AD-A136 277 AN ENDANGERED SPECIES SURVEY OF ABANDONED MINE SHAFTS IN THE BIG SOUTH FO..(U) FISH AND WILDLIFE SERVICE COOKEVILLE TN ECOLOGICAL SERVICES O.. 1/2

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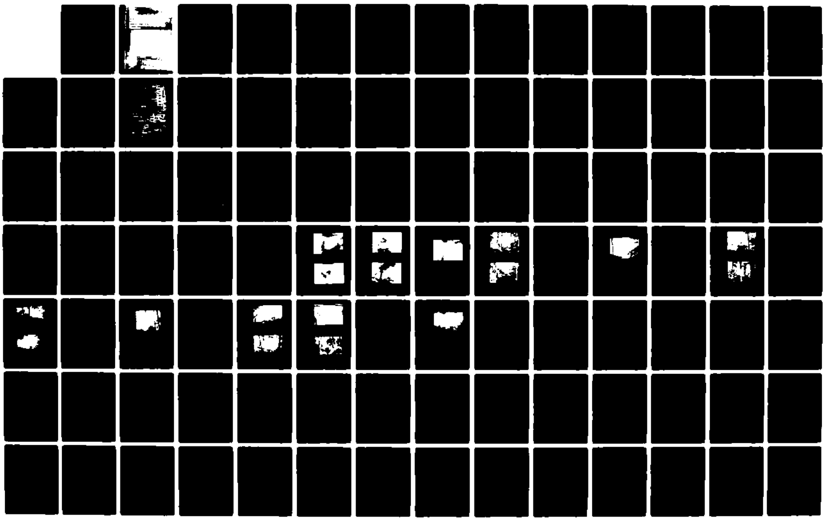

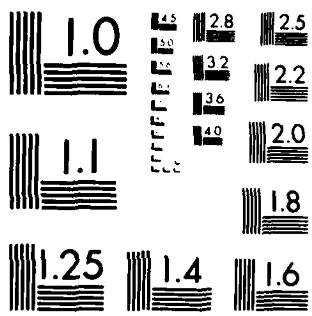
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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO. AD-A136277	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) An Endangered Species Survey of Abandoned Mine Shafts in the Big South Fork National River & Recreation Area, Kentucky & Tenn.		5. TYPE OF REPORT & PERIOD COVERED Final Report
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Barclay, Lee A., Jr., and David R. Parsons		8. CONTRACT OR GRANT NUMBER(s) Order No. 83-11
9. PERFORMING ORGANIZATION NAME AND ADDRESS Ecological Services Office, U.S. Fish and Wildlife Service, P.O. Box 845, Cookeville, Tennessee 38503		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS Endangered Species BSFNRRA
11. CONTROLLING OFFICE NAME AND ADDRESS Nashville District Corps of Engineers P.O. Box 1070 Nashville, Tennessee 37202		12. REPORT DATE September 1983
		13. NUMBER OF PAGES 92
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Available from National Technical Information Service
5285 Port Royal Road
Springfield, Virginia 22151

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Myotis sodalis, Myotis lucifugus, Myotis keenii, Myotis leibii, Pipistrellus subflavus, Eptesicus fuscus, Plecotus rafinesquii, Indian bat, little brown bat, Keen's bat, small-footed bat, eastern pipistrelle, big brown bat, Rafinesque's big-eared bat, BSFNRRA, abandoned mines, mine closure, endangered species.

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A total of 114 abandoned mine openings in the Big South Fork National River and Recreation Area (BSFNRRA) was surveyed for the presence of endangered species of bats between December 10, 1982, and April 14, 1983. Although no endangered species were found, 351 bats representing 6 species were encountered using these mines. Species encountered include eastern pipistrelle, Rafinesque's big-eared bat, big brown bat, Keen's bat, little brown bat, and small-

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Block 20 (cont.): footed bat. Suitability of mines as bat habitat, accounts of bat species encountered, life history requisites of endangered Indiana and gray bats, methods of closing abandoned mine openings, protecting bat habitat and the public, and other management considerations are discussed. Alternatives for treatment of abandoned mine openings in the BSFNRRA are presented.

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ACKNOWLEDGEMENTS

Successful completion of this project is the result of countless hours of effort by a number of individuals. National Park Service (NPS) Rangers Bill Carroll and Glenn King provided invaluable logistical support throughout the project. Other NPS employees who assisted with field work were Mike Duwe, Larry Kangas, Michael Rikard, and Ken Kern. Glen Voss, Mike Duwe, and Bruce Gregory of the NPS were particularly helpful during project planning and evaluation, and generously committed staff support to the project. Our sincere thanks to each of these individuals.

Technical assistance in bat identification and survey methodologies was generously provided by Bob Currie (U.S. Fish and Wildlife Service) and John MacGregor (Kentucky Department of Fish and Wildlife Resources), and both individuals assisted in portions of the field work and critically reviewed the manuscript. Doug Stevens and Jeff Sole (KDFWR) assisted in portions of the mist net survey; Danny Reed (Tennessee Division of Land Reclamation) provided logistical support during Tennessee portions of the study. We gratefully acknowledge the help of these five individuals.

Tom Talley, Bob Bay, Mitch King, and Doug Winford of the U.S. Fish and Wildlife Service assisted with the mist net survey, for which we are grateful. Additionally, Tom Talley (Supervisor, Ecological Services Office, USFWS, Cookeville, TN) allowed the authors the necessary schedule flexibility and administrative support to successfully complete the project. Melissa Roberts typed the manuscript, for which we are grateful.

Jim Sharber, Corps of Engineers' Project Officer, provided guidance, technical assistance, and contractual flexibility throughout the duration of this study; his efforts are gratefully acknowledged.

ABSTRACT

Because of historical land uses, a large number of abandoned mine openings are found in the Big South Fork National River and Recreation Area (BSFNRRA), Kentucky and Tennessee. Because of safety hazards associated with open mine shafts in a national recreation area, methods of sealing or otherwise making these mine shafts inaccessible to humans are being investigated by the U.S. Army Corps of Engineers and the National Park Service. Because of the possibility that some of these abandoned mines were being utilized by endangered species of bats, the U.S. Fish and Wildlife Service was asked to (1) survey the BSFNRRA abandoned mine shafts for the presence of endangered species of bats; (2) determine, if endangered species are present, the degree of importance that the mine shafts have to the continued existence of the species inhabiting them; and (3) recommend methods of excluding humans from the mine shafts without jeopardizing the continued existence of an endangered species.

A total of 114 abandoned mine openings located within or adjacent to the BSFNRRA was inspected between December 10, 1982, and February 17, 1983. When physical conditions permitted, each mine was surveyed for the presence of hibernating bats and for other evidence of bat use (e.g., guano deposits). When safety considerations or mine complexity prevented a thorough survey of a given mine, it was alternately

surveyed by mist-netting for bats at shaft openings during the period April 12-14, 1983. Ninety-six abandoned mine openings were surveyed by physical entry and visual inspection, while 18 mine openings were surveyed by mist-netting.

A total of 351 bats representing 6 species was observed using abandoned mines in the BSFNRRA during the course of this study. Of these, 267 bats representing 4 species (eastern pipistrelle, Rafinesque's big-eared bat, big brown bat, and little brown bat) were observed hibernating in 27 shafts; 44 bats representing 5 species (Keen's bat, small-footed bat, eastern pipistrelle, Rafinesque's big-eared bat, and little brown bat) were captured in mist nets at 12 mine openings. Combining data from the mist-netting and in-shaft surveys, 32 of the 114 mine shafts surveyed during this study (28 percent) contained bats.

No endangered species or signs of endangered species use were encountered during the course of this study. One specimen of the endangered Indiana bat, however, was captured during a preliminary survey in September 1981. It now appears likely that this individual was a migrant that was using the mine as a day roost during migration.

Suitability of mines as bat habitat, accounts of bat species encountered in the BSFNRRA, methods of closing abandoned mine openings, protecting bat habitat and the public, condition of mine

openings and shafts, and other management considerations are discussed. Based on considerations of human safety, environmental quality, and protection of bat habitat, alternatives for treatment of abandoned mine openings in the BSFNRRA are presented. Preferred alternatives include gating 20 mine openings, dry sealing 51 openings, hydraulically sealing or sealing with drains 29 openings, and leaving open (with treatment of mine drainage when present) 14 openings.

INTRODUCTION

The Big South Fork National River and Recreation Area (BSFNRRA) was authorized by Section 108 of the Water Resources Development Act of March 7, 1974 (P.L. 93-251). The U.S. Army Corps of Engineers (COE) is lead agency for acquisition and development of the BSFNRRA "to conserve and interpret an area containing unique cultural, historic and natural values, and preserve the Big South Fork River as a natural and free-flowing stream." Public Law 93-251 was amended on October 22, 1976, to direct the National Park Service (NPS) to provide interim management and technical assistance in the development phase, and to assume overall management responsibility for the area upon completion of acquisition and development efforts.

As set forth in the enabling legislation, the BSFNRRA is to be a multi-use recreational facility. The primary activities will be hunting, hiking, camping, and river-related recreation such as canoeing, rafting, and fishing. Proposed development sites are depicted in Figure 1.

Historically, the Big South Fork area was a major center for coal mining activities. The earliest mining activity recorded for the area dates from the mid-1820's. Coal close to the surface was hand worked, loaded on river barges, and floated downstream. Further mining activity is documented as having occurred during the Civil War years.

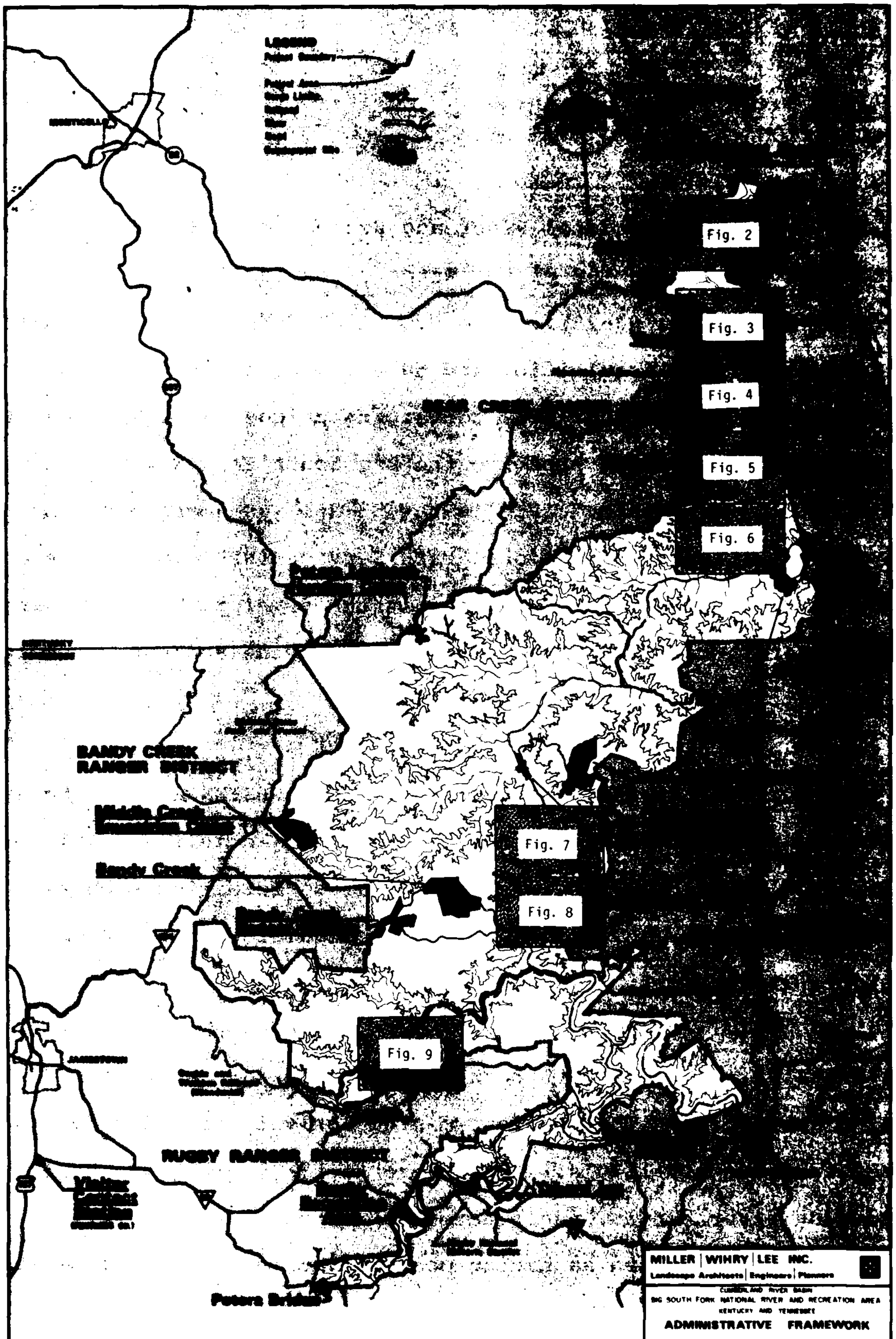


Figure 1. Map of the Big South Fork National River and Recreation Area depicting proposed development sites and relative locations of areas detailed in Figures 2 through 9.

