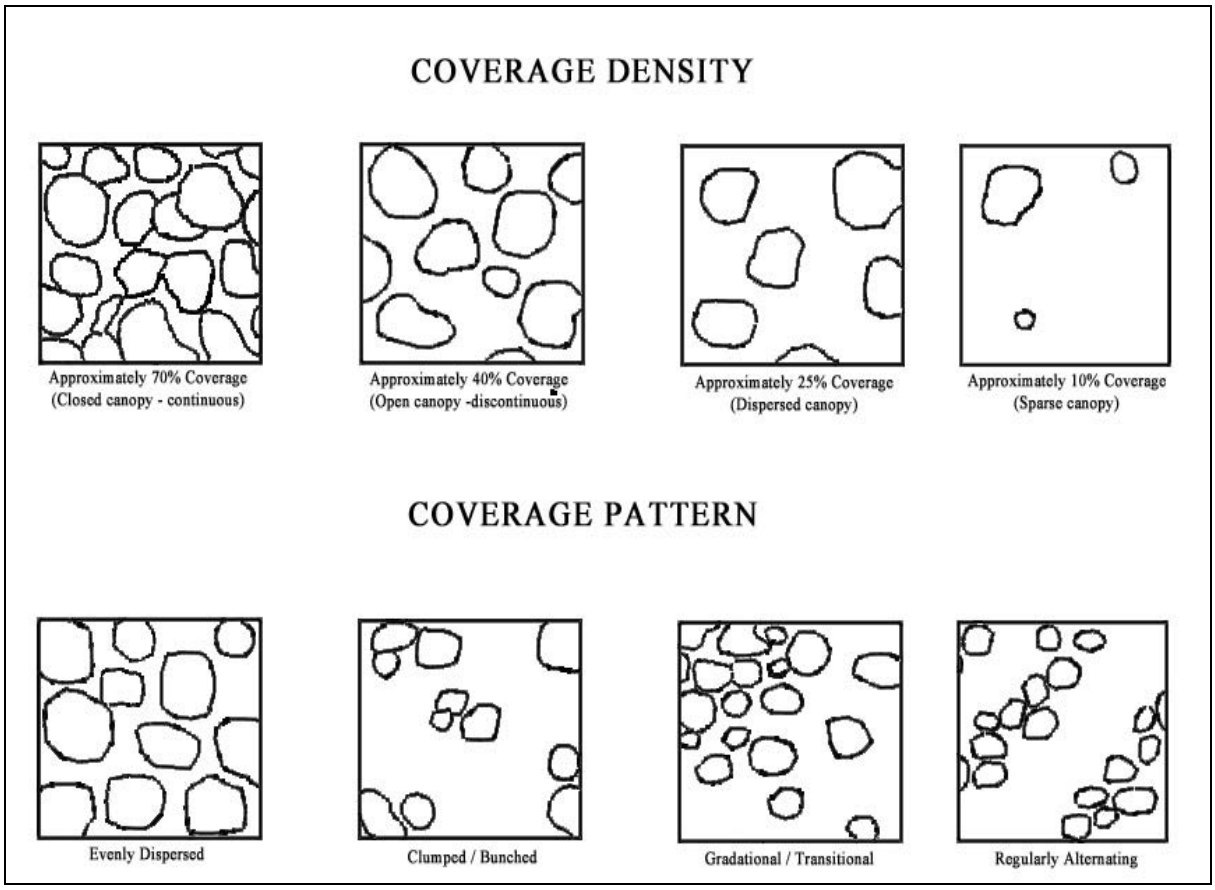

Figure 4. Standard Interpretative Conventions / Structural Categories.

