ACCURACY ASSESSMENTS OF LANDSCAPE DATABASES: A CASE STUDY OF HEYBURN STATE PARK, IDAHO

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ABSTRACT

Accurate GIS databases can provide reliable information for management decisions used in the development of prescribed burn programs in reserves and protected areas. A GIS database was developed for Heyburn State Park in northern Idaho to provide an inventory of its resources and to identify potential and present management problems (both human and ecological). The objective was to test accuracy assessment methodology on this database and to determine the areas within the park where prescribed fire was suited as an ecosystem restoration tool. Computer analysis was used to select 2,346 acres (938 hectares) of ponderosa pine (*Pinus ponderosa*) and ponderosa pine–Douglas-fir (*Pseudotsuga menziesii*) forests for fire restoration. This restoration area had 427 acres (171 hectares) requiring prescribed burning and 1,919 acres (767 hectares) requiring thinning before prescribed burning. The accuracy assessments of the GIS data increased confidence in the design and implementation of the Heyburn State Park prescribed burning program.

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INTRODUCTION

Catastrophic wildfires consume large areas of forest throughout the world. Many of these forests once existed under a frequent non-catastrophic surface fire regime. Fire suppression, livestock grazing, exploitive logging practices, and the relocation of aboriginal peoples have changed these fire regimes and made them more catastrophic than they were previously (van Wagtendonk 1985). These wildfires are greater in extent, intensity, and severity than historic surface wildfires. The potential negative impacts of catastrophic wildfires are especially important to small land areas, typically less than a few thousand hectares. Just one wildfire consuming several thousand hectares can consume an entire park, refuge, or reserve. Protection of small landbases requires the treatment of areas within and outside of management units with prescribed fire. The reintroduction of prescribed fire into fire-dependent forest communities helps reverse current catastrophic wildfire trends and protect small landbases. However, several important questions must be addressed. What areas do land managers treat with prescribed fire? How much land do they treat on a yearly basis? What type of management prescriptions are suitable for the different plant community types existing across a landscape? These types of questions are best answered at a landscape level with geographic information systems (GIS) and remote sensing technology.

Use of GIS databases by private and government organizations is growing exponentially (Rose and Draughn 1991, van Wagtendonk 1991, Waggoner 1991). However, managers need to assess the reliability of GIS databases from which they are making management decisions. GIS data are typically collected, manipulated, and then assumed to be accurate. In most cases data verification procedures are absent or inadequate. Verification is commonly conducted on the classification of polygon data, such as vegetation types, land uses, and soil classes (Campbell 1987, Hall et al. 1991). An "error matrix" approach is used in these assessments (Rosenfield 1986, Veregin 1989, Congalton and Biging 1992). In this method, actual and estimated attribute classes are cross-tabulated for a selected sample of cells or plots on a map. It is then possible to calculate the proportion of cells or plots that are correctly classified and determine the accuracy of the entire map (Veregin 1989). Position accuracy of line and point data typically receives the least amount of attention in assessing GIS database accuracy. Research has been conducted to evaluate use of polygon overlay routines (Brusegard and Menger 1989), probability distributions (Maffini et al. 1989), Thiessen and triangulation routines (Brusegard and Menger 1989), and distance calculations (Slonecker and Hewitt 1991) for assessing position errors. However, none of these techniques provide a quick, efficient and simple method usable by land managers, except for distance calculations. Distance calculations between related points or coordinates can efficiently determine the position error between map feature coordinates and coordinates recorded from the field. Distance calculation techniques may be the most usable procedure for determining the accuracy of position data.

We used the ARC/INFO distance calculation procedure called POINTDISTANCE to assess the Heyburn State Park GIS. The use of this quick, efficient, and simple accuracy assessment procedure helped personnel at Heyburn State Park create an accurate GIS database. The database was used to help accomplish the following park management goals and objectives:

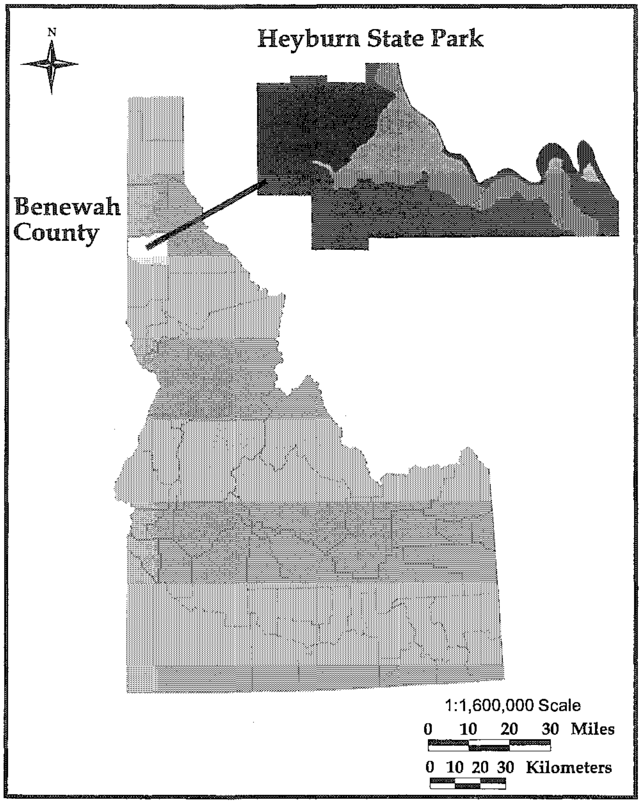

Fig. 1. Heyburn State Park, Benewah County, Idaho.

- Restore, maintain, and protect significant natural communities
- Maintain ecosystem resistance and resilience mechanisms, so that natural communities can be sustained
- Restore and maintain natural resources as representative examples of Idaho's original natural system
- Preserve biological diversity by protecting habitats for rare plant and animal species
- Promote air and water quality
- Conserve soil resources
- Provide wildlife viewing opportunities
- Provide aesthetically pleasing natural environments for people to enjoy
- Control the proliferation of exotic species
- Preserve cultural values

These goals and objectives were adopted by the Idaho State Board of Parks and Recreation and provide the policy framework for natural resource activities within Heyburn State Park. The GIS database provides a tool for examining strategies which may help maintain or complete these goals and objectives. The restoration of historical ponderosa pine (*Pinus ponderosa*) communities has been the primary focus of Heyburn State Park. The GIS database provides a high level of confidence in spatial and attribute data and helped develop a strategy for restoring fire to ponderosa pine forests.