The advent of deep underground mining in the area is thought to have begun around the turn of the century. The Stearns Coal Company was organized in 1898-1899 and opened its first drift mine in 1902 along Roaring Paunch Creek (a drift mine is a mine with nearly horizontal passageways driven on or parallel to the course of a coal seam). Their mining activity reached its peak in about 1960 and declined rapidly thereafter. The Stearns Coal Company ceased mining operations in 1975. In about 1925, the Comargo Coal Company started operations on the west side of the river in the vicinity of Roaring Paunch Creek; Comargo abandoned further active mining in the area following the major flood of 1929 which washed out a majority of the company's equipment.

Due to the historical land use, a large number of open abandoned mine shafts are found on BSFNRRA lands. Over the years, most of these shafts have become unstable and have undergone some degree of infilling or collapse. Because of the obvious safety hazards associated with open mine shafts in a national recreation area (e.g., hazards in these mines include potential roof collapse, oxygen deficiency, poisonous or explosive mine atmospheres, and human disorientation), the NPS and COE are investigating methods to seal or otherwise make these mine shafts inaccessible to humans. In response to a NPS request for technical assistance in evaluating impacts of mine closure and gob pile treatment on fish and wildlife resources, representatives of the U.S. Fish and Wildlife Service (FWS), U.S.

Office of Surface Mining (OSM), Kentucky Department of Fish and Wildlife Resources (KDFWR), and the Tennessee Wildlife Resources Agency (TWRA) participated with NPS representatives in a field inspection of BSFNRRA abandoned mine shafts on September 16, 1981. During this trip, 7 abandoned mine shafts were entered and 4 were found to contain bats; one individual of the endangered Indiana bat (Myotis sodalis) was collected by John R. MacGregor and Lee A. Barclay. Informal endangered species consultation with the U.S. Fish and Wildlife Service's Asheville Area Office (letter from William C. Hickling, Area Manager, dated November 4, 1981) confirmed the possibility that some of these abandoned mine shafts are being utilized by endangered species of bats. In partial response to this, the COE contracted with the Cookeville, Tennessee, Ecological Services Office of the U.S. Fish and Wildlife Service for assistance in analyzing potential environmental impacts associated with closure of these shafts. This document represents the final report from that contract.

Based on the published literature and knowledge of the life histories and geographic distribution of the endangered and threatened species of Kentucky and Tennessee, only two endangered species appeared likely to utilize the BSFNRRA abandoned mine shafts--the Indiana bat (Myotis sodalis) and the gray bat (Myotis grisescens). Both species utilize caves and mines at critical stages in their life cycles, and both have been recorded from counties encompassing or adjacent to the BSFNRRA.

Hibernaculum requirements for the Indiana and gray bats are detailed later (see Discussion). Briefly, Indiana bats require caves exhibiting high relative humidities and stable mid-winter temperatures averaging 4 to 8^{o} C, while gray bats also require caves with high humidities and mid-winter temperatures averaging 6 to 11^{o} C. Gray bats also require unusually warm caves in summer for maternity colonies. Indiana bats, on the other hand, form small maternity colonies under the bark of trees, usually in or near riparian habitat.

The most critical period for the Indiana bat and probably for the gray bat, as regards endangerment, is the winter hibernation period. Because of the narrow and unusual range of conditions required for suitable hibernacula, both species have extremely limited choices for hibernation sites. As a consequence, each species typically overwinters in huge colonies in a very limited number of hibernacula. Since Indiana bats are known to hibernate in mines exhibiting suitable temperature and humidity conditions, and since gray bats have similar hibernaculum requirements, it was reasonable to suspect that one or more of the abandoned mine shafts in the BSFNRRA might possess the habitat conditions required to support hibernating bats of one or both of these species, or gray bat summer colonies. If this were true, sealing the mine openings could potentially have an adverse impact on the continued existence of one or both species. Since options are available for protecting human health and safety without completely sealing the mine openings (e.g., erecting bat gates or fences), the current study was undertaken. The objectives of the study were to:

1. survey the abandoned mine shafts in the BSFNRRA for the presence of endangered species (of bats);

2. determine, if endangered species are present, the degree of importance that the inhabited mine shafts have to the continued existence of the species inhabiting them; and

3. recommend methods of excluding humans from the mine shafts without jeopardizing the continued existence of an endangered species.

STUDY AREA

The Big South Fork (BSF) of the Cumberland River and its tributaries form a dendritic pattern typical of areas with relatively homogeneous, horizontal sedimentary deposits. Stream valleys are deeply dissected in the southern headwater areas, creating considerable relief (1,000 to 1,900 feet). Northward, towards the confluence of the BSF with the Cumberland River, the terrain becomes less rugged. Stream valleys in the BSFNRRA are nearly devoid of floodplains with the base of steep slopes coming to or near the edge of the streams. The BSF is formed in the southern portion of the proposed BSFNRRA by the confluence of the New and Clear Fork rivers. Portions of these two streams are also included in the BSFNRRA.

Most streams in the BSFNRRA system meet EPA water quality criteria for public uses and aquatic life. However, some major stream reaches and many small tributaries have recurring or continuous pollution problems due to coal mining, timber operations, oil and gas drilling, and inefficient operation of wastewater treatment facilities.

The vegetation of the BSFNRRA watershed is extremely diverse and reflects the effects of differing moisture regimes, soil and substrate types, light intensities, exposures, and slope gradients. Except for a few scattered man-made clearings, the entire area is wooded. Twenty-two forest types have been described for the BSF basin. Specialized habitats exist on the floodplain, in protected coves and ravines, on moist northfacing slopes, and on sandstone caprock with dry, shallow soils. A soil moisture regime generally distinguishes these habitats from plateau top to floodplain bottom. Virginia and shortleaf pine are prevalent on dry, shallow soils of bluff rims and plateau tops. Deciduous hardwoods such as white oak and northern red oak occur in the deeper, well-drained soils. Beech, sugar maple, yellow birch, white pine, and several other tree species characterize moist soils of protected coves and ravines. Hemlock grows on the very moist, acidic soils of north-facing slopes, and river birch and sycamore typify the periodically flooded soils of the riparian zones. Less commercially valuable tree species such as chestnut oak and scarlet oak have increased in abundance following repeated logging of the more desirable timber species such as white oak, northern red oak, and yellow poplar.

Wildlife species present on the proposed BSFNRRA are primarily those associated with extensive forest habitats. The interspersion of numerous forest types, presence of scattered openings and other disturbed areas, and the availability of water from numerous creeks and branches fulfill the habitat requirements of many species of wildlife, resulting in a diverse faunal community.

Abandoned mines are not evenly distributed throughout the BSFNRRA. Rather, they are clumped around the various coal seam outcroppings on the steep ridge slopes above the river and its tributaries. They occur at various elevations ranging from only a few feet above water level along several tributaries to over 100 feet above the river itself. Major areas of abandoned mine openings are described in the following paragraphs, proceeding from north to south.

Of 114 known abandoned mine openings in the BSFNRRA, 104 occur in McCreary County, Kentucky. In addition, a large number of mine shafts have been completely sealed over the years, either by natural events or by man's devices. Proceeding upstream from Lake Cumberland, major concentrations of abandoned mine openings occur in the following areas (see Figure 1): (1) both sides of the river in the vicinity of Alum Ford; (2) lower Wolf Creek valley on the west side of the river near Yamacraw Bridge; (3) along Grassy Fork of Rock Creek, and just upstream from the junction of Rock Creek and the BSF river; (4) both sides of the river in the vicinity of Worley; (5) at Barthell on lower Roaring Paunch Creek; (6) and on both sides of the river in the Blue Heron area from the mouth of Roaring Paunch Creek to Big Spring Hollow. One opening each occurs near the mouth of Salt Branch and on Watsons Branch.

A total of 10 open abandoned mine shafts are known to occur in the Tennessee portion of the BSFNRRA. Seven of these occur along the east side of the BSF river in a 4-mile stretch immediately north (downstream) of Leatherwood Ford in Scott County. The other three are located on both sides of North White Oak Creek at the old Zenith mining/logging camp in Fentress County.

METHODS AND MATERIALS

All known mine shafts within the BSFNRRA boundaries, and all but two in areas adjacent to the BSFNRRA (where the owner refused permission to enter), were inspected between December 10, 1982, and February 17, 1983. When physical conditions permitted, each shaft was surveyed for the presence of hibernating bats and for other evidence of bat use (e.g., guano). When safety considerations or mine size and complexity precluded a thorough survey of a given mine, that mine was alternately surveyed by mist-netting for bats at the shaft openings during the period April 12-14, 1983.

Open abandoned mine shafts in the Kentucky portion of the BSFNRRA were previously located by field surveys conducted by NPS employees. Maps (Figures 2-6) and field data sheets were provided to FWS biologists for use in this survey. In addition, a NPS employee (ranger or biologist) accompanied FWS biologists to most mine sites to aid in mine location and to provide logistical support. Tennessee mine openings (Figures 7-9) were identified through field surveys by personnel from the Division of Land Reclamation, Tennessee Department of Conservation. A representative of the Tennessee AML Section accompanied FWS and NPS biologists to the open mine shafts located in the Tennessee portion of the BSFNRRA. All abandoned mine openings surveyed were identified for future reference by nailing a numbered aluminum tag to either the rock surface at the mine entrance or to a nearby tree. Sites 5, 15, 69, and 80 -- previously identified by the NPS and appearing herein on Figures 3 and 4 -- were not located during this survey. Site 41 (Figure 3) was marked with tag #197, and therefore is identified as site 197 throughout this report.

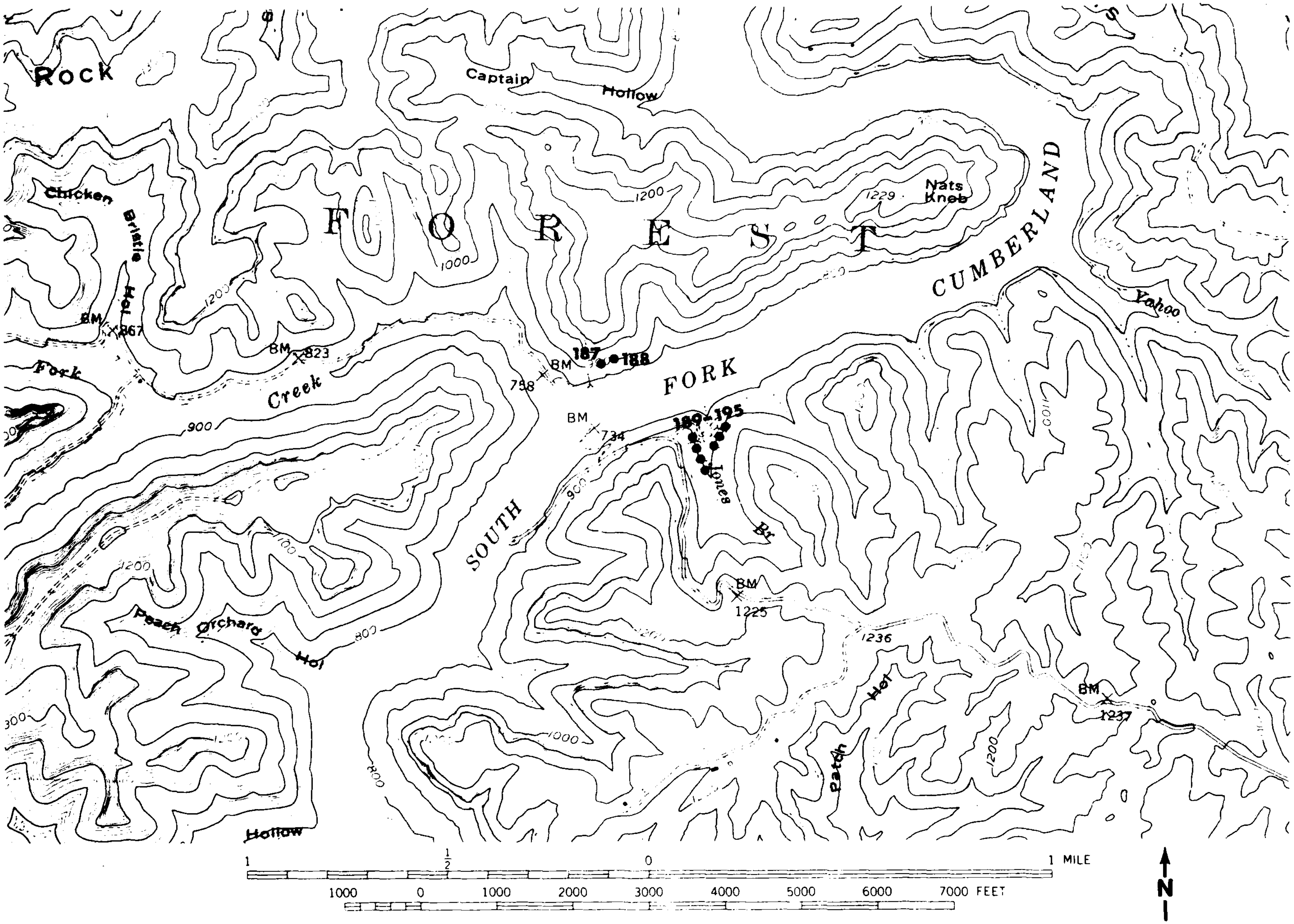


Figure 2. Location of abandoned mine openings in Kentucky portion of the BSFNRRA (1 of 5).