Structural Categories	
HEIGHT	
6	> 30 Meters
5	15 - 30 Meters
4	5 - 15 Meters
3	1 - 5 Meters
2	0.5 - 1 Meter
COVERAGE DENSITY	
1	Closed Canopy / Continuous
2	Discontinuous
3	Dispersed
4	Sparse
COVERAGE PATTERNS	
1	Evenly Dispersed
2	Clumped / Bunched
3	Gradational / Transitional
4	Alternating

Table 4. Structural Categories for Vegetation Mapped Using NVCS.

veg_code	description
bew	Ash Leaf Maple / Choke Cherry Forest
gplb	Little Bluestem - Grama (Side-Oats, Blue) - Threadleaf Sedge Herbaceous Vegetation
kbg	Kentucky Bluegrass Disturbed Community
kbg-ws	Kentucky Bluegrass / Western Snowberry Shrubland Mosaic
ppbw	Ponderosa Pine / Bearberry Woodland
ppcj	Ponderosa Pine / Common Juniper Woodland
pplb	Ponderosa Pine / Little Bluestem Woodland
ppnf	Ponderosa Pine / Ninebark Forest
ppsf	Ponderosa Pine / Snowberry Forest
ppss	Ponderosa Pine / Sun Sedge Woodland
pt	Quaking Aspen / Choke Cherry Forest
ws	Western Snowberry Shrubland
wwbg	Western-Wheatgrass - Blue Grama - Threadleaf Sedge Herbaceous Vegetation

Table 5. List of Vegetation Code (veg_code) and Vegetation Association Descriptions**.**

Accuracy Assessment

To assess the thematic accuracy of the vegetation map we conducted an accuracy assessment that allows the user of the digital information an additional perspective upon the data. The final product attempts to achieve the 80% per class accuracy required for this product.

Not all mapping units were tested for accuracy. Since the final map contains two separate classification systems (see 'Vegetation Classification'), only the mapped areas that fall under the NVCS were included in the accuracy assessment. Areas such as agricultural and undescribed vegetation units and other areas classified using Anderson Level II classification were eliminated from the sample process. Besides excluding the Anderson classified polygons we also excluded vegetation polygons visited and sampled during either the vegetation. description or verification phase that were small enough to confidently say were entirely correct. These were typically riparian polygons in Hell Canyon. These small polygons were eliminated

from a site visit in the random selection process but were included in the final accuracy assessment matrix.

The remaining areas for sampling were then stratified and sampled according to the number of polygons in each class and the area occupied by each class. Table 6 shows the recommended number of samples per class using a stratified sampling process (*Accuracy Assessment Procedures*, The Nature Conservancy 1994).

Field Procedure: The field crew consisted of two botanists that were not involved in any part of the previous work on the park. Field work was conducted September 5 through September 9, 1997. This crew either worked together or separately depending upon local conditions. Both botanists were supplied with a list of points to visit, a field key for map class identification, field data forms, and a GPS to navigate to each site (see Plant Association Key and sample field forms attached with TNC report). Both crew members worked "blind', meaning that neither one was aware of the existing mapped class designations. Upon arriving at each site, the crews scanned a wide area around the immediate location and observed any local variation in the plant associations. Using the key, the crew then assigned a plant association to the accuracy point. In cases where the variation was significant the crew made a "best fit" judgment to the class name. In addition, other associations in the area and those that might be confused with other plant associations were also noted on each field form.

Site Selection: The stratified random selection of accuracy assessment sites was done on the original map classes (see 'Vegetation Classification'). The original map classes, the number of sites selected and the number of sites visited are listed in Table 7.

The x and y coordinates of each accuracy point were derived from the original vegetation coverage. The coverage was gridded into 50 x 50 meter cells using ArcGrid. A 50-meter grid was chosen because it approximates the minimum mapping unit (MMU) for the project. Using a random number generator, we then re-selected the appropriate number of grids/samples from each class and put them into a separate grid. Additional points were selected for each class over the required number to allow the field crew some latitude in case some sites were inaccessible. The reselected cells where then converted into a point coverage. The x and y coordinate for each point was then transferred to an ascii file. This coordinate file was then used by the field team along with a GPS PLGR unit to locate the position in the field. The locations of all accuracy points are shown in Figure 5. The point coverage with the accuracy locations and the assigned map unit code are included as a digital coverage.

Data Analysis: Due to the inherent heterogeneity of many natural systems, many of the map class determinations where determined to be incorrect. However, when map classes were considered in a landscape context they were correct. To address this issue we attempted to include a 'fuzzy' protocol in analyzing the field accuracy data. For example, when the field crew visited a site they noted not only the appropriate vegetation association designation for the immediate area but also other associations present. When field codes where then compared with the mapped class the point was designated correct if it agreed with any of the associations noted on the field form.