STUDY AREA

Heyburn State Park is located in Idaho's northern panhandle region between the communities of St. Maries and Plummer (Figure 1). The park consists of 5,744 acres (2,298 hectares) of land and 2,332 acres (933 hectares) of water. The geology of the area consists of Precambrian sedimentary rock or igneous basalt rock from the Miocene. The igneous rocks were established by basalt flows created from the formation of the Columbia River plateau. The flows form horizontal terraces that have a depth of 2–10 feet (0.6–3.0 meters). After the formation of the basalt flows, glaciers from the retreat of the Rathdrum Lobe created Lake Coeur d'Alene (South 1990). The present water areas in the Heyburn State Park area consist of Chatcolet Lake, Hidden Lake, and Benewah Lake and form the the southern extension of Lake Coeur d'Alene. These lakes were created with the establishment of the Post Falls dam in 1903 (South 1990). Prior to the dam, the area consisted of wet meadows, bogs, black cottonwood (*Populus trichocarpa*) forests, and smaller versions of Chatcolet Lake and Benewah Lake (Palmer et al. 1987, South 1990). The rise in water level sub-

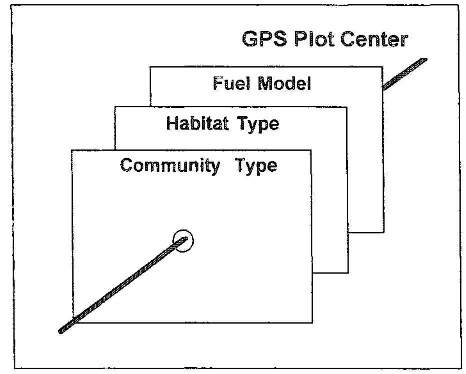

Fig. 2. GPS points at plot centers act as pins which register GIS maps to universal transverse mercator coordinates.

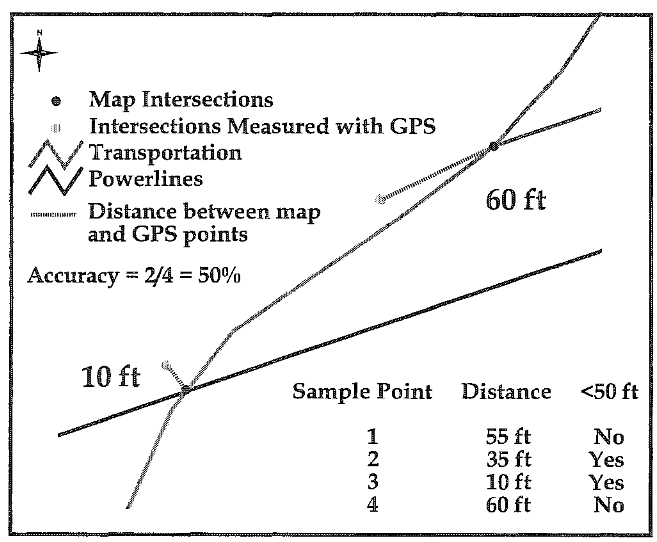

Fig. 3. The ARC/INFO POINTDISTANCE procedure assesses the position accuracy of lines and polygons. The above example is assessing the position accuracy of a road or line feature. The procedure measures the distance between a map point and a GPS point. Multiple measurements determine an average position accuracy.

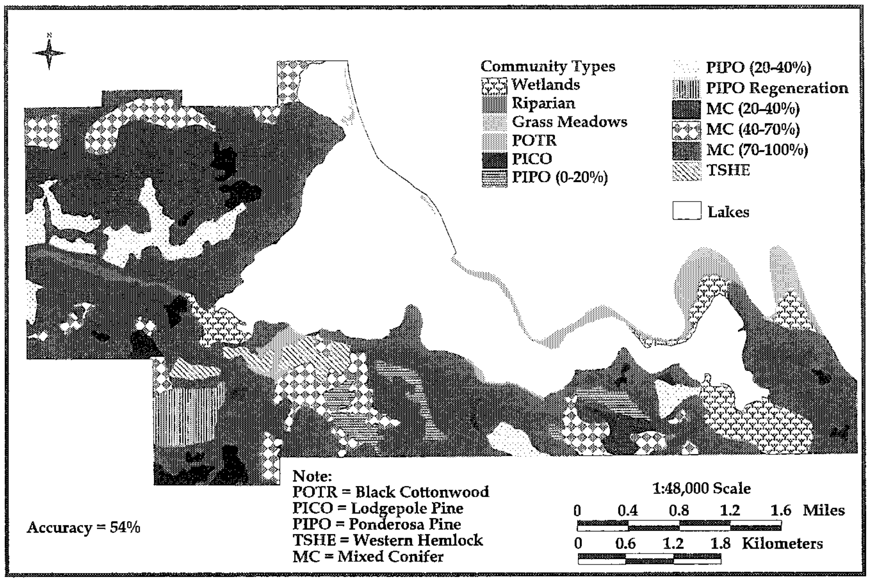

Fig. 4. The community type map was constructed from 1991 panchromatic aerial photographs.

merged these land areas and bogs and expanded the lakes to their present state. Vegetation within the park ranges from marshes, deciduous woodlands, dense mixed-coniferous forests, and open ponderosa pine forests. Draws and drainage bottoms have dispersed patches of old-growth western white pine (*Pinus monticola*), while black cottonwood forests are along the lake shore and the banks of the St. Joe River. The park is surrounded by multiple ownerships of farms, livestock ranches, homesteads, public land, and Coeur d'Alene tribal holdings (South 1990).

METHODS

We used the following steps to develop an accuracy assessed GIS database: GIS data aquisition and construction, development of database design, accuracy assessments, and statistical analysis. Ponderosa pine restoration prescriptions were developed in the form of composite maps from the accuracy assessed database.

GIS Data Aquisition and Construction

GIS data were provided by the Natural Resource Department of the Coeur d'Alene tribe (NRDCDA), U. S. Geological Survey (USGS), Soil Conservation Service (SCS), U. S. Bureau of Mines (USBM), and Heyburn State Park (Appendix A). The data were complete except for the transportation and structures maps. Missing data were collected with a Trimble Basic + Global Positioning System (GPS). Transportation (line) data were collected at 5-second intervals from automobile or by foot, while structure (point) data were sampled by collecting 30 GPS readings per location. The accuracy of the GPS was 9.8–16.4 feet (3–5 meters). Maps in the database were also assessed for their fullfillment of metadata standards designed by the Idaho Geographic Information Advisory Committee (Hallen 1991, Idaho Geographic Information Advisory Committee Metadata Subcommittee 1993).