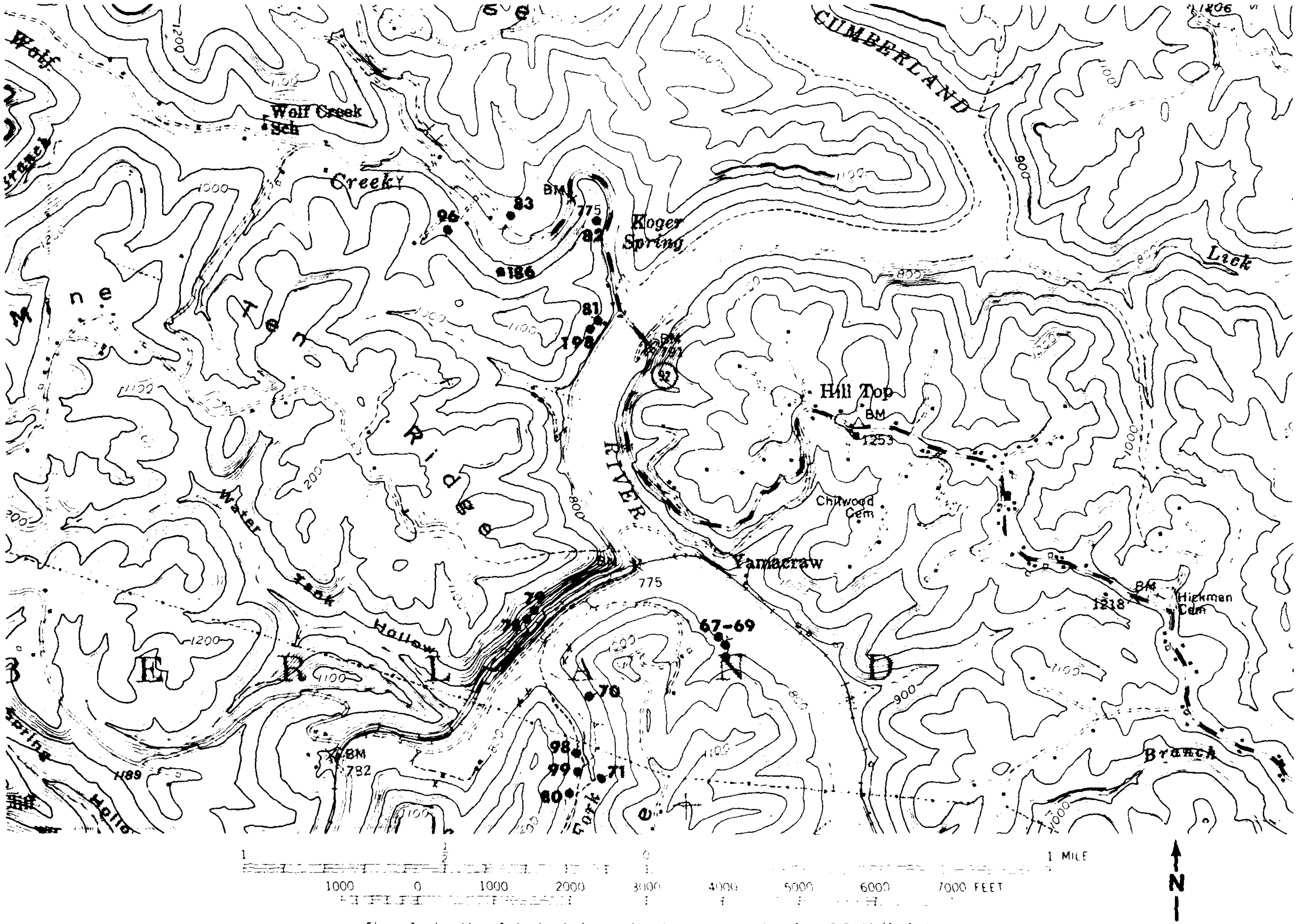


Figure 3. Location of abandoned mine openings in Kentucky portion of the BSFNRRA (2 of 5).

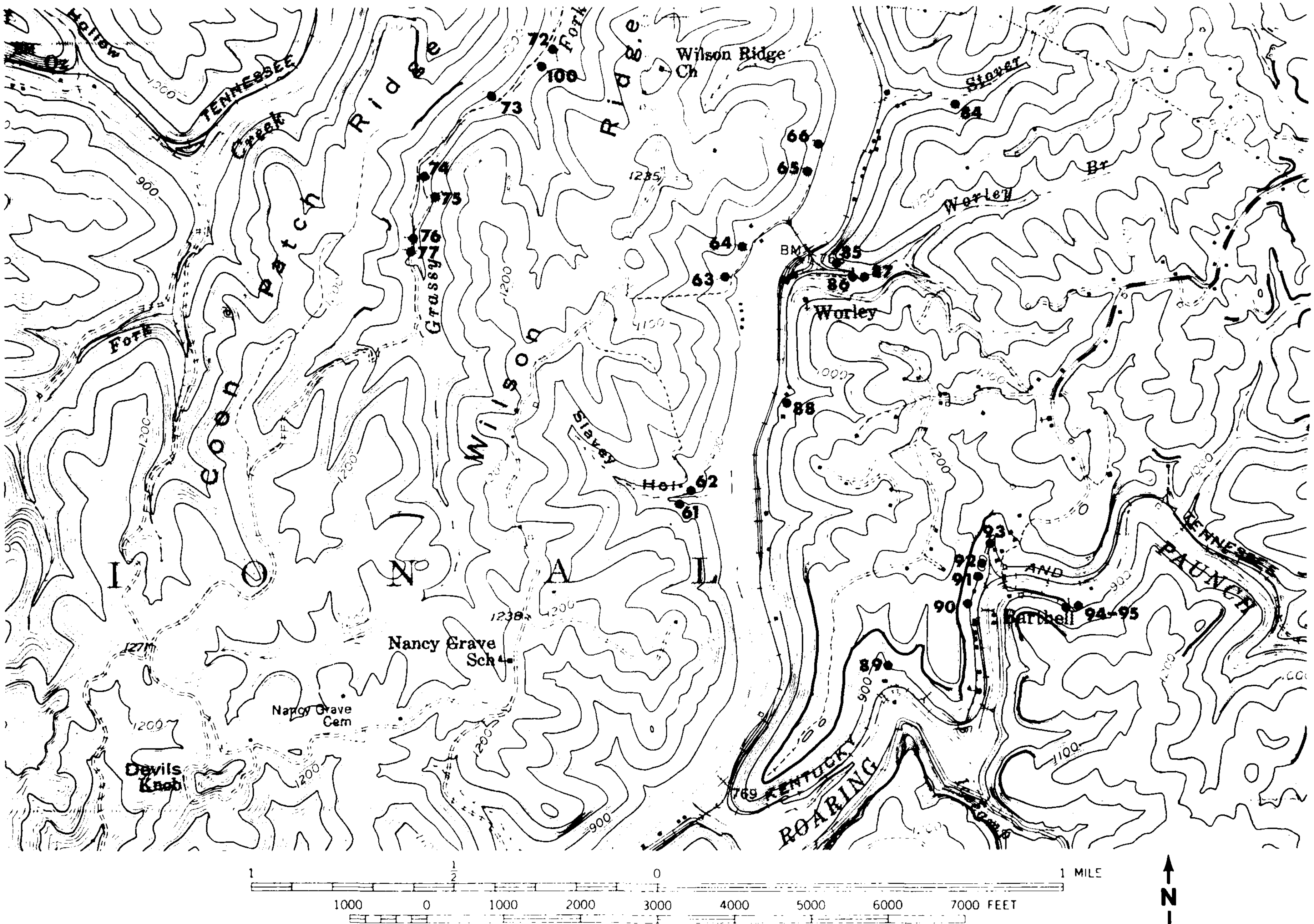


Figure 4. Location of abandoned mine openings in Kentucky portion of the BSFNRRA (3 of 5).

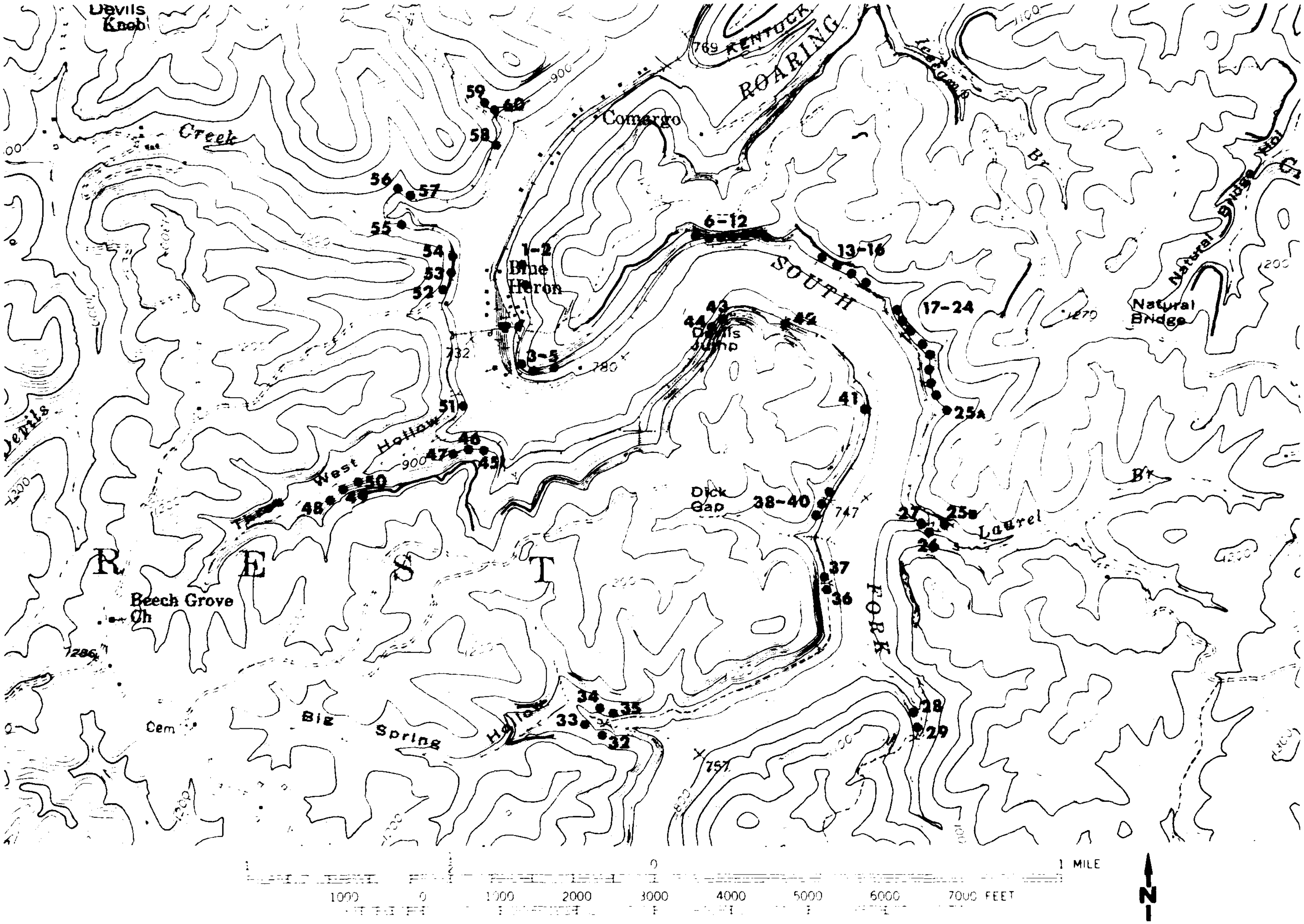


Figure 5. Location of abandoned mine openings in Kentucky portion of the BSFNRRA (4 of 5).

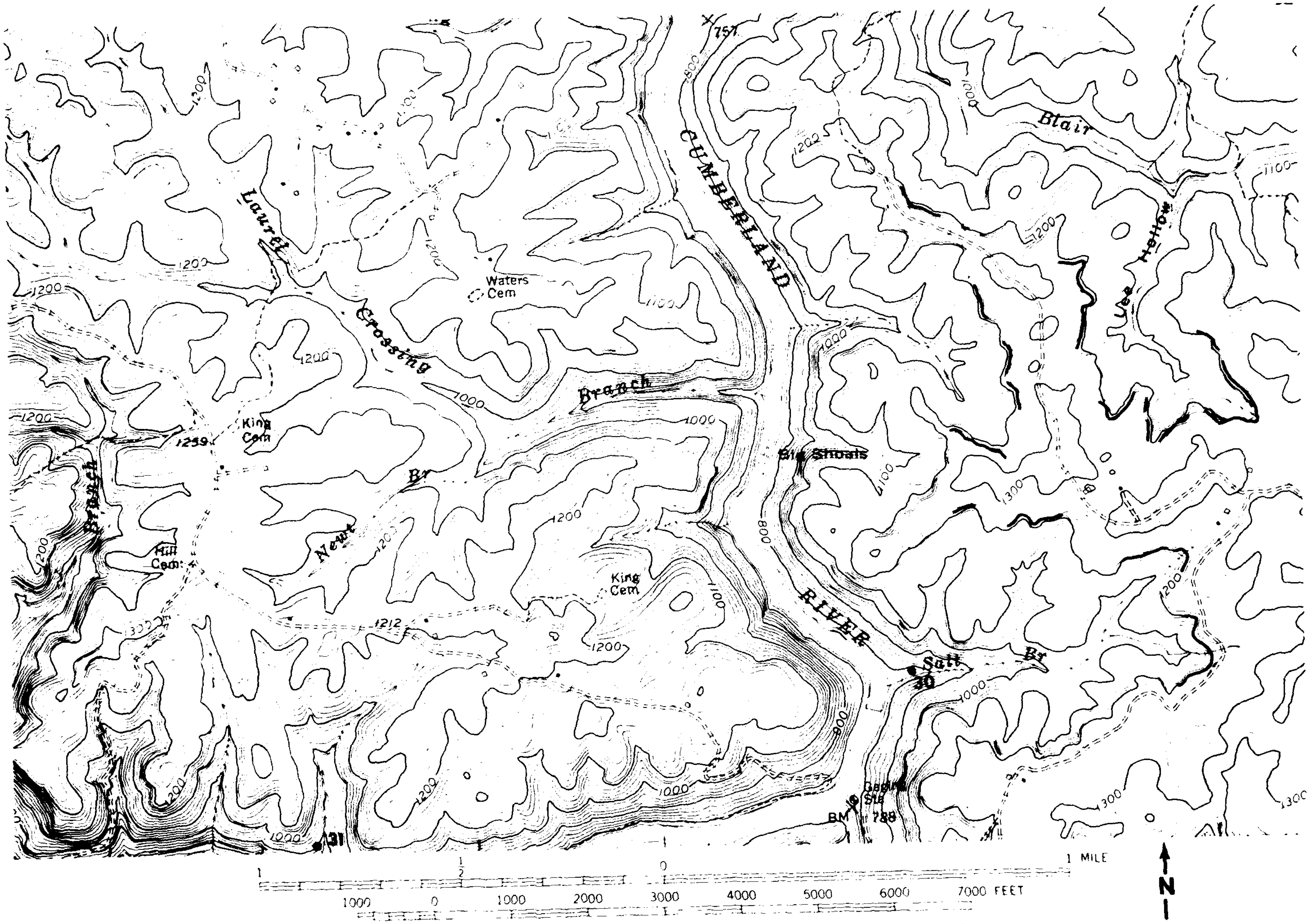


Figure 6. Location of abandoned mine openings in Kentucky portion of the BSFNRRA (5 of 5).