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

Table 6. Number of Sites per Class. The recommended sample sizes for the stratified sampling process (MMU = Minimum Mapping Unit) *Accuracy Assessment Procedures* (The Nature Conservancy 1994).

Using the original interpretations and map units we then created a contingency matrix to identify the source and magnitude of map errors. The preliminary matrix is shown in Table 8. The table identified consistent sources of error that allowed us to combine certain classes into the final contingency table (Table 9). Classes were combined where they made some ecological sense. For example, pine types were often combined into north and south facing slopes. Grassland types were also combined into one map class.

Statistical Methods: This mapping effort only evaluates the thematic accuracy of the final product and ignores the positional accuracy. Positional accuracy is assumed to have been met because polygon delineations were transferred to a highly accurate base map. In addition, the lines transferred to the base map are often abstractions and really represent a continuum of change from one plant association to another. The continuum may also be considered an ecotone. These ecotones are not being mapped nor classified.

The statistical methods for the production of the contingency tables are discussed in *Accuracy Assessment Procedures* (The Nature Conservancy 1994). The statistical parameters are as follows: the overall and individual accuracies are calculated using overall measures of accuracy rather than the Kappa index (Kappa index for overall accuracy is included in the contingency table) The confidence intervals are calculated using a two tailed 90% confidence interval. Accuracy standards for overall or individual class accuracies are assumed to have been met if they fall within the confidence interval.

Preliminary Map Class Name	Number of sites selected for sample	Number of sites actually visited
Schizachyrium scoparium - Bouteloua curtipendula - Carex filifolia Herbaceous Vegetation	5	5
Poa pratensis / Symphoricarpos albus Shrubland Mosaic	All	1
Pascopyrum smithii / *Bouteloua gracilis* Herbaceous Vegetation	30	30
Poa pratensis Herbaceous Vegetation	20	17
Pinus Ponderosa / *Juniperous communis* Woodland	30	28
Pinus Ponderosa / *Schizachyrium scoparium* Woodland	30	30
Pinus Ponderosa / *Symphoricarpos albus* Forest	30	30
Pinus Ponderosa / *Physocarpus monogynus* Forest	30	30
Pinus Ponderosa / *Arctostaphylos uva-ursi* Woodland	30	30
Pinus Ponderosa / *Carex heliophila* Woodland	30	30
Symphoricarpos occidentalis Shrubland *	0	0

Table 7. List of preliminary map classes used during the accuracy assessment. (* *Symphoricarpos occidentalis* Shrubland was not observed until the accuracy assessment and was therefore not included in the initial stratification.)