A plant community map was required for all levels of restoration analysis. This map was delineated using 1991 panchromatic aerial photographs (1:15840) provided by the NRDCDA. Plant community types were delineated by texture, tone, crown shape, and canopy coverage, while wetland community types were delineated by texture and tone. The following forest community types were delineated from the procedure: lodgepole pine (*Pinus contorta*), ponderosa pine, western hemlock (*Tsuga heterophylla*), black cottonwood, and seral mixed-conifer forest. Plummer marsh, Benewah marsh, and three nameless marsh areas were also delineated from the photos. We used the ocular method and a visual density guide (Tomar and Maslekar 1974) to estimate forest canopy coverage. The coverage consists of the following closure categories: open (< 20%), scattered (20–40%), moderate (40–70%), and dense (70–100%).

Development of a Database Design

Map scale in the Heyburn State Park GIS database needed to be consistent to avoid data manipulation and analysis errors (Goodchild 1989, Herzog 1989, Kennedy 1989). The maps obtained from the NRDCDA, USGS, SCS, USBM and the rectified GPS data are all at a 1:24000 scale. However, the mylar overlay created from the aerial photo interpretation was at a scale of 1:15840 scale, so it was changed to the 1:24000 scale during the digitization process. The map overlay was shifted from a coarse scale (e.g., 15,840 scale) to a fine scale (e.g., 24,000 scale) to avoid the introduction of error (Walsh et al. 1987, Woodcock and Strahler 1987).

Minimum mapping units were assigned to the different topological map features (polygons, lines, and points). The minimum mapping unit fixes a lower limit

Table 1. Error matrix for Heyburn State Park community types. Community type codes: MC = mixed conifer, PICO = lodgepole pine, PSME = Douglas-fir, PIPO = ponderosa pine, POTR = black cottonwood, TSHE = western hemlock, Regen. = regeneration.

	Community type map data								
Community type	MC (70–100%)	MC (40–70%)	MC (20–40%)	MC (0–20%)	PICO	PSME	PIPO Regen.	PIPO (P–20%)	PIPO (20–40%)
Plot Data									
MC (70–100%)	**29**	6	1	2	0	3	0	0	0
MC (40–70%)	4	**11**	1	0	0	3	0	0	0
MC (20–40%)	0	2	**1**	0	0	0	0	0	0
MC (0–20%)	0	0	0	**0**	0	0	0	0	0
PICO	7	0	0	0	**1**	5	0	0	0
PSME	0	0	0	0	0	**0**	0	0	0
PIPO Regen.	0	0	0	0	0	0	**3**	0	0
PIPO (0–20%)	0	0	0	2	0	0	0	**4**	0
PIPO (20–40%)	0	2	2	0	0	0	0	2	**4**
PIPO (40–70%)	0	0	0	0	0	0	0	0	0
POTR	0	0	0	0	0	0	0	0	0
Riparian	0	0	0	0	0	0	0	0	0
Grass & Shrub Mix	0	0	0	0	0	0	0	0	0
Grass Meadow	0	0	0	0	0	0	0	0	0
TSHE	4	0	0	0	0	0	0	0	0
Column Total	44	21	5	4	1	11	3	6	4
Commission Error	34.1%	47.6%	80.0%	10.0%	0.0%	100.0%	0.0%	33.3%	0.0%

Community type	PIPO (40–70%)	POTR	Riparian	Grass-shrub mix	Grass meadow	TSHE	Total row	Omission error
Plot Data								
MC (70–100%)	2	0	0	0	0	0	43	32.6%
MC (40–70%)	1	0	0	0	0	0	20	45.0%
MC (20–40%)	0	0	0	0	0	0	3	66.7%
MC (0–20%)	0	0	0	0	0	0	0	0.0%
PICO	0	0	0	0	0	0	13	92.3%
PSME	0	0	0	0	0	0	0	0.0%
PIPO Regen.	0	0	0	0	0	0	3	0.0%
PIPO (0–20%)	0	0	0	0	0	0	6	33.3%
PIPO (20–40%)	0	0	0	0	1	0	11	63.6%
PIPO (40–70%)	**0**	0	0	0	0	0	0	0.0%
POTR	0	**6**	0	0	0	0	6	0.0%
Riparian	0	0	**2**	0	0	0	2	0.0%
Grass & Shrub Mix	0	0	0	**0**	0	0	0	0.0%
Grass Meadow	0	1	0	2	**0**	0	3	100.0%
TSHE	0	0	0	0	0	**0**	4	100.0%
Column Total	3	7	2	2	1	0	**114**	
Commission Error	100.0%	14.3%	0.0%	100.0%	100.0%	0.0%	Accuracy =	53.5%

on acceptable topological feature size or deviation of coordinates from real world coordinates. The minimum mapping unit for polygons is 5 acres ± 50 feet at a 20% error level (based on map scale), so polygons less than the minimum mapping unit are excluded from all maps. For example, a polygon of lodgepole pine that was less than 5 acres ± 50 feet in size and surrounded by a polygon of seral mixed forest would be ignored and grouped into the mixed forest polygon. The minimum mapping unit for the line and point data were ± 50 feet at a 20% error level or ± 70 feet at a 30% error level. These standards were used for the position accuracy assessments of line and polygon maps.

After the rescaling process and the establishment of minimum map unit standards, GIS maps were compiled into a landscape database. In addition, attribute data were linked to GIS maps in a relational database format. An attribute is a characteristic of a map feature described by numbers or characters (Environment Systems Research Institute, Inc. 1990) and is linked to a map feature by a user-assigned identifier. The attribute data are linked to related spatial data to form a relational GIS database. For example, a user assigned identifier for a vegetation map may be the community type. Attribute data for a given community type can then be linked to the community type polygons by this identifier. Attribute data exists in a spreadsheet, text file, or photograph format within the Heyburn State Park GIS database. Attribute data in the plant com-munity type map include habitat type, tree and snag data (species, basal area, density, structural stage, tree regeneration, and height and age for one dominant tree for each species), understory plants, rare plants, down woody debris, insect and disease species, potential wildlife species, and Fire Behavior Prediction System fuel models (Fischer 1981a, Fischer 1981b, Anderson 1982). Natural resource attribute data were collected from 114 circular 0.1 acre (0.04 hectare) sample plots.