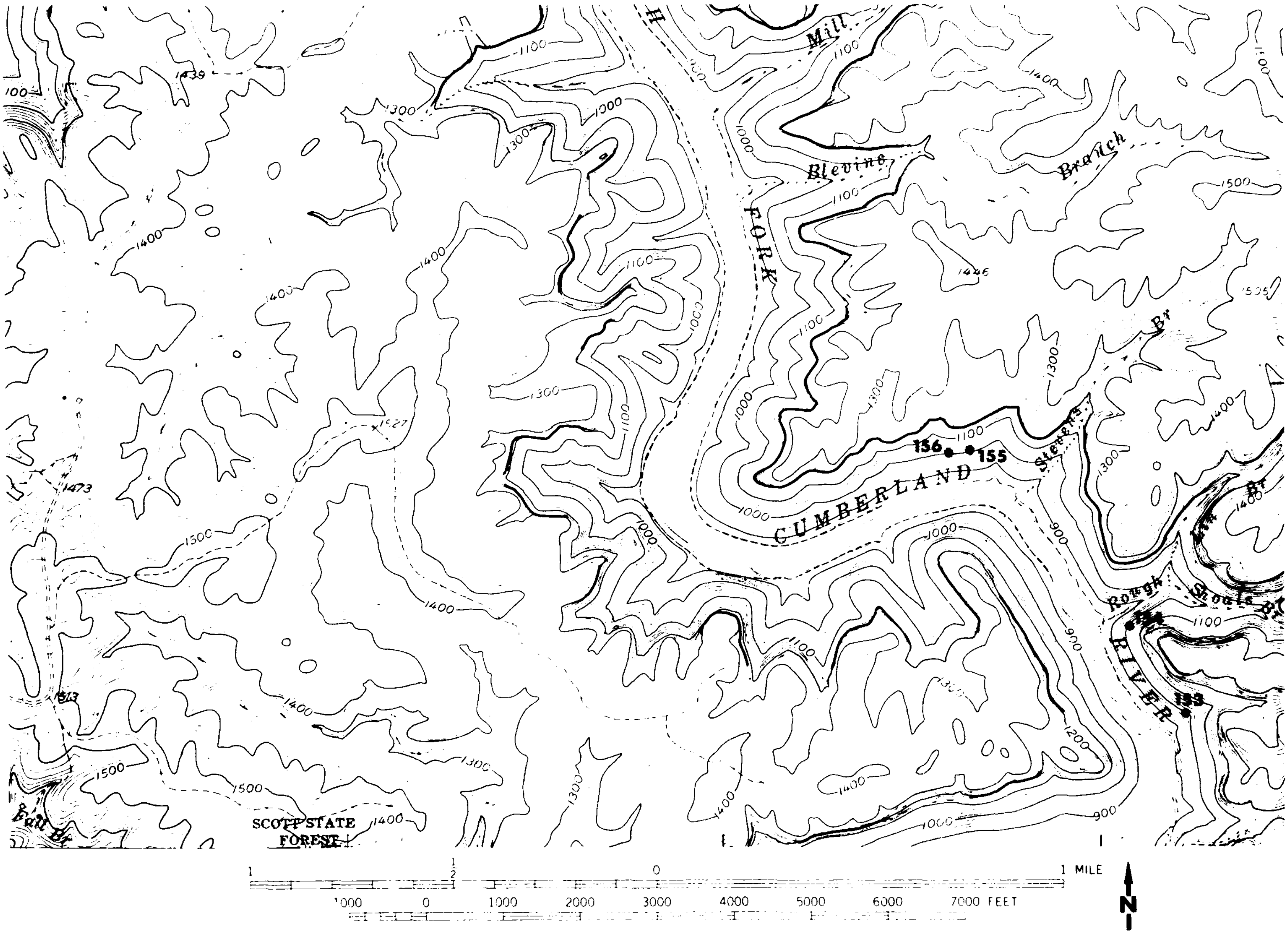


Figure 7. Location of abandoned mine openings in Tennessee portion of the BSFNRRA (1 of 3).

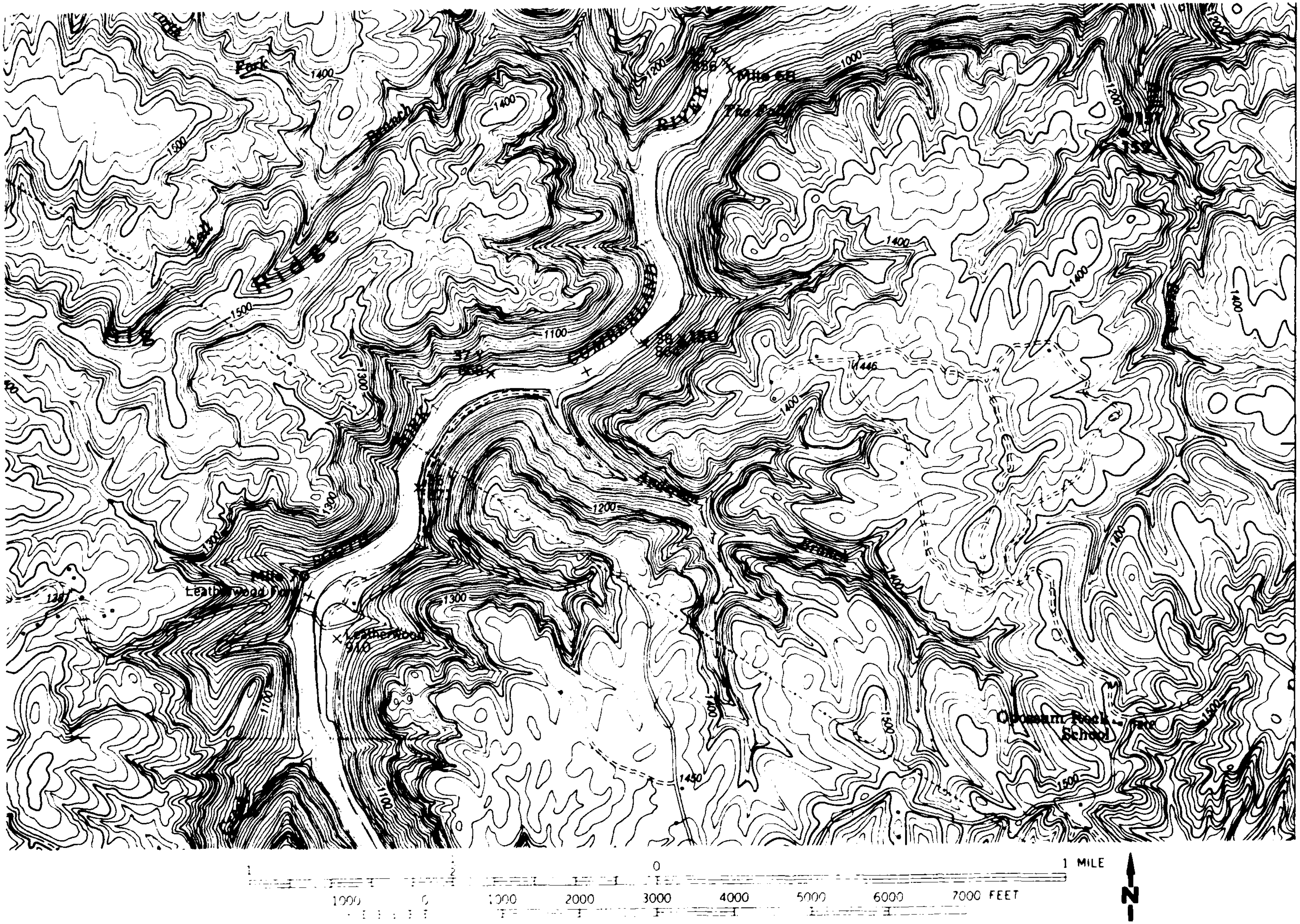


Figure 8. Location of abandoned mine openings in Tennessee portion of the BSFNRRA (2 of 3).

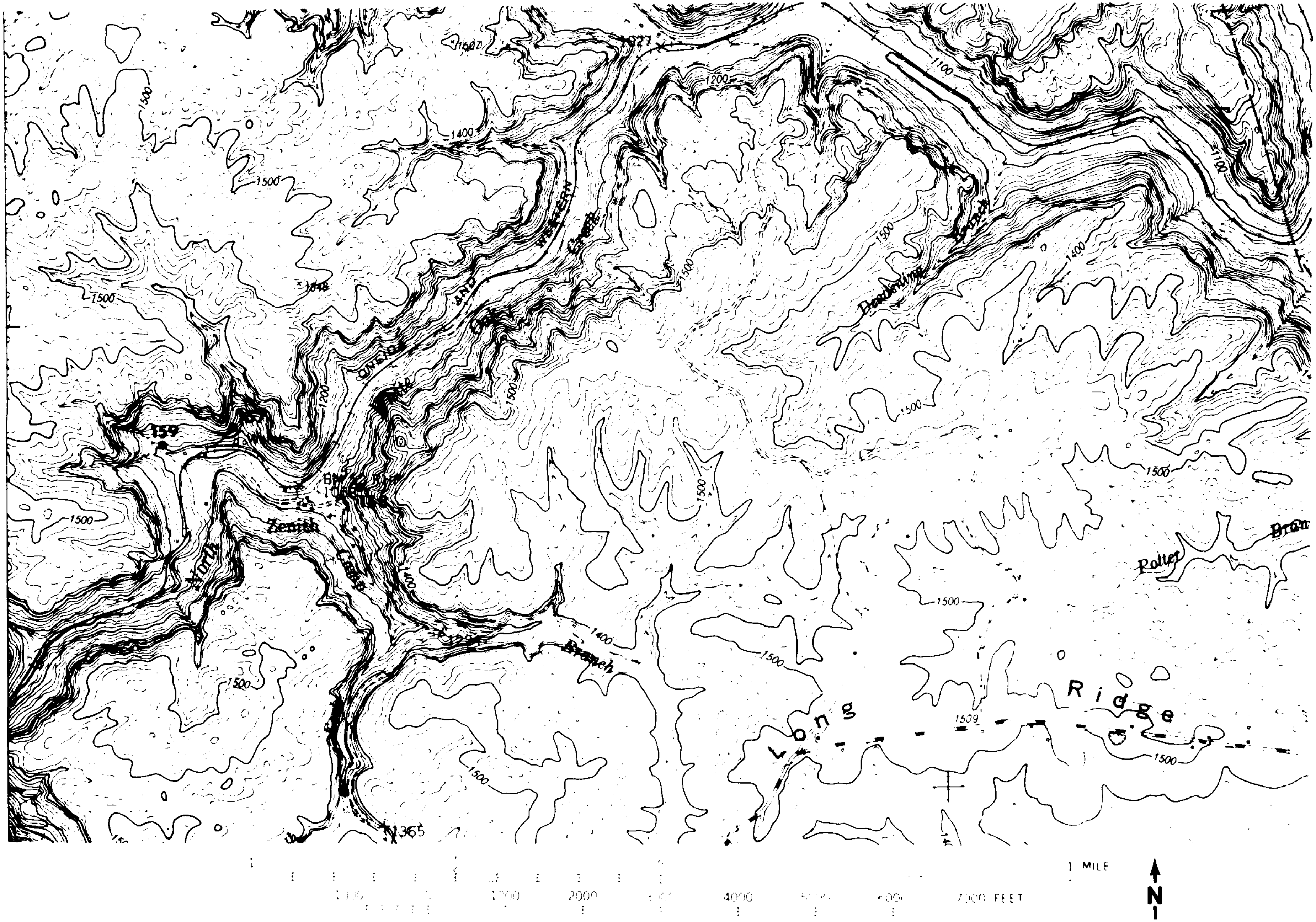


Figure 4. Location of abandoned mine openings in Tennessee portion of the BSFNRRA (3 of 3).