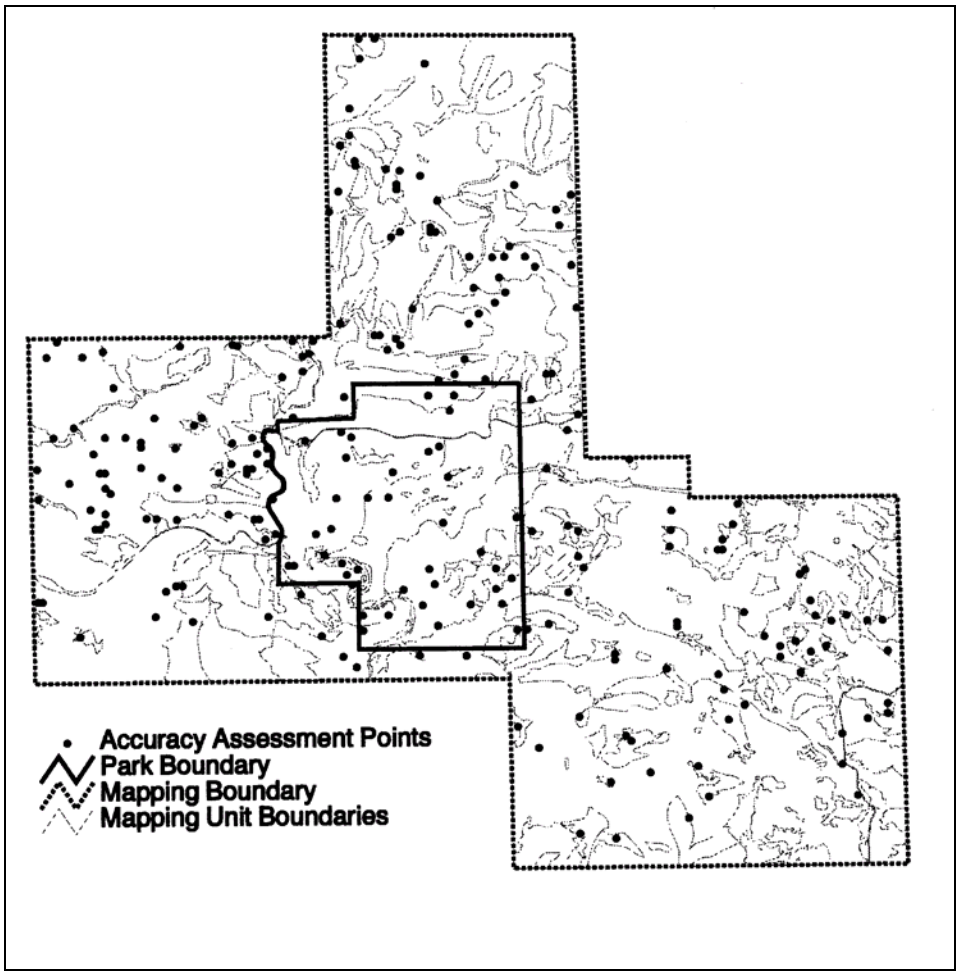

Figure 5. Locations of accuracy assessment points for Jewel Cave National Monument.

															COMMISSION	CONFIDENCE	
															ERROR - %	INTERVAL	
														TOTAL N	CORRECT		
M	C		WW	GP	KB	KW	PB	PF	PJ	PN	PS	PW	WS			-	+
A	L	WW	10	7	7	4	0	0	0	0	0	0	2	30	33.3	21.8	48.5
P	A	GP	0	2	2	1	0	0	0	0	0	0	0	5	40	11.2	79.8
P	S	KB	0	0	17	0	0	0	0	0	0	0	0	17	100	87.2	100
E	S	KW	0	0	0	1	0	0	0	0	0	0	0	1	100	10	100
D		PB	0	0	0	0	15	3	5	3	3	1	0	30	50	36.8	63.2
		PF	0	0	0	0	5	10	3	3	4	5	0	30	33.3	21.8	48.5
		PJ	0	0	0	0	2	1	20	4	0	1	0	28	71.4	57.2	81.3
		PN	0	0	0	0	2	3	3	19	2	1	0	30	63.3	48.7	75.2
		PS	0	0	0	0	14	3	0	2	11	0	0	30	36.7	24.8	51.3
		PW	0	0	0	0	9	3	1	3	8	6	0	30	20	10.8	36.7
		WS	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
		TOTAL N	10	9	26	6	47	23	32	34	28	14	2	231			
OMMISSION ERROR - % CORRECT																	
% CORRECT			100	22.2	65.4	16.7	32	43.5	62.5	55.9	39.3	42.9	0				
90% CONFIDENCE INTERVAL																	
-			79.4	6.1	50.4	1.7	23	28.5	48.9	42.4	26.4	24.1	0				
+			100	62.4	77	79	44	60.2	73.8	68.2	54.5	64.8	0				
OVERALL KAPPA ACCURACY = 48.1%																	
OVERALL KAPPA INDEX = 41.4%																	
OVERALL TOATAL ACCURACY 90% LOWER & UPPER CONFIDENCE INTERVALS: 42.1%, 54.0%																	
(OMMISSION & COMMISSION ERRORS CALCULATED USING TOTAL ACCURACY, NOT KAPPA INDEX)																	

Abbreviations

WW	Western-wheat Grass - Blue Grama - Threadleaf Sedge Herbaceous Vegetation	PF	Ponderosa Pine / Snowberry Forest
GP	Little Bluestem - Threadleaf Sedge Herbaceous Vegetation	PJ	Ponderosa Pine / Common Juniper Woodland
KB	Kentucky Bluegrass Disturbed Community	PN	Ponderosa Pine / Ninebark Forest
KW	Kentucky Bluegrass / Snowberry Mosaic	PS	Ponderosa Pine / Sunsedge Woodland
PB	Ponderosa Pine / Little Bluestem Woodland	PW	Ponderosa Pine / Bearberry Woodland
		WS	Western Snowberry Shrubland

Table 8. Preliminary Contingency Table for Vegetation Accuracy Assessment.