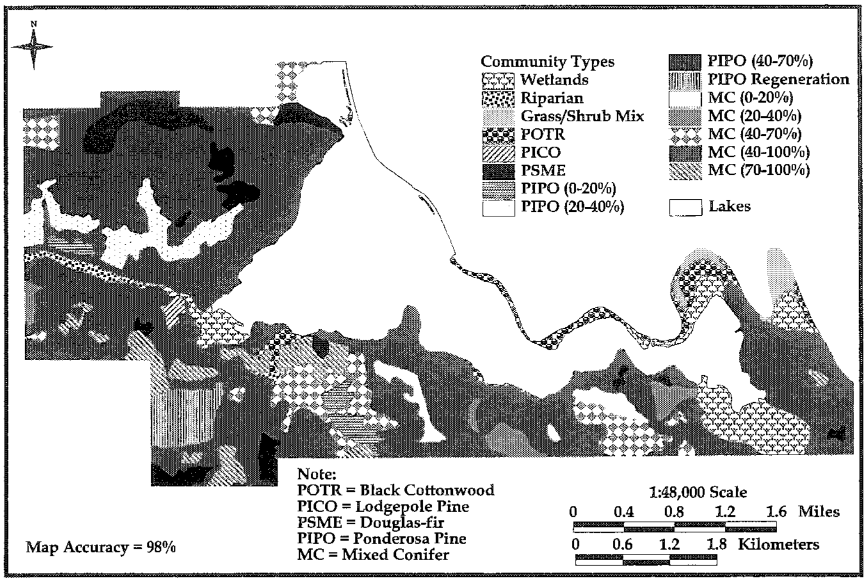

Fig. 5. The revised community type map was corrected with data from 114 sample plots.

Accuracy Assessments and Statistical Analysis

Upon completion of the Heyburn State Park GIS database, accuracy assessments were conducted on polygon and line GIS data. A classification accuracy assessment of the landscape database was conducted with 114 square 1.0 acre (0.4 hectare) sample plots (> 1% of the area). These plots were mapped with a GPS unit and registered to real world coordinates. The registration of maps allowed us to determine the presence or absence of features within the sampling units (Figure 2). The overall errors in each community type classified from aerial photographs were determined from an error matrix (Rosenfield 1986, Veregin 1989, Congalton and Biging 1992). The matrix was constructed by comparing the presence or absence of community types in the classified GIS map with community types obtained from sample plots. Mean accuracy percentages were calculated from the comparison. If the presence or absence sampling corresponded with a 70% level of accuracy, the aerial photo data, GPS data, and GIS maps in the database were considered reliable.

Position accuracy of line and polygon features was determined with the POINTDISTANCE command in ARC/INFO (Ver. 7.1.1). GPS points were taken at distinguishable locations (road and stream intersections, dead ends, etc.) for line and polygon features in order to create a GPS point intersection map. A second point intersection map was generated by locating these distinguished locations within the database. The POINTDISTANCE procedure (Figure 3) calculated the distance between the GPS point and the map intersection point (Environmental Systems Research Institute 1997). Lines and polygon line segments were analyzed at a standard of ± 50 feet and ± 70 feet. So for the standard of ± 50 feet, sample points with a distance > 50 feet were considered unacceptable at the ± 50 feet error level. Progressive mean accuracy was generated for maps tested for position accuracy (Mueller-Dombois and Ellenberg 1974, Zar 1984, Microsoft Corp. 1993, Ott 1993). The progressive mean accuracy was determined by calculating the mean accuracy with each addition to sample size (Mueller-Dombois and Ellenberg 1974, Zar 1984, Microsoft Corp. 1993, Ott 1993). T-tests (Zar 1984, Microsoft Corp. 1993, Ott 1993) were also generated on the POINTDISTANCE data sets. These statistics were used to determine if each map was accurate to within 50 feet or 70 feet of real world coordinates (Ho: $\mu \leq$ 50 feet or 70 feet; Ha: $\mu >$ 50 feet or 70 feet).

Construction of Composite Maps

The ability to use existing GIS maps to create new maps is a valuable GIS tool. The following GIS maps were created from the accuracy assessed database: habitat type and forest fuel process models, optimal and suitable western white pine habitats, ponderosa pine distribution, prescribed burn areas, harvest prescriptions, and fire hazard maps. These maps were created by combining existing GIS maps and attribute information.

ACCURACY ASSESSMENTS

Classification Accuracy

Georeferenced plot centers were used in the classification assessment of the plant community type map in order to register community type polygons to universal transverse mercator (UTM) coordinates (Figure 2). The data collected at these points were used to determine attribute type or to change polygons to their appropriate attribute type. The classification assessment of the plant community type map had a map accuracy of 53.5% (Figure 4; Table 1). Error in identifying community types represented 28.9% of the total error. Corrections of misclassified cover type names increased this accuracy to 82.4%. The western hemlock polygons had the highest amount of error. The polygons were not composed of pure western hemlock, but contained a mixture of western hemlock, western redcedar (*Thuja plicata*), grand fir (*Abies grandis*), lodgepole pine, Douglas-fir (*Pseudotsuga menziesii*), western larch (*Larix occidentalis*), and ponderosa pine. Hence, the polygons were classified as a mixed-conifer community type. The community type with the second highest rate of classification error was lodgepole pine. Twelve lodgepole pine polygons were classified from the aerial photographs. After ground truthing, five of these polygons were classified as Douglas-fir community types and seven into mixed-conifer community types. The third highest rate of classification error occurred between ponderosa pine and mixed-conifer community types. Finally, grass polygons were changed to a grass and shrub mixture due to the presence of red-osier dogwood (*Cornus stolonifera*) and black hawthorn (*Crataegus douglasii*) in the polygon.

Misclassification of canopy coverage represented 15.8% of the remaining error in the plant community type map. The greatest error occurred in the mixed-conifer polygons with a moderate (40–70%) or dense (70–100%) canopy cover. This error was corrected by combining classes into a mixed-conifer class with a canopy coverage of 40–100%. The final accuracy of the plant community type map was 98.2% (Figure 5).

Position Accuracy

The ability to assess the position accuracy of line and polygon data in a simplified, fast, and efficient manner is an invaluable tool for land managers. The POINTDISTANCE procedure in ARC/INFO 7.1.1 was used to check the position accuracy of the park boundary, lakes, streams, powerlines, digitized transportation, and GPS generated transportation maps (Figures 6, 7 and 8). Powerlines had the greatest accuracy and the streams had the lowest (Figure 6). Maps assessed for a ± 70 feet error had higher accuracy than maps assessed for ± 50 feet error. Maps generated with a GPS had a higher accuracy than digitized maps. The digitized park boundary was an exception and had the second highest map accuracy at 81.2% (Figure 7). T-tests indicate that average sample point accuracy is <50 feet and <70 feet for all maps (Tables 2 and 3, respectively).