Hibernaculum suitability surveys were conducted by physical entrance into and inspection of 96 abandoned mine openings in Kentucky (86 openings) and Tennessee (10 openings) portions of the BSFNRRA and adjacent areas. Depending upon shaft dimensions and condition, surveying biologists walked or crawled throughout the abandoned mines in search of hibernating bats or signs of bat use. Visibility was enhanced by use of rechargeable Koehler wheat lamps, which were recharged overnight during the survey period. A Koehler mine safety lantern was employed to detect the potential presence of either explosive gases or oxygen-deficient air in the mine shafts. Temperatures were measured to the nearest one-tenth degree Centigrade by an Atkins model 44000 C digital temperature probe. Almost all bats were identified as they hung in a state of torpor, and no bat was disturbed more than necessary to assure positive species identification.

Because of either safety considerations or the fact that a few openings led to huge, complex mines that were too extensive to thoroughly survey within reasonable time constraints, a total of 18 mine openings in McCreary County, Kentucky, was surveyed by mist-netting. Netting was done during the early spring period when bats had become active following hibernation but prior to their dispersal to summer habitats. This period usually occurs from late March through early May in Kentucky (Barbour and Davis 1974). Because of extended cold weather, bats did not become active in large numbers in Kentucky until early April in 1983. In this survey, mist-nets were set up at mine openings at least an hour before dusk, and netting generally continued for two hours after dusk or until bat activity subsided substantially.

RESULTS

A total of 351 bats representing 6 species was observed using abandoned mine shafts in the BSFNRRA during the course of this study. Of these, 267 bats representing 4 species (*Pipistrellus subflavus*, the eastern pipistrelle; *Plecotus rafinesquii*, Rafinesque's big-eared bat; *Eptesicus fuscus*, the big brown bat; and *Myotis lucifugus*, the little brown bat) were observed hibernating in 27 shafts between December 10, 1982 and February 17, 1983. Forty-four bats representing 5 species (*Myotis keenii*, Keens' bat; *Myotis leibii*, the small-footed bat; *P. subflavus*; *P. rafinesquii*; and *M. lucifugus*) were captured in mist nets at 18 mine openings during the period April 12-April 14, 1983. An additional 40 bats (*P. subflavus*) were observed in various stages of torpor during a resurvey of mine shaft no. 67 during the night of April 14, 1983. Table 1 presents data, by species, on bats observed hibernating in the mine shafts. Table 2 details mist net captures by species and mine shaft.

Table 1. Number of bats, by species and mine shaft occupied, observed hibernating in abandoned mines in the Big South Fork National River and Recreation Area, McCreary County, Kentucky, during the period December 10, 1982, through February 17, 1983.

Shaft No.	*Pipistrellus subflavus*	*Plecotus rafinesquii*	*Eptesicus fuscus*	*Myotis lucifugus*
1	3	1		
3	29	1	1	1
14	1			
18	2	2	1	
25(b)	1			
27	4			
28		2		
32	8			
33	2	16		
37	5			
40	1			
43		1		
44		56		
51	1			
54	5	2		
62		3		
67	41	1		1
70	1			
71	6			
72	4		1	2
84	3			
92		1	3	
95		1		
96	8			
99	21			3
100	20			
188	1			
TOTALS	167	87	6	7

Table 2. Number of bats, by species and mine shaft captured, collected by mist netting at entrances to abandoned mines in the Big South Fork National River and Recreation Area, McCreary County, Kentucky, during the period April 12-14, 1983.

Shaft Number	*Pipistrellus subflavus*	*Plecotus rafinesquii*	*Myotis keenii*	*Myotis lucifugus*	*Myotis leibii*
3	2	3	1		1
9	2			3	
10	1			2	
25(a)	1		1		
43		2			
44		1			
54	1			1	
67	3		1		
72	5		2	1	
100	2		1		
191	1		3		
193	3				
TOTALS	21	6	9	7	1

Combining data from the mist-netting and in-shaft surveys, 32 of the 114 mine shafts surveyed during this study (28 percent) contained bats. Of the 104 abandoned mine shafts surveyed in McCreary County, Kentucky, 32 shafts (31 percent) contained bats. None of the 10 shafts surveyed in Tennessee contained bats.

Bats were observed hibernating in a wide variety of temperature zones. The average temperature where *Pipistrellus subflavus* was found was 9.8° C, ranging from 8.4° C to 13.0° C. *Plecotus rafinesquii* was found at an average temperature of 8.0° C, with a range of 5.7° C to 11.2° C. *Eptesicus fuscus* had an average hibernating temperature of 5.0° C, ranging from 3.8° C to 7.1° C. The average hibernating temperature for *Myotis lucifugus* was 9.4° C, based on a sample of only two individuals. Table 3 summarizes data on temperatures at the actual sites of hibernation within abandoned mine shafts for each species.

No endangered species were encountered during the course of this study. One specimen of the endangered Indiana bat (*Myotis sodalis*), however, was captured by Lee A. Barclay and John R. MacGregor (nongame biologist, Kentucky Department of Fish and Wildlife Resources) at mine shaft no. 9 during a preliminary survey on September 18, 1981. The specimen was hanging from the ceiling of the mine, torpid, about 120 feet from the entrance. It is probable that

Table 3. Temperature (degrees Centigrade) measured within one (1) foot of hibernating bats in abandoned mines in the Big South Fork National River and Recreation Area, McCreary County, Kentucky, during the period December 10, 1982, through February 17, 1983. Numbers in parentheses represent the number of individuals found in the same temperature zone at that shaft.

Pipistrellus subflavus	*Plecotus rafinesquii*	*Eptesicus fuscus*	*Myotis lucifugus*
8.4(3)	8.4(1)	7.1(1)	9.4(1)
9.5(29)	9.4(1)	3.8(1)	9.4(1)
9.6(1)	8.9(1)	4.2(1)	
10.0(1)	9.8(16)	4.9(1)	9.4 avg.
11.4(1)	10.2(1)		
9.7(8)	7.1(50)	5.0 avg.	
9.2(1)	10.8(3)		
11.6(3)	8.9(1)		
11.4(1)	5.7(1)		
11.2(1)	11.2(1)		
10.9(1)	8.6(2)		
9.1(1)			
11.5(3)	8.0 avg.		
11.8(1)			
9.4(41)			
13.0(1)			
12.3(1)			
11.2(1)			
12.8(1)			
8.6(1)			
9.8 avg.			

this individual was a migrant that was using the mine as a day roost during migration.

DISCUSSION

Suitability of Mines as Bat Habitat

Functionally, abandoned mines are essentially man-made caves and provide suitable habitat for a number of cavernicolous organisms, including several species of bats. Many mines, however, become structurally unstable and hazardous, and may have a rather short geological life expectancy. This is particularly true of underground coal mines. Abandoned mines can, nonetheless, provide valuable cavelike habitat for many decades if left undisturbed. In the following discussion, the term "cave" will be used to mean "cave and/or mine" for brevity and ease of presentation.

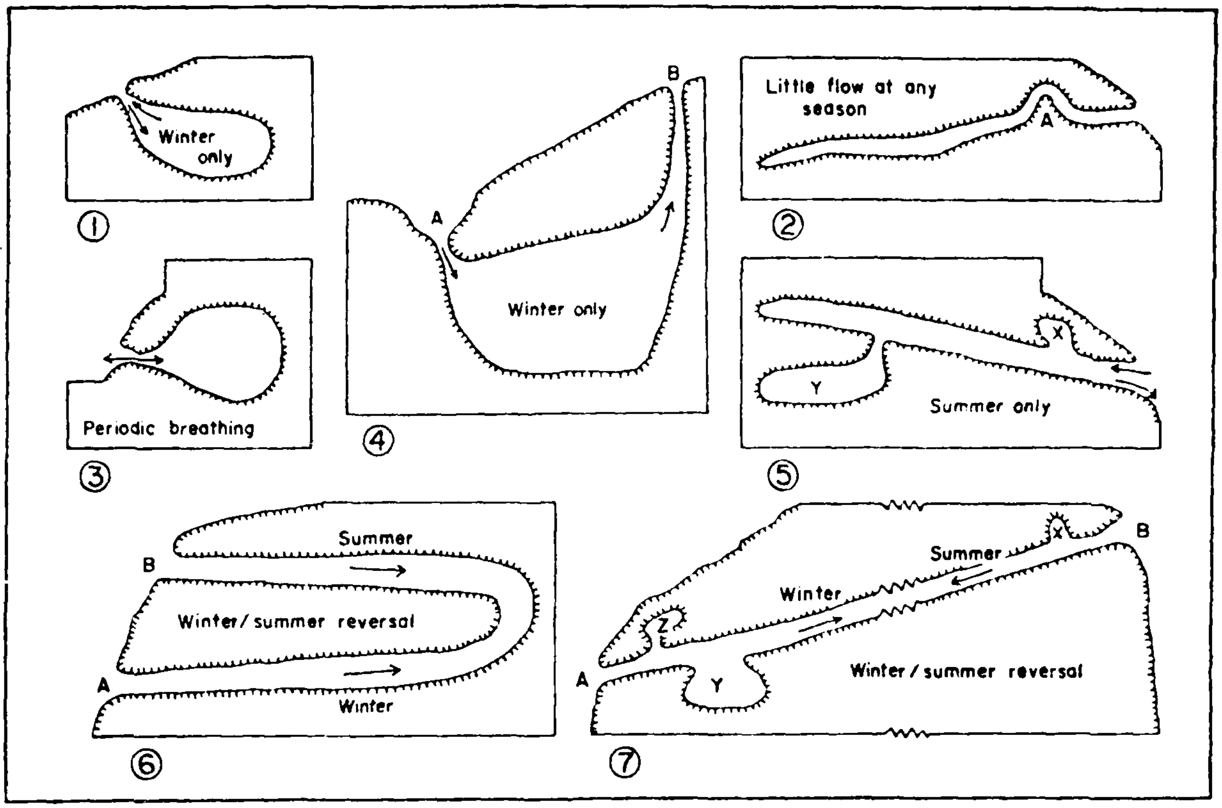
The cave environment is highly buffered in relation to the outside environment. Generally, temperature fluctuations are greatly reduced inside caves as compared with those outside, and humidity levels are usually quite high. Overall temporal and spatial variation of temperature and humidity among and within caves, however, is far greater than is generally suspected (Tuttle and Stevenson 1978). The principle buffering agent in caves is the cave wall itself; within only a few feet of the surface, interior temperatures of rock (and earth) remain very close to mean annual surface temperature. The main effect of this cave wall temperature constancy is to gradually bring differing air and water temperatures to mean annual surface temperature; the more isolated a cave zone is from outside influences (whether by distance or physical barriers), the more nearly its temperature will approximate mean annual surface temperature (Tuttle and Stevenson 1978).

In order for internal temperatures to vary above or below mean annual surface temperature, a cave must have a route of communication with the temperature fluctuations of the outside atmosphere; the two main routes of communication are circulation of air and of water. Although exceptions do occur, air circulation in caves generally has a far greater influence than does water circulation, primarily because most caves have some air circulation whereas a much smaller proportion have major water circulation (Tuttle and Stevenson 1978).

Thermal convection is generally believed to be the most important factor affecting air exchange between a cave and the outside environment (Geiger 1965). As noted by Tuttle and Stevenson (1978, p.111): "The principle of thermal convection in caves is that air escapes (rises) through an upper entrance (or through the top of a single entrance) when it is warmer than the outside air. Conversely, air will escape through a lower entrance (or through the bottom of a single entrance) when it is cooler than the outside air. The greater the inside-to-outside temperature gradient, the faster the rate of air movement; flow ceases when the temperatures are the same."

The impact of air circulation is greatly influenced by the structure or passage configuration of the cave itself. Figure 10 depicts several examples of how air circulation works in caves of different structure. Both the number of entrances and the elevational difference between multiple entrances are extremely important in determining air circulation patterns (Geiger 1965). Temperature differentials between inside and out can create powerful chimney effects in caves with entrances at different elevations (see Figure 10, Types 4, 6, and 7). If a cave slopes downward from the entrance, cold air will flow downhill inside it and become trapped; caves of this type act as cold air reservoirs. Caves sloping upward from the entrance or having high domes or chambers above the main passages, on the other hand, can act as warm air traps. Lack of elevational differences between multiple entrances, small entrance size (especially in single-entrance caves), and berms or other vertical undulations (dams) can reduce or nearly eliminate air circulation (Geiger 1965, Tuttle and Stevenson 1978).

Substrate type, ground moisture, and the presence of flowing or standing water all contribute to relative humidity levels in caves. Rates of air flow plus temperature and humidity of inflowing air are



Simplified cave structures. Air flow indicated as occurring in "winter" will generally occur when outside temperature is below mean annual surface temperature (MAST); flow marked "summer" will occur when outside temperature is above MAST. *Type 1*: Breathes (as indicated by arrows) in winter; stores cold air in summer. *Type 2*: Undulation at A acts as dam inhibiting air flow; temperature relatively constant beyond dam. *Type 3*: "Jug" shape often postulated to exhibit resonance; may have pulsing in and out air movement, especially when outside air deviates from MAST. See text for alternate explanation for the oscillation of air. *Type 4*: Strong air circulation from A to B in winter; stores cold air in summer. *Type 5*: The reverse of Type 1; warm air enters along ceiling in summer while air cooled by cave walls flows out along floor. No flow in winter. X is a warm air trap, Y stays a relatively constant temperature. *Type 6*: Strong air flow from A to B in winter; equally strong air flow in opposite direction in summer. *Type 7*: Same as Type 6, with a warm air trap (X), cold air trap (Y), and an area of relatively constant temperature (Z). Distance between and elevational displacement of the entrances are critical factors in the air flow direction in these two cave types; the flow of air (cooled relative to outside temperatures by the cave walls) down in summer must be strong in order to overcome the tendency for warm outside air to rise into A. Similarly, in winter the "negative pressure" created by air (now warmer than outside air due to the MAST effect of the cave walls) rising out of B must be strong enough to pull cold air up into A.