								COMMISSION	CONFIDENCE	
	REFERENCE CLASS							ERROR	INTERVAL	
							TOTAL N	% CORRECT	-	+
		BW	PT	GS	PP1	PP2				
	BW	1	0	0	0	0	1	100	10	100
MAP	PT	0	2	0	0	0	2	100	31.6	100
CLASS	GS	0	0	53	0	0	53	100	95.7	100
	PP1	0	0	0	67	23	23	74	67.1	80
	PP2	0	0	0	22	66	88	75	67.7	80.7
TOTAL N		1	2	53	89	89	234			
OMISS % ERR		100	100	100	75.3	74.2				
90% CONFIDENCE INTERVAL										
-		10	31.6	95.7	68	66.7				
+		100	100	100	80.9	80				
OVERALL TOTAL ACCURACY = 80.8										
OVERALL KAPPA INDEX = 70.8										
OVERALL TOTAL ACCURACY 90% LOWER & UPPER CONFIDENCE INTERVALS 75.7%, 84.88%										
(OMISSION & COMMISSION ERRORS CALCULATED USING TOTAL ACCURACY, NOT USING KAPPPA INDEX)										

Abbreviations:

BW	Ash Leaf Maple / Choke Cherry Forest	GS	Grass / Shrubland Complex
PT	Quaking Aspen / Choke Cherry Forest	PP1	Ponderosa Pine Complex I
		PP2	Ponderosa Pine Complex II

Table 9. Final Contingency Table for Vegetation Accuracy Assessment

RESULTS

Hectares for all mapping units are summarized in Table 10 for both the entire mapping area and the park itself. The listed codes are described in Tables 2 and 3.

map_unit	anderson_code	Hectares	
		Within Mapping Area	Within Park Boundary
-	11	0.5	0.5
-	12	2.1	2.1
-	14	11.6	2.0
-	21	321.8	1.0
-	53	0.1	0
-	62	0.4	0
-	75	1.6	0
BW	-	2.8	0
GS	-	75.5	21.6
P1	-	2270.5	227.6
P2	-	1099.3	287.4
PT	-	15.9	0
Total		**3801.7**	**542.0**

Table 10. Hectares of mapping units within the mapping area and within Jewel Cave National Monument.

DISCUSSION

During this mapping effort we encountered situations that, in retrospect, we would have approached differently. These include both the initial field work and the photointerpretation. However, this mapping effort gave great insight into the feasibility of mapping to the association level.

Initial field work included the placement of vegetation plots which were used to describe the vegetative associations that exist within Monument boundaries. These vegetation plots were very time intensive and provided us with a limited perspective of the variation present within the park. During the map validation field trip we used the more rapid observation plots which allowed us to visit a larger portion of the park during the time allotted. The validation trip provided us with a much greater perspective of the variation and spatial extent of these

associations. The information gathered from the second field trip would have benefited us greatly during the first field trip. Future mapping efforts should begin with a broader and quicker 'look' at the vegetation with observation plots and followed up with vegetation plots.

Problems with the photointerpretation were related to the lack of a firm classification system from which to work. We originally thought we could map to the association level. Therefore, initial photointerpretive classes were the same as the initial vegetation association classes. We thought we could probably separate many classes with similar signatures on some environmental indicator such as soils, slope, aspect, etc. This did not bear out. For example, the distribution of pine types had only very general tendencies for north and south aspects. Consequently, our final mapping units reflected these tendencies. In addition, grass associations were very difficult to discern and were combined into one class. Exceptions to the grass map unit were the mosaic grass map units. These were only separable because these areas were visited in their entirety. Photo signatures for all grass types were variable and unpredictable. Future mapping should take into account the cosmopolitan distribution of pine types in the Black Hills in addition to the unreliability of distinguishing many grassland types. An initial review of preliminary association classes and subsequent combining of classes into realistic map units would prevent a great deal of confusion and frustration.