Composite Maps and Models

GIS maps in the database and associated attribute data provided information that was used to develop composite maps. The composite maps consist of habitat type and forest fuel process models, optimal and suitable western white pine habitats, ponderosa pine distribution, prescribed burn areas, harvest prescriptions, and fire hazard maps. These composite maps are only as accurate as the least accurate map used in their development (Walsh et al. 1987). Consequently, a database with high accuracy will allow maps developed from it to maintain this high accuracy. For example, fire hazard analysis is dependent on many different

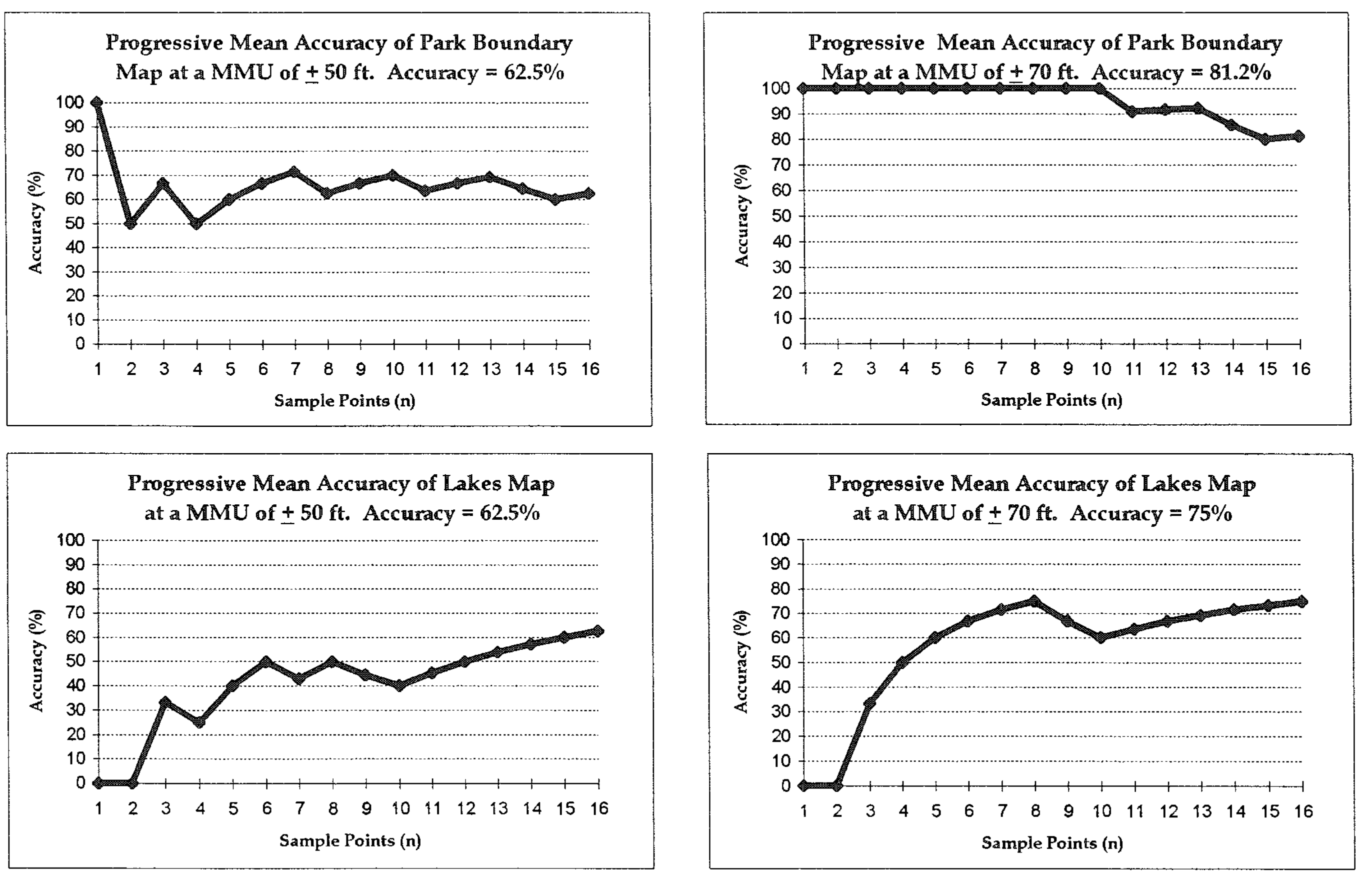

Fig. 6. Progressive mean accuracy plots of the park boundary and lake maps. MMU = minimum mapping unit.