Figure 10. Simplified examples of how air circulation works in caves of different structure (from Tuttle and Stevenson 1978).

also important contributors to humidity levels in caves. As might be expected, relative humidity in caves varies most near the entrance where air from the outside has its greatest influence. Most caves exhibit high humidity levels (Geiger 1965).

It is extremely important for bats to select roosting sites with temperatures appropriate to support the required metabolic processes (i.e., warm in the summer to aid in digestion and growth, and cool in the winter to induce and support hibernation); these optimum temperatures vary between species (Twente 1955). Most caves in the United States occur at temperate latitudes where the mean annual surface temperature ranges from 12 to 20^{o} C. Consequently, most caves in the United States are unsuitable for bat use for summer nurseries or winter hibernacula. Cave bats thus are generally forced to select the very few caves that have structures permitting them to deviate well above (for summer use) or below (for winter use) mean annual surface temperature (Tuttle and Stevenson 1978). Summer maternity roosts generally are restricted to heat traps, winter hibernacula usually are restricted to cold traps, and the ideal bat cave is generally one which provides a wide thermal range (Tuttle and Stevenson 1978). It is rare for any one cave to provide sufficient thermal complexity for year-round occupation; thus, seasonal migration between caves is usually necessary for bats which use caves year-round (e.g., the gray bat).

Some mine shafts, by the very nature of their formation, have great potential for supporting bats, especially in the winter. Mines following downward-trending coal seams offer great potential to serve as cold traps, and if these mines have multi-level entrances or air shafts, air circulation is greatly enhanced. Large-sized deep mines (i.e., mines with deep vertical entrances such as many of the coal mines in Appalachia), if abandoned by humans, have great potential for cave-dwelling bats; they would be most similar to Type 4 caves in Figure 10.

Many abandoned mine shafts, particularly drift mines and other types of mines with near-horizontal shafts, have a high potential for supporting nursery populations of bats during the summer. This is because large domed chambers are commonly found in abandoned mines where major ceiling collapse has occurred. These domed chambers can serve as heat traps if the adjoining shaft is large enough to contain the collapsed material without major impairment to lateral air flow.

Abandoned mines in the BSFNRRA possess several of the attributes listed above as being favorable to bat hibernation. Almost all shafts slope gradually downward, which should enhance their ability to trap and hold cold air. Many of the shafts have high domed chambers formed by ceiling collapse. Some of these domed areas have good potential to serve as heat traps. And extremely high humidity levels are common to these abandoned mines.

Many of the abandoned mines in the BSFNRRA also exhibit one or more physical attributes which tend to reduce their likelihood of serving as prime habitat for bats. Many mine entrances are partially blocked by berms of earth and rock resulting from collapse due to the forces of nature; these berms serve to reduce air circulation within the mines. Thermal convection is also reduced by the relative gentleness of the slope of many mine shafts; a steeper slope would enhance the movement of cold air down the shafts. Air movement is also reduced in those mines with small entrances or constricted (by design or collapse) passageways, and in those with only one entrance. And, finally, most of the abandoned mines in the BSFNRRA lack multiple entrances (or airways) with significant elevational differences; they are thus unable to create the highly desirable "chimney effect" described earlier when temperature differentials exist between inside and out.

Descriptions of Representative Abandoned Mines

Abandoned mines surveyed in the BSFNRRA exhibited tremendous variability. A few were "punch mines" extending only 30-40 feet into the hillside, while others extended over 1,000 feet and had complex networks of side shafts. While the general mine configuration was one main shaft with adjoining side shafts, several mines exhibited two or three parallel main shafts that were interconnected by lateral shafts.

The shafts normally sloped gently downward, and their physical condition ranged from fairly stable (original shaft generally intact) to extremely unstable (numerous ceiling and wall collapses, much loose rock overhead). Figures 11 through 15 are representative of these conditions. Most shafts ranged from damp to wet, and standing pools of water were common. Most water in these shafts appeared to be the result of normal hydrologic flow through the earth strata above (i.e., seepage), and water dripping from the ceiling was a common occurrence. Water occasionally ponded in the shafts in such a manner as to form hydrologic seals (i.e., water extended from floor to ceiling), and in a few instances (8 of 114 mine openings) water flowed strongly from the mine openings.

The following paragraphs and figures are of representative abandoned mines surveyed in the course of this study. They are intended to give the reader a better feel for the conditions encountered. Refer to Figures 2-6 for locations.

Sites 1, 2.--Located behind and just north of the Blue Heron tipple, openings 1 and 2 were located approximately 30 feet apart and were interconnected inside. Opening #1 measures approximately 7' h x 15' w, while opening #2 was considerably smaller; both openings exhibited considerable bank sloughing at their entrances (Figures 16 and 17). I~side, the main shaft extends over 200 feet; within this distance, 3 minor side shafts were dug on the left and 1 shaft (to opening #2)

Figure 11. Relatively stable condition inside abandoned mine at site 18.

Figure 12. Ceiling collapse inside abandoned mine at site 18.

Figure 13. Major collapse inside abandoned mine at site 33.

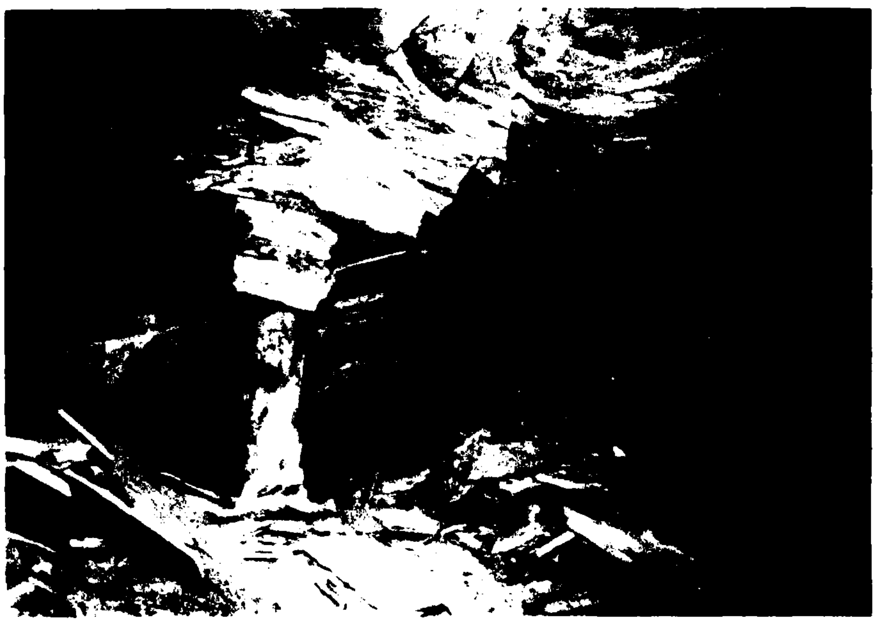


Figure 14. Major collapse inside abandoned mine at site 33.

Figure 15. Collapsed conditions encountered inside abandoned mine at site 100.

Figure 16. Entrance to abandoned mine at site 1.

Figure 17. Entrance to abandoned mine at site 2.

joined from the right. A major ceiling collapse occurred at approximately 150 feet.

On December 14, 1982, this mine was surveyed to a depth of 200 feet, at which point the flame in our safety lantern went out (indicating the possibility of low oxygen levels). Considering the potential safety hazard and the fact that temperatures were too high for hibernation by either Indiana or gray bats, we stopped at this point. Three *Pipistrellus subflavus* and 1 *Plecotus rafinesquii* were encountered approximately 100 feet inside, hanging torpid at a temperature of 8.4° C. Temperature at the mine entrance was 4.8° C, and at 130 feet inside (beyond the major collapse pile) it was 12.4° C.

Site 3.--Located about 500 feet south of the Blue Heron tipple, the entrance occurred under a rock ledge and measured approximately 3' h x 5' w (Figure 18). Bank sloughing has considerably obscured the entrance, and one must climb down the collapse pile to get inside. Two parallel shafts extend approximately 200 feet before a major collapse virtually seals them.

Thirty-two bats representing 4 species were found in this mine on December 14, 1982. One *Eptesicus fuscus* was located approximately 20 feet from the entrance, in a temperature zone of 7.1° C. One *Myotis lucifugus* and 1 *Plecotus rafinesquii* were hanging at

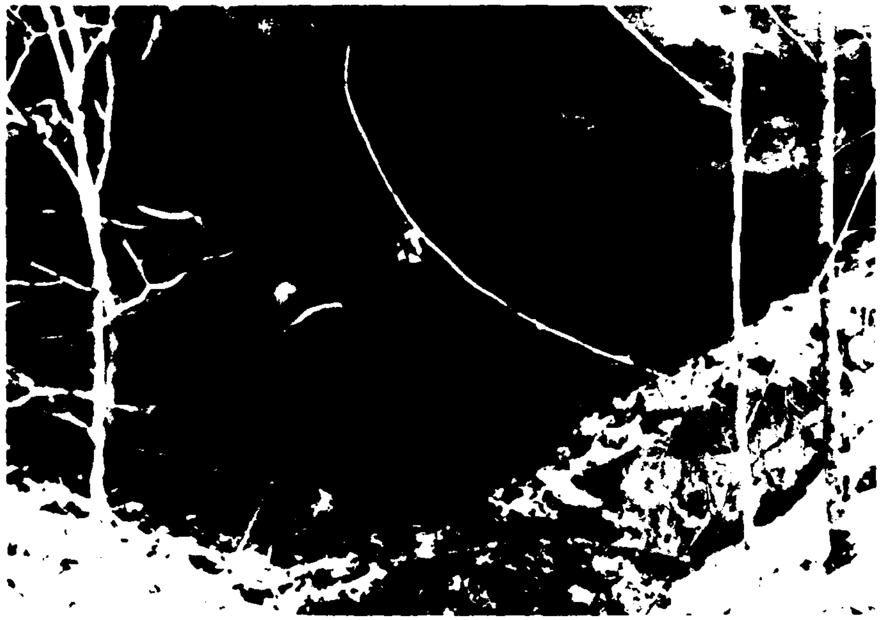


Figure 18. Entrance to abandoned mine at site 3.

9.4° C approximately 155-160 feet inside. Twenty-nine Pipistrellus subflavus were scattered throughout the two shafts, hanging in temperature zones ranging from 8.0° C to 11.0° C. All bats were torpid. In a mist net survey on April 12, 1983, four species were collected at the entrance to this mine: Pipistrellus subflavus (2), Plecotus rafinesquii (3), Myotis keenii (1) and Myotis leibii (1).

Site 18.--This mine is located on the old tramway about one mile east of the Blue Heron tipple. The entrance measured about 25' h x 15' w due to collapse, but the condition of the mine shafts was surprisingly stable (Figure 19). The main shaft ran through the ridge for a distance of approximately 630 feet before punching through the other side at opening #22. Three shafts extended to the right, leading to mine openings #19, #20, and #21, and one extended to the left for a short distance. Except for two or three fairly large collapses, the ceiling was largely intact; numerous ceiling bolts were noted.

On December 16, 1982, three species of bats were encountered in this mine, all hanging singly and torpid. One Eptesicus fuscus was observed within 20 feet of the entrance (no temperature recorded); 2 Plecotus rafinesquii were found 195 feet and 225 feet inside, respectively, at 8.9° C; and 2 Pipistrellus subflavus were

Figure 19. Entrance to abandoned mine at site 18.

Figure 20. Entrance to abandoned mine at site 33.

observed 210 feet and 390 feet inside at 11.4° C and 10.0° C, respectively.

Site 33.--Located on the south slope of Big Spring Hollow, the entrance to this mine measured approximately 6' h x 10' w (Figure 20). Inside, fairly deep standing water was encountered at 80 feet. Two side shafts were observed, one on the left and one on the right of the main shaft, and both had been previously sealed with mortar and concrete blocks. The seal on the left shaft had been breached, and this shaft was observed to extend 70 feet into the mountain before sealed by a major collapse pile. Considerable ceiling collapse was observed throughout this mine.

On January 6, 1983, a cluster of 14 Plecotus rafinesquii was observed hanging from the ceiling near a large pool of water; 2 additional individuals of the same species were hanging within a few feet of the cluster. Air temperature at this cluster, located 80 feet from the mine entrance, was 9.8° C. Two Pipistrellus subflavus were also encountered 40 and 60 feet inside, respectively, at 9.8° C each.

Sites 34, 35.--Located on the north slope of Big Spring Hollow, these two entrances to the same mine measured approximately 3' h x 12' w and 10' h x 10' w, respectively. Bank sloughing has partially obscured both openings (Figures 21 and 22). Both shafts contain deep

Figure 21. Entrance to abandoned mine at site 34.