The accuracy assessment underscored the problems associated with the original classification discussed above. In fact, the accuracy assessment showed us where the confusion occurred and directed the construction of the final map unit designations. Initial map units were combined, where it made ecological sense, to produce the final map classification. The final map classification was then assessed again using the combined classes to produce the final accuracy assessment. Combining classes increased the initial overall accuracy assessment from 48.1% to a final overall map accuracy of 80.8%. Most individual class accuracies also exceeded the target value of 80% for errors both of omission and commission. Those individual classes that did not meet the target value of 80% were at least within the 90% confidence interval in either omission or commission errors. These classes may have been combined with others to produce an even higher map accuracy for both individual class accuracy and overall map accuracy. This option was discussed at length with members of the USGS/BRD and NPS staff. Any further combination of classes was rejected due to the significant loss of information. For example, the final classification contained two Ponderosa Pine complexes that showed considerable confusion between the two. Both complexes were below the 80% requirement for individual class accuracy. Combining the two would have created a pine complex with more than 90% accuracy. However, these two pine types also make up almost 90% of the entire mapping area. We decided to accept the lower individual accuracies for some classes to preserve some detail. Information about the distribution of associations can still be acquired from the three point coverages delivered with this report. These point coverages can be accessed and queried with most GIS's.

REFERENCES

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. Gov't. Printing Office, Washington. 28pp.

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

The Nature Conservancy. 1994. Accuracy Assessment Procedures - NBS/NPS Vegetation Mapping Program. Report prepared for U.S. Dept. Of Interior, National Biological Survey and National Park Service.

The Nature Conservancy. 1994. Field Methods for Vegetation Mapping - NBS/NPS Vegetation Mapping Program. Report prepared for U.S. Dept. Of Interior, National Biological Survey and National Park Service.

APPENDICES

Annotated List of Slides

1) Aspen / Choke Cherry Woodland, Hell Canyon
2) Wolfberry (foreground) and Aspen / Choke Cherry Woodland (background), Hell Canyon
3) Wolfberry (foreground) and Aspen / Choke Cherry Woodland (background), Hell Canyon
4) Ponderosa Pine / Common Juniper Woodland, Hell Canyon
5) Box Elder Woodland, Hell Canyon
6) Ponderosa Pine / Little Bluestem Woodland
7) Ponderosa Pine / Little Bluestem Woodland
8) Phlox
9) Dododecathon
10) Dododecathon
11) Curious George, Hell Canyon
12) Box Elder Woodland, Hell Canyon
13) Ponderosa Pine / Common Juniper Woodland (background), Aspen / Choke Cherry (middle ground), Wolfberry Shrubland (foreground), Hell Canyon
14) Location of vegetation and verification plots
15) Location of accuracy assessment points

Photointerpretive Key to the Map Units for Jewel Cave National Monument

1. Tree cover > 10%
    2. Color dark green, topographic position not in valleys/draws
        3. Topographic position on south facing aspect, slopes variable, tree crowns often not completely concealing ground cover.
        Ponderosa Pine Complex I
        3. Topographic position on north facing aspect, slopes variable, tree crowns (canopy and sub-canopy) often completely interlocking, ground cover not usually visible.
        Ponderosa Pine Complex II
    2. Color light to medium green, topographic position in valleys/draws
        3. Hell Canyon from highway north about 800 meters
        Boxelder Woodland *
        3. Hell Canyon, extending from about 800 meters north of highway to northern extent of mapping area
        Aspen / Chokecherry Woodland *

1. Tree cover < 10%
    4. Ground cover not urban, built up, or actively under agricultural use
        5. Ground cover removed, pits or quarries visible, usually extensive off road use visible
        Barren Land - Strip Mines, Quarries, and Gravel Pits
        5. Ground not cultivated or hayed
            6. Color light green, often mottled, topographic position in basin or draw
            Wetland - Nonforested Wetland
            6. Color light green to light brown, topographic position usually upland
            Grass / Shrub Complex
    4. Ground cover urban, built up, or actively under agricultural use
        7. Ground tilled or under pasture
        Agricultural Land - Cropland and Pasture *
        7. Other urban or built-up land
            8. Transportation corridor
            Urban and Build-up Land - Transportation, Communication, and Utilities
            8. Not as above
                9. Buildings present, residential
                Urban and Build-up Land - Residential
                9. Buildings present, commercial and services
                Urban and Build-up Land - Commercial