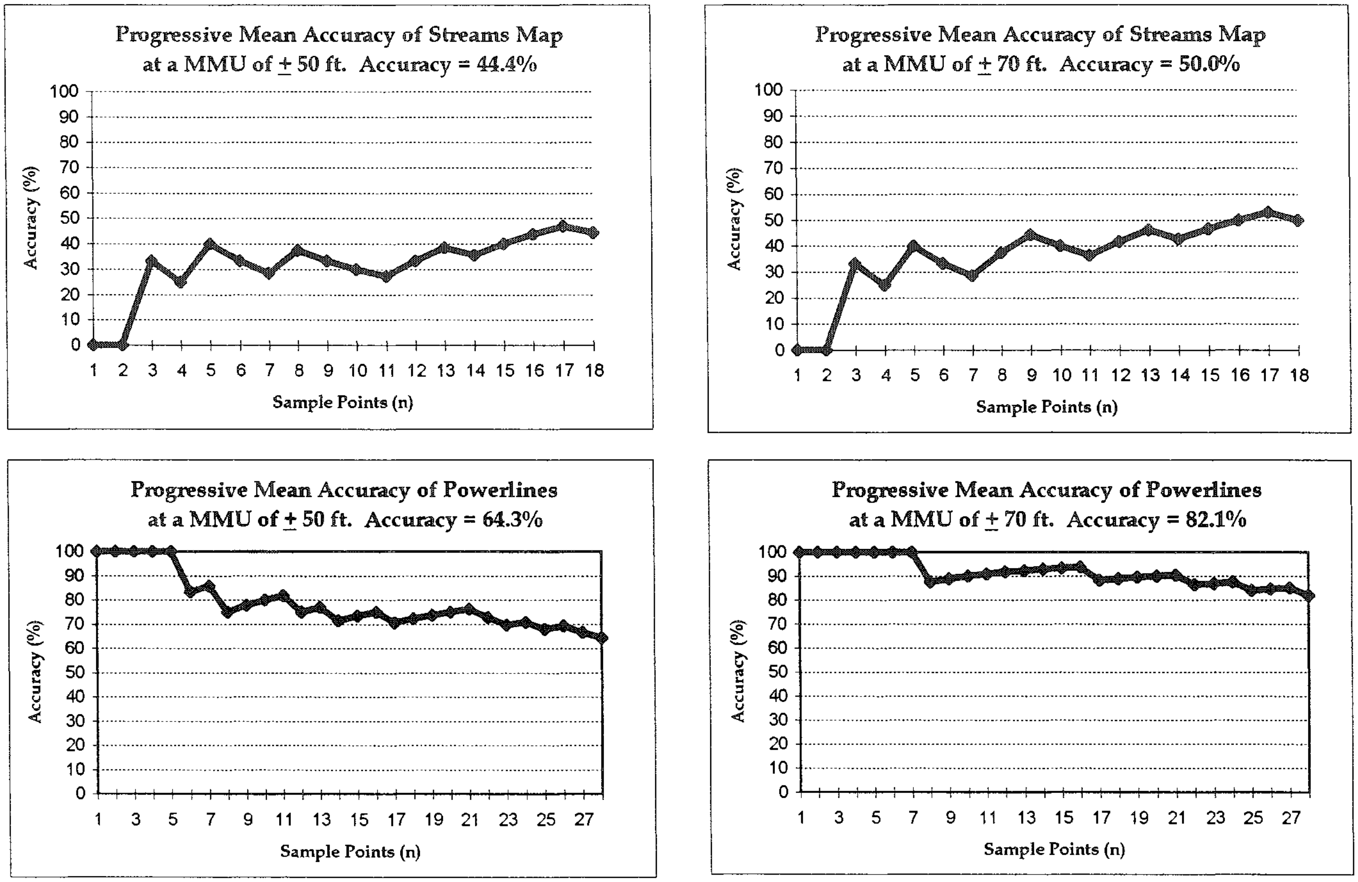

Fig. 7. Progressive mean accuracy plots of the streams and powerlines maps. MMU = minimum mapping unit.

data layers including vegetation, transportation, powerlines, structures, significant species and communities, fuel models, and ownerships. The maps containing these variables will each have a different accuracy and results will only be as accurate as the least accurate input map. The accuracy of the Heyburn State Park fire hazard map was 67% due to the transportation map (Figure 9).

FUELS MANAGEMENT AND SUPPRESSION STRATEGIES

The accuracy of the Heyburn State Park GIS database increased the confidence in the design and implementation of the Heyburn State Park prescribed burning program. According to our analysis criteria, 2,346 acres (938 hectares) of ponderosa pine and ponderosa pine—Douglas-fir forests were selected for fire restoration. This restoration area had 427 acres (171 hectares) requiring prescribed burning and 1,919 acres (767 hectares) requiring thinning before prescribed burning (Figure 10). Besides providing the spatial location of fire restoration areas, the GIS database provided information useful and needed for prescribed buring or fire suppression. For instance, the database was able to provide us with unit size, aspect, slope, elevation, fuel model, tree density, snag density, basal area, and understory species for any location within the proposed restoration areas (Figure 11). Accuracy assessments are associated with these GIS data. The reliability of GIS-based decisions made by managers, planners, burn bosses, and fire management officers can be determined from accuracy information. With accurate information, managers can identify and prioritize burn projects and restore a landscape burn pattern. They can also use this information for developing wildfire suppression strategies, designating escape routes and safety zones, and locating firebreaks and extremely hazardous fuels. However, managers need to be cautious of the dangers of using prescriptions and suppression strategies based on low or unknown accuracy data.

SENSITIVE, RARE AND ENDANGERED SPECIES AND COMMUNITIES

The use of prescribed fire can be either positive or negative to some species and communities (Bendell 1974). Fire effects are especially important when managers are dealing with rare and endangered species or communities. The locations of species or communities that require fire versus those that are degraded by fire need to be identified before implementation of a prescribed burning program. The identification of these locations is necessary whether the management objective is to reintroduce fire to enhance a system or pro-