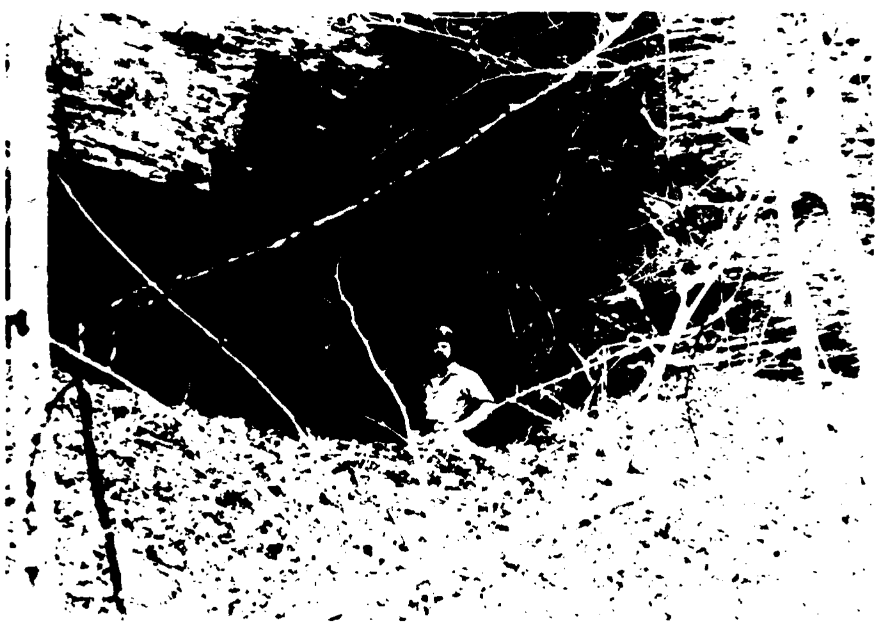


Figure 22. Entrance to abandoned mine at site 35.

standing water: the main shaft of #34 was flooded behind the berm at the entrance, and water reached the ceiling at an inner distance of about 60 feet; the primary shaft to #35 was flooded to within 30 feet of the entrance. Side shafts connected the two main shafts. Although seepage under the berm at opening #34 was not observed, it probably occurs during wet periods of the year. No bats were observed in this mine, which was surveyed on January 6, 1983.

Site 37.--This mine is situated high on the west side of the river overlooking the mouth of Laurel Branch. Bank sloughing has largely obscured the opening, which measures approximately 4' h x 5' w (Figure 23). This is a very complex mine, with numerous side shafts branching off to the right and left. Although 3-4 sizable ceiling collapses were found in the 400-foot section surveyed, overall this mine was fairly stable and in relatively good condition compared with most others surveyed in the BSFNRRA.

Only 5 Pipistrellus subflavus were encountered in the 400-foot section surveyed on January 6, 1983, and these were found at temperatures exceeding 11° C. Because of the high temperatures encountered throughout the area surveyed, inspection was curtailed at 400 feet.

Sites 43, 44.--Located high above the river on the west side overlooking Devil's Jump, these two entrances to the same mine

Figure 23. Entrance to abandoned mine at site 37.

measured approximately 5' h x 12' w and 4' h x 15' w, respectively (Figures 24 and 25). Opening #43 extended 100 feet to a major collapse which sealed the shaft; a side shaft connected it with the main shaft from opening #44. The main shaft of #44 contains deep standing water beginning about 40 feet from the entrance; this water appears to meet the ceiling at an inner depth of about 120 feet.

The January 6, 1983, survey revealed a cluster of 50 _Plecotus rafinesquii_ hanging on a vertical rock surface above a large, 3-foot deep pool of water (Figure 26). Six other individuals of the same species were hanging singly within a few feet of the cluster. Air temperature within a foot of the cluster was 7.1^{o} C. No other bats were encountered. However, 3 _Plecotus rafinesquii_ were taken in mist nets at these two mine entrances on April 13, 1983.

Sites 67, 68.--Located at the northern rim of Wilson Ridge overlooking the river, these two entrances to the same mine complex measured 6' h x 12' w and 3' h x 6' w, respectively (Figure 27). Internally, the mine has 3 parallel main shafts interconnected by side passages. The shafts averaged 12-15 feet wide and up to 5 feet high; they were composed of soft slate and were fairly stable. Shallow water ponded in low places on the mine floor.

These shafts were surveyed to an inner depth of about 250 feet on December 17, 1982. Three species of bats were encountered: 1

Figure 24. Entrance to abandoned mine at site 43.

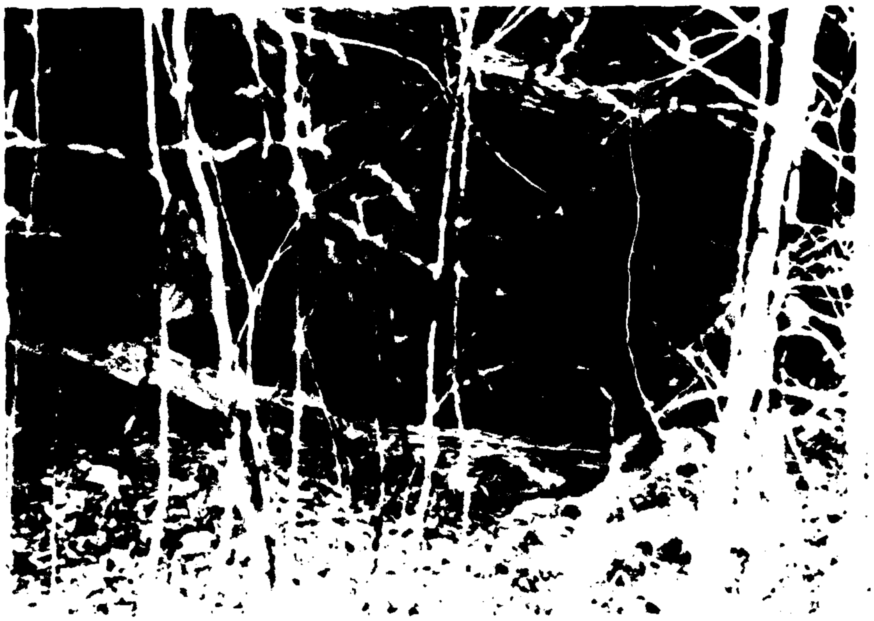


Figure 25. Entrance to abandoned mine at site 44.

Figure 26. Cluster of 50 Plecotus rafinesquii on vertical wall over a pool of water inside mine at site 44.

Figure 27. Entrances to an abandoned mine. Site 67, on the right, is the main entrance. Site 68, on the left, is much smaller.

specimen of *Plecotus rafinesquii* was encountered 25 feet from the entrance at 8.9° C; 1 *Myotis lucifugus* was found 75 feet from the entrance at 9.4° C; and 41 *Pipistrellus subflavus* were found scattered about from 50 to 250 feet from the entrance at a nearly constant temperature of 9.4° C. Additionally, two 5-6 inch larval spring salamanders (*Gyrinophilus porphyriticus*) were observed in a clear-water pool approximately 200 feet inside the mine. Also, numerous fossils of ferns and other plants were found throughout this mine; a few were provided to the NPS for possible use as interpretive materials. Three *Pipistrellus subflavus* and 1 *Myotis keenii* were captured by mist net at entrance no. 67 on April 14, 1983. After the mist nets were taken down, this shaft was resurveyed by physical entry and inspection. An additional 40 individuals of *Pipistrellus subflavus* were observed hanging from the ceiling in various stages of torpor. This resurvey vividly pointed out the possibility that a one-night mist net survey can result in a significant under-estimation of bat population numbers at a given mine site.

Site 100.--Located on the east side of Grassy Fork, just outside of the BSFNRRA boundary, the 5' h x 8' w entrance was situated at an elevation of only 5-6 feet above the stream bed (Figure 28). This small, inconspicuous entranceway, though, led to an extensive mine complex that extended over 1,000 feet into Wilson Ridge and had numerous lateral shafts extending off the single main shaft. The main shaft averaged 10-12 feet wide and 3-5 feet high and, although

Figure 28. Entrance to abandoned mine at site 100.

considerable breakdown had occurred in the first 100 feet, the rest of the mine was fairly stable. Numerous plant fossils were observed deep in the mine.

A total of 20 Pipistrellus subflavus was observed in this mine on February 17, 1983. Although temperature measurements were not made, it was noted that the mine was quite warm, probably averaging in the 11-12^{o} C range. No other bats were encountered inside the mine. A mist net survey was conducted at this mine entrance on April 14, 1983; 2 Pipistrellus subflavus and 1 Myotis keenii were captured.

Endangered Species of Bats in the BSFNRRA

The fact that 351 bats representing 6 species were found utilizing abandoned mines in the BSFNRRA during the course of this study (and a seventh species, the endangered Indiana bat, was found during a preliminary survey of the area just prior to initiation of this study) is ample evidence that bats do utilize many of these mines. That only one specimen of an endangered species has been encountered to date in any of these mines, however, deserves further discussion.

The major winter populations of M. sodalis are found in cave regions of the eastern and central United States. Two caves in Kentucky (Bat Cave, Carter County and Coach Cave, Edmonson County) and a cave and a mine in Missouri (Bat Cave, Shannon County and Pilot Knob

Mine, Iron County) each harbored about 100,000 Indiana bats during the winters of 1956 to 1961, which accounted for about 90 percent of the known population of the species at that time (Hall 1962, IBRT 1976). The rest occurred in groups numbering from a few individuals to several thousand in several dozen caves and mines scattered throughout its range. Temperature and relative humidity are important factors influencing the selection of hibernation sites. During mid-winter, temperature in M. sodalis hibernacula averages 4 to 8° C, ensuring a sufficiently low metabolic rate for fat reserves to last the six-month hibernation period (Hall 1962, Humphrey 1978, Clawson et al 1980). Humidity preferences are in the 75-100 percent range according to Humphrey (1978), although they apparently shun 100 percent humidity zones in Kentucky (John R. MacGregor, KDFWR, pers. comm.). These conditions are generally found only in a rather narrow zone close to the cave or mine entrance (Hall 1962, Tuttle and Stevenson 1978).

Indiana bats usually leave the hibernacula in April or May and generally disperse over a wide area. Females establish small maternity colonies under the bark of trees in or near riparian habitat, where they raise their young (Humphrey et al 1977, LaVal and LaVal 1980). Adult males of this species roost in small groups in caves and mines during the summer. Preferred foraging habitat appears to be over streams and in adjacent riparian and floodplain forest edge habitats, but males are known to forage in densely forested hillsides and ridges in some portions of their range (Hall 1962, Humphrey et al 1977, LaVal et al 1977, LaVal and LaVal 1980). Moths and other flying insects are the principle dietary items (LaVal and LaVal 1980).

The gray bat is one of the most restricted to cave habitats of any U.S. mammal. With rare exception, it roosts in caves year-round. Populations are found mainly in Alabama, Arkansas, Kentucky, Missouri, and Tennessee. Approximately 95 percent of the entire known population hibernates in only nine caves each winter, with more than half in a single cave (Tuttle 1976a). Most gray bats migrate seasonally between unusually cold (6 to 11^{o} C) hibernacula and unusually warm (14 to 26^{o} C) maternity caves (Hall and Nixon 1966; Tuttle 1975, 1976b, 1979; Rabinowitz and Tuttle 1980).

Summer caves, particularly those used by gray bat maternity colonies, are nearly always located within 1-2 kilometers of large streams, rivers, or reservoirs over which the bats feed (Tuttle 1979). Adult gray bats feed almost exclusively over water, and appear to be opportunistic feeders concentrating on the flying insects available where they forage (Tuttle 1976b, 1979; LaVal and LaVal 1980). Some colonies, however, appear to be dependent upon mayflies for survival (GBRT 1982).

A number of factors may be serving to reduce or prevent use of BSFNRRA abandoned mines by these two species of endangered bats. First, the temperature and/or humidity requirements may not be fully met in these mines, as detailed in the previous section. Second, many researchers have reported a strong loyalty (philopatry) by these species to their specific hibernacula and summer colony areas (Hall 1962; Hall and Nixon 1966; Tuttle 1976a, 1979; Elder and Gunier 1978; Humphrey 1978); this strong philopatry may slow or thwart colonization of new habitats such as mines or recolonization of previously occupied habitats abandoned because of human disturbances. The relatively short amount of time (geologically) that any given mine has been in existence may also help explain the paucity of mine use by endangered bats, especially when considered in light of their strong philopatry (however, the large colony of Indiana bats (100,000+) known to hibernate in Missouri's Pilot Knob Mine raises questions regarding philopatry and the presumed slowness of invasion by bats). The relatively unstable condition of most abandoned mines in the BSFNRRA may also be an important consideration; the physical nature of a particular roost site may change from year-to-year due to minor or major collapse. And, finally, the fact that there are no major limestone caves in close proximity to the BSFNRRA may lessen the possibility of bats discovering suitable habitat in these abandoned mines even if it exists.

The above notwithstanding, the BSFNRRA abandoned mines could be serving as summer habitat for either the Indiana bat or the gray bat, or both. Female gray bats could be utilizing domed chambers in the mine shaft ceilings as maternity habitat if these chambers are functioning effectively as heat traps. And male gray or Indiana bats, with their broader thermal tolerance ranges in summer (Tuttle 1976a, 1979), may use these mines as summer roosts. However, no guano piles were found in the domed chambers or at mine entrances during the course of this survey, which is strong evidence that the surveyed mine shafts are not supporting large numbers of bats during any season.

Species Accounts

A brief account of information obtained on each of the six species encountered during this study is presented below.