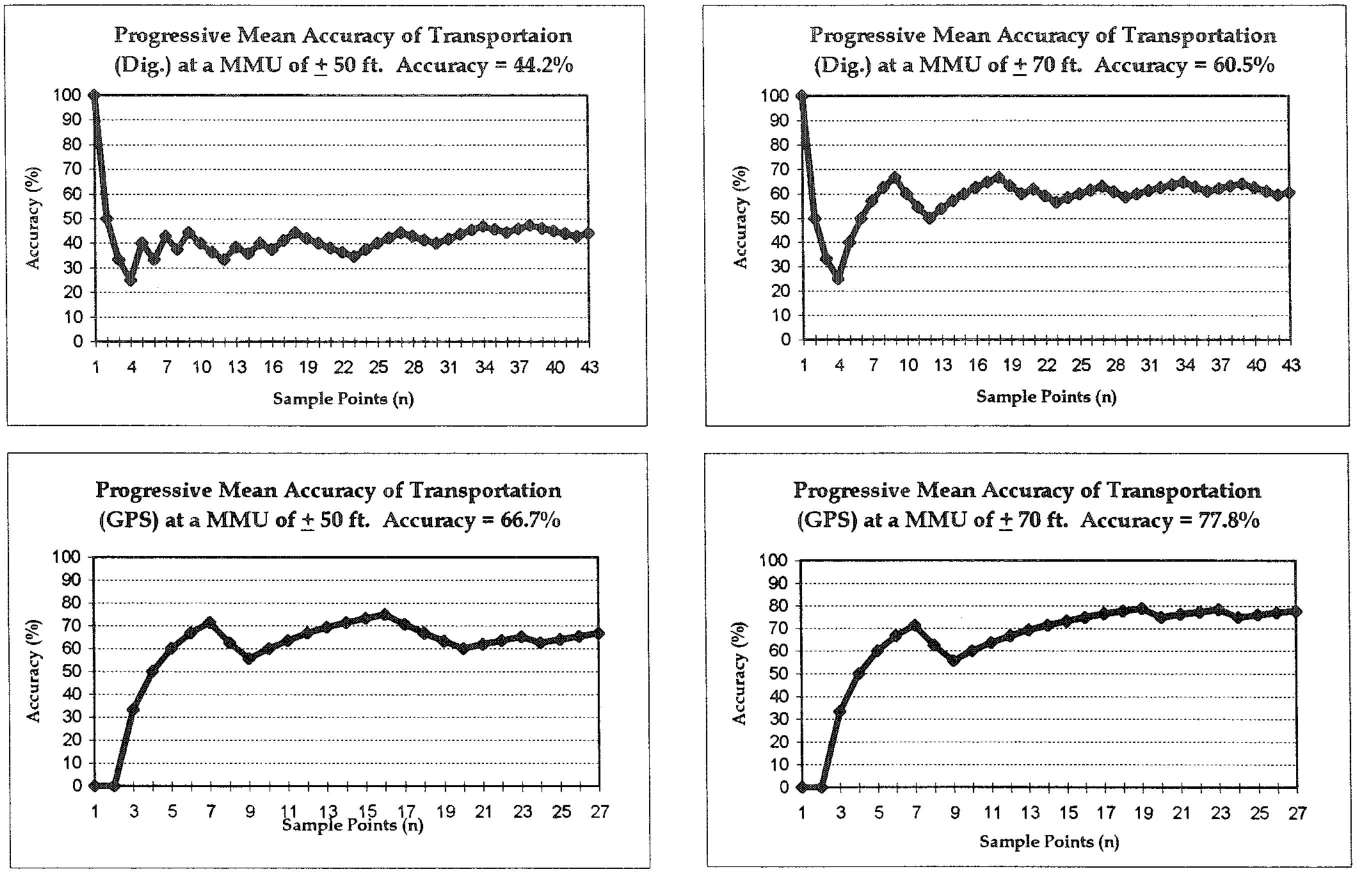

Fig. 8. Progressive mean accuracy plots of digitized transportation and GPS transportation maps. MMU = minimum mapping unit.

tect a system from fire hazards. Land managers need to understand, identify, and locate potential habitats and distributions of sensitive, rare and endangered species. They must plan in order to minimize negative impacts on the distribution, forage, movement, and shelter requirements of these species (Bendell 1974). Accurate databases provide reliable information on the areas used by species and are useful in determining the effects of fire reintroduction in and near critical habitats.

In Heyburn State Park, potential habitat exists for the pygmy nuthatch (*Sitta pygmaea*), a bird listed on the Bureau of Land Management sensitive species list for the state of Idaho (Idaho Conservation Data Center 1994). This species prefers open ponderosa pine communities and shuns other forest community types (Burleigh 1972). GIS analysis determined that the restoration of dense ponderosa pine forests to open ponderosa pine forests would provide 2,346 acres (938 hectares) of habitat within the park for this species (Figure 10). The Hall's lungwort (*Lobaria hallii*) and the Coeur d' Alene salamander (*Plethodon vandykei idahoensis*) are also listed and present in Heyburn State Park. The restoration prescription did not overlap with the habitats of these species; therefore, prescribed fire should probably not impact them.

MANAGEMENT IMPLICATIONS

The complete assessment of GIS databases has the following management implications for fire restoration, maintenance, fuels treatment, fire suppression, and protection of threatened and endangered species and ecosystems.

Table 2. Tests used to determine map accuracy significance of lines or line segments at a ±50 foot error level.

Maps	n	df	t	$t_{0.05}$	Conclusion
Park Boundary	16	15	0.084	1.753	≤50
Lakes	16	15	0.223	1.753	≤50
Streams	18	17	0.576	1.740	≤50
Powerlines	28	27	−0.165	1.703	≤50
Transportation (Dig.)	43	42	0.425	1.682	≤50
Transportation (GPS)	27	26	0.142	1.706	≤50

Table 3. Tests used to determine map accuracy significance of lines or line segments at a ±70 foot error level.

Maps	n	df	t	$t_{0.05}$	Conclusion
Park Boundary	16	15	−0.410	1.753	≤70
Lakes	16	15	−0.182	1.753	≤70
Streams	18	17	−0.283	1.740	≤70
Powerlines	28	27	−0.751	1.703	≤70
Transportation (Dig.)	43	42	0.072	1.682	≤70
Transportation (GPS)	27	26	−0.204	1.706	≤70

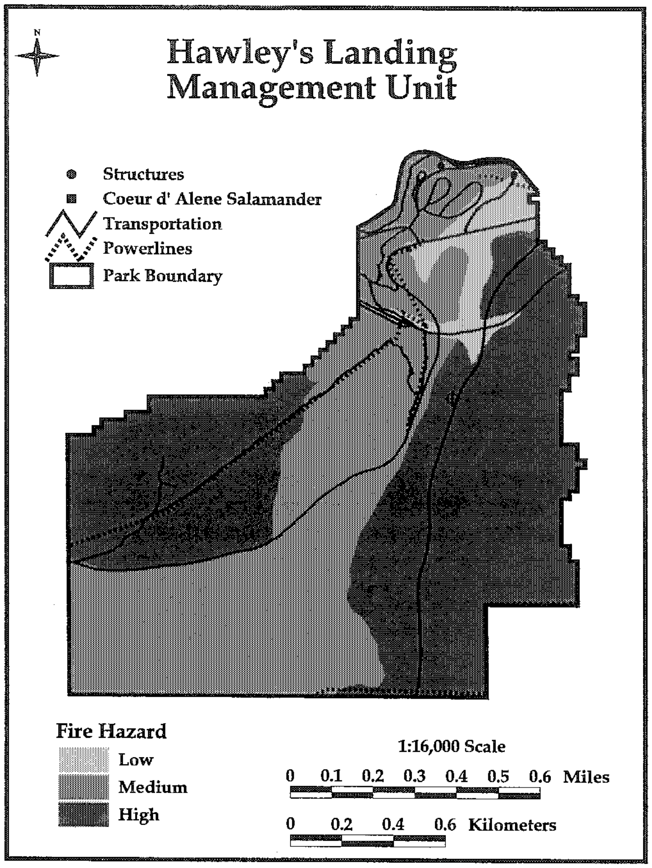

Fig. 9. Fire hazard map for the Hawley's Landing management unit in Heyburn State Park.

1. The GIS database will have an increased position accuracy of line and polygon data layers.
2. GIS maps created from the assessed database are developed at a high level of accuracy due to their registration to georeferenced sample points.
3. Fire simulation models (e.g., FARSITE) and fire effects models increase in accuracy. The use of accurate inputs to models improves the final products generated by these models. Even without accurate input data the information generated by models can be used as spatial attribute data.
4. Fire managers can develop suppression strategies of improved efficiency and safety with the data and knowledge provided by an accurate GIS database.
5. Accurate GIS databases are useful management tools for developing reliable fuels management strategies and prescriptions.
6. Fire hazard assessments demonstrate an increased accuracy in finding areas that endanger cultural and natural resources.
7. Accurate GIS databases help managers locate rare and endangered species or communities. Managers can then develop management strategies suitable for these areas.
8. Conservation strategies for threatened and endangered species and ecosystems can be designed and effectively implemented with an accurate GIS database.
9. Methods for restoration and maintenance of fire-dependent communities are more effective.
10. Communication of information to the public about the complex issues of fire restoration is enhanced with the specific areas identified for the restoration.

The most important management implication of an accuracy assessed database is the increased efficiency of land managers and scientists to maintain or restore ecosystem patterns and processes across a landscape. This allows managers to shift from wildfire suppression to prescribed burning through strategic long-range planning. Wildfire suppression activities are thus pri-

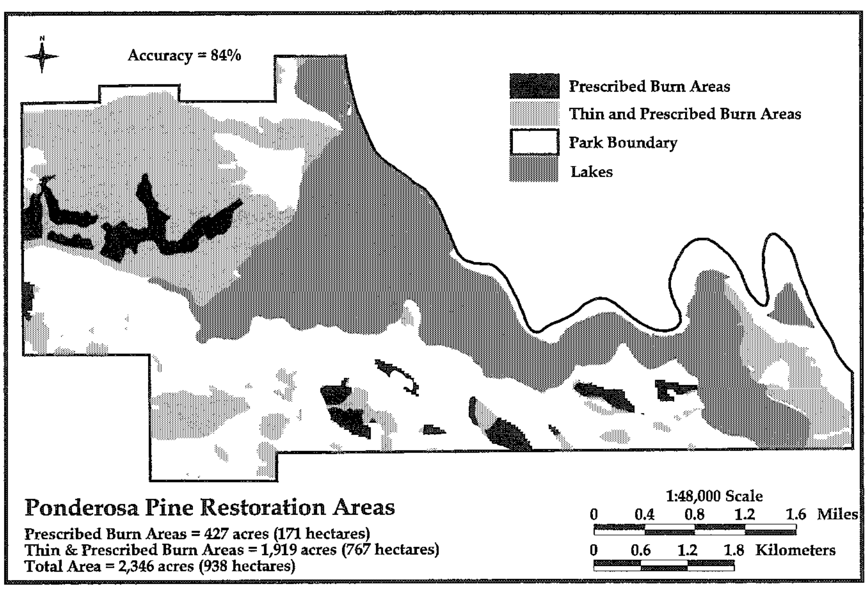

Fig. 10. Prescribed fire and thinning with prescribed fire were designated for ponderosa pine (*Pinus ponderosa*) restoration areas. The treated areas will be converted from a dense forest structure to an open forest structure. These areas will benefit the pygmy nuthatch (*Sitta pygmaea*) and other species dependent on open ponderosa pine forests.

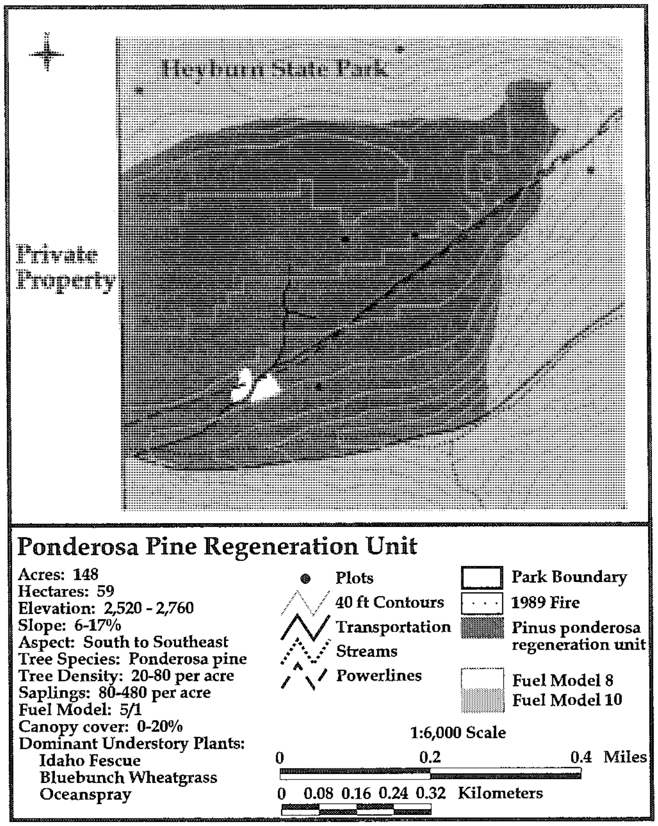

Fig. 11. The spatial and attribute data were used in developing a fuels management prescription for the ponderosa pine (*Pinus ponderosa*) regeneration unit.

oritized with the appropriate level of response to specific areas within the park.

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Appendix A. The list of GIS coverages, attribute data and models incorporated into the Heyburn State Park GIS database from the Natural Resource Department of the Coeur d'Alene tribe (NRDCDA), U.S. Geological Survey (USGS), Soil Conservation Service (SCS), U.S. Bureau of Mines (USBM) and Heyburn State Park (HSP).

Maps, models and attribute data	Source
Elevation	USGS, NRDCDA & HSP
Slope	USGS, NRDCDA & HSP
Aspect	USGS, NRDCDA & HSP
Park Boundary	NRDCDA
Lakes	NRDCDA
Rivers and Streams	NRDCDA
Subwatersheds	NRDCDA
Watersheds	NRDCDA
Public Land Survey	NRDCDA
Structures	NRDCDA & HSP
Transportation	NRDCDA & HSP
Habitat Type	HSP
Community Type	HSP
Fuel Models	HSP
Significant Animal Communities	HSP
Exotic Species List	HSP
Insect & Disease Species List	HSP
Fire Hazard Model	HSP
Powerlines	HSP
Management Zones	HSP
Management Subzones	HSP
Wildlife Species Lists	HSP
Tree & Snag Data	HSP
Understory Plant Species List	HSP
Soils	SCS
Geologic Sites	USBM