1. *Pipistrellus subflavus* (eastern pipistrelle)

A total of 167 pipistrelles was observed hibernating in abandoned mines of the BSFNRRA between December 10, 1982 and February 17, 1983 (Table 1). Twenty-one specimens were collected in mist nets at mine entrances between April 12 and April 14, 1982 (Table 2), and 40 pipistrelles were observed in various stages of torpor during a resurvey of mine shaft no. 67 on April 14, 1983. Combining all data, 228 pipistrelles were encountered at 26 of 32 bat-inhabited shafts (81 percent).

Of the bats encountered in BSFNRRA mines, pipistrelles occupied the warmest zones. The average temperature at hibernation sites for this species was 9.8° C, ranging from 8.4 to 13.0° (Table 3). Barbour and Davis (1974) report that pipistrelles choose hibernating sites where the temperature averages 11 to 13° C. Beads of moisture were often observed covering the fur of this species in the mines; Barbour and Davis (1974) note that this is a common occurrence, attributing it to the relative infrequency of activity periods during the hibernation season. These authors also report that the eastern pipistrelle inhabits more caves and mines in Kentucky than any other species of bat. Pipistrelles encountered in BSFNRRA mines were generally hanging singly and were often scattered throughout a given mine.

The eastern pipistrelle was reported to occur in large numbers in silica and fluorite mines of southern Illinois, where it was the most frequently encountered bat species (Pearson 1962, Whitaker and Winter 1977). Other authors report that the eastern pipistrelle is found in small numbers during winter months in most caves within its range that are suitable for bat hibernation (e.g., LaVal and LaVal 1980, Barbour and Davis 1974).

LaVal and LaVal (1980) report that pipistrelles are among the last bats to leave hibernation in the spring and the first to enter in the fall. Our mid-April mist netting may have been somewhat early for pipistrelle spring movements, a suspicion reinforced by a resurvey of mine shaft no. 67 during the night of April 14, 1983, which revealed a total of 40 bats (41 were observed in hibernation on December 17, 1982) in various stages of torpor.

During nonhibernating periods, pipistrelles emerge relatively early in the evening, often before dusk (Mumford and Whitaker 1974). Whitaker and Mumford (1971) reported that this species was active around cave entrances throughout the evening. Our data (Table 4) support both of these observations; in our study, pipistrelles began emerging from mine shafts before dusk and were active throughout the mist-netting period.

2. *Plecotus rafinesquii* (Rafinesque's big-eared bat)

Eighty-seven big-eared bats were found hibernating in abandoned mines (Table 1), and 6 individuals of this species were captured by mist nets (Table 2) during the course of this study. *Plecotus* were encountered at 12 of 32 bat-inhabited mine shafts (37.5 percent) in the BSFNRRA. This was the second-most commonly encountered species during this study.

The average temperature at hibernation sites for this species was 8.0° C (Table 3). This is somewhat warmer than the 5.1° C reported for bats of this species hibernating in silica mines of southern Illinois (Pearson 1962). Whitaker and Winter (1977) reported

Table 4. Number of bats captured, by relative time period, in mist nets set at the entrances to abandoned mines in the Big South Fork National River and Recreation Area, McCreary County, Kentucky, during the period April 12-14, 1983. Dusk occurred at approximately 7:30 p.m.

	7:00 to 7:29	7:30 to 7:59	8:00 to 8:29	8:30 to 8:59	9:00 to 9:29
Pipistrellus subflavus	5	5	3	3	1
Plecotus rafinesquii		5		1	
Myotis keenii	1	4	2		
Myotis lucifugus		7			
Myotis leibii		1			

finding a single Plecotus rafinesquii in a large silica mine in Union County, Illinois, but no temperature data were given.

Barbour and Davis (1974) state that this is one of the least studied of American bats, and that its patterns of distribution and population numbers are mysterious. They further state that the whereabouts of this species in winter is largely unknown. John MacGregor and co-workers have found a number of Plecotus rafinesquii colonies in Kentucky caves, mines, and a cistern during the past several winters; including those found in this study, the known Kentucky population of this species probably does not exceed 300 individuals (John R. MacGregor, KDFWR, pers. comm.).

Two clusters of hibernating Plecotus rafinesquii were found during this study, one of 14 individuals on the ceiling of mine shaft no. 33 and the other of 50 individuals on a vertical wall of mine shaft no. 44. The large cluster was hanging directly over a 3-foot deep pool of water, and the smaller cluster, while not directly over water, was near a large pool of water. The clusters were tightly packed, and were comprised of both males and females. Further information on these hibernating clusters is presented in Barclay and Parsons (in prep.).

During the period April 12-14, 1983, this species was captured in mist nets primarily within the first half-hour after dusk (Table 4).

During summer, this species inhabits caves and buildings (Barbour and Davis 1974).

3. Eptesicus fuscus (big brown bat)

Six Eptesicus were encountered hibernating in abandoned mines during this survey (Table 1), while none were taken in mist nets. Eptesicus were found in 4 of 32 bat-inhabited mine shafts (12.5 percent) in the BSFNRRA. Specimens encountered were hanging singly and torpid.

Eptesicus hibernated in much colder zones of the BSFNRRA abandoned mines than did the other species encountered, averaging 5.0° C (Table 3). It is not uncommon to find this species in sites where the temperature drops below freezing (Barbour and Davis 1974, Beer and Richards 1956). They frequently use sites near the entrances in caves and mines, where they may come and go even in cold weather (Barbour and Davis 1974). LaVal and LaVal (1980) report that it is common for this species to crawl into inaccessible holes and crevices, behavior which might account for our low observation numbers.

Eptesicus fuscus has been reported from silica mines in southern Illinois (Pearson 1962), from man-made tunnels in Minnesota (Beer and Richards 1956), and from silica and fluorite mines in southern Illinois (Whitaker and Winter 1977). In summer, it inhabits buildings of all types that can provide it with adequate dark retreats and protection.

4. *Myotis lucifugus* (little brown bat)

Seven *Myotis lucifugus* were observed hibernating in abandoned mines of the BSFNRRA (Table 1), and 7 individuals of this species were collected with mist nets at mine entrances (Table 2) during the course of this study. *Myotis lucifugus* were encountered at 7 of 32 bat-inhabited mine shafts (22 percent) in the BSFNRRA.

Temperature measurements were made at only two hibernating sites for this species, and both sites measured 9.4^{o} C (Table 3). This is fairly consistent with hibernaculum temperatures reported for this species by Barbour and Davis (1969). *Myotis lucifugus* is common in caves throughout its range during winter (Barbour and Davis 1969), and has been reported from silica and fluorite mines in southern Illinois (Pearson 1962, Whitaker and Winter 1977), from iron mines in New York (Davis and Hitchcock 1965), and from the famous Pilot Knob Mine in Missouri (LaVal and LaVal 1980).

All seven individuals of this species captured by mist netting entrances to abandoned mines in the BSFNRRA during mid-April 1983 were taken within the first half-hour after dusk (Table 4). Whitaker and Mumford (1971) similarly reported *Myotis lucifugus* to be most active at and just after dark at an Indiana cave. The same authors, in a later paper, state that most Myotis lucifugus remain in their daytime roosts until it is dark, or nearly so (Mumford and Whitaker 1974).

In summer this species typically inhabits buildings, usually choosing a hot attic to establish large nursery colonies. Colonies are usually close to a lake or stream, preferred foraging habitat for this species (Barbour and Davis 1974).

5. Myotis keenii (Keen's bat)

This is the most perplexing species encountered in the study, as no specimens were encountered during the December 10, 1982 to February 17, 1983 in-mine hibernaculum suitability surveys of 96 abandoned mine openings in the BSFNRRA, while 9 individuals were captured from 6 of 18 mine entrances surveyed by mist netting during the period April 12-14, 1983. Was this species present but overlooked during the in-mine surveys, or had the species moved into the mine shafts sometime between February 17 and April 12, 1983?

It appears from the literature that Myotis keenii perplexes most bat researchers. Barbour and Davis (1974) state that . . . "We do not understand the distribution and abundance of this bat in Kentucky . . ." and present data to indicate that this species was collected by night at the entrance of a given cave, yet the species was not present in the cave during the day; similarly confounding data are also presented. Confusion over the daily whereabouts of this species is also expressed by Mills (1971), Pearson (1962), and Caire et al (1979).

The literature also contains possible explanations. Pearson (1962) reported collecting two females of this species hibernating in a drill hole in a silica mine. Caire et al (1979), in studies on Myotis keenii ecology in Missouri, report that many of the hibernating Keen's bats observed were secluded in the formations of the caves (i.e., the cracks and crevices). They further report trapping individuals of this species exiting the caves that were soiled with mud and clay, and cite this as additional evidence that this species roosts in the tighter crevices and other recesses of the caves.

From the above, it appears plausible that Myotis keenii might have been present in the tight recesses of the BSFNRRA abandoned mines during the winter of 1982-1983, and was overlooked by our survey team. Without doubt there were numerous recesses available behind partially collapsed ceiling layers, in fracture cracks, and behind caved-in materials where a small bat could go unobserved. However, Myotis keenii is a northern species found most frequently hibernating in caves and mines across the northern U.S. and southern Canada (Barbour and Davis 1974). Hibernation is reported as ending in late March or early April in Missouri, at which time females disperse to maternity sites throughout nearby states (Caire et al 1979). Thus, it is possible that the Myotis keenii encountered in this study had just arrived in the BSFNRRA from distant hibernacula. John R. MacGregor (nongame biologist, KDFWR, pers. comm.) states . . . "I believe that keenii hibernates in the BSFNRRA mines but chooses crevices that are difficult or even dangerous to look in."

6. Myotis leibii (small-footed bat)

The only specimen of this diminutive bat encountered in the course of this study was captured in a mist net at the entrance to mine shaft no. 3 on April 12, 1983. It is unknown whether this individual wintered in the BSFNRRA or had only recently arrived.

Myotis leibii are apparently easy to overlook in caves and mines, and little is known of their hibernaculum site preferences. However, New Mammouth Cave in Campbell County, Tennessee, supports wintering populations of this species, as does Rocky Hollow Cave in southwest Virginia, located at approximately the same latitude as the BSFNRRA (Robert Currie, U.S. Fish and Wildlife Service, Asheville, NC, pers. comm.).

The following information is taken from Barbour and Davis (1974, page 83):

"In the East this species is known primarily from specimens found hibernating in mines and caves in Pennsylvania, New York, Vermont, and Ontario, where they sometimes form groups of several dozen bats. Occasional individuals are found in winter in caves as far south as Georgia. The locality nearest Kentucky where this bat is regularly found in winter is Saltpeter Cave, at Greenville, West Virginia. There are March records from a cave in Campbell County, Tennessee, just a few miles from southeastern Kentucky; this leads us to suppose that the species will eventually be found occasionally in winter in Kentucky caves. Kentucky records of this bat are all from the warm months."

MANAGEMENT CONSIDERATIONS

A number of factors must be considered before final decisions can be made regarding the fate of abandoned mine openings in the BSFNRRA. First consideration must be human health and safety. In this regard, proximity to areas of high public use is an important consideration. Other factors which must be considered include costs of closing or otherwise treating shafts, physical condition of shafts, biological value of abandoned mines, and possible interpretive value. These considerations are treated in the following paragraphs, culminating in our shaft-by-shaft recommendations.

Proximity to High Public Use Areas

Public use areas planned for the BSFNRRA are detailed in Design Memorandum No. 7 of the BSFNRRA Master Plan, prepared by Miller, Wihry & Lee, Inc., for the COE (undated). Based on information contained in this document and on our locality data for abandoned mine openings, potential public use conflicts with abandoned mines are summarized in Table 5.

Probably all abandoned mine openings in close proximity to high public use areas should ultimately be treated to prevent entry by humans. Timing of such treatment will likely depend on the BSFNRRA development schedule, the degree of public use expected in a given area, and costs of treatment. Based on potential for public use, we would prioritize the types of public use areas as follows:

Priority 1 -- All areas within the safety zones of a development area.

Priority 2 -- Day trails.

Priority 3 -- Pack and equestrian trails and backcountry roads.

Table 5. Proximity of abandoned mine openings to proposed high public use areas in the Big South Fork National River and Recreation Area (BSFNRRA). Shafts listed without comment are located *within the boundaries of* the BSFNRRA but are not in high public use areas.

Shaft No.	Public Use Area and Comments	
1	Within Blue Heron safety zone	Both very near trailhead.
2	" " "	
3	" " "	
200	" " "	
4	" " "	
6	" " "	
7	" " "	
8	" " "	
9	" " "	
10	" " "	
11	" " "	
12	" " "	All are located adjacent to equestrian and pack trail.
13	" " "	
14	" " "	
16	" " "	
17	" " "	
18	" " "	
19	" " "	
20	" " "	
21	" " "	
22	" " "	
23	" " "	
24	" " "	
25(a)	" " "	
25(b)	" " "	All 3 on S side Laurel Br., little contact likely
26	" " "	
27	" " "	
28		
29		
30	Just across Salt Br. from day trail, just N. of Bear Creek safety zone.	
31		
199		
32		
33		
34		
35	All 16 on pack trail on W. side of river between Blue Heron and Bear Creek development areas.	
36		

Table 5 (cont.)

37	
38	
39	
40	
197	
42	
43	
44	
45	
46	
47	
48	All 3 on equestrian/pack trail on W. side of river across from Blue Heron.
49	
50	
51	All 6 on day/pack trail on W. side of river across from Blue Heron.
52	
53	
54	
56	
57	
58	All 3 on day trail on W. side of river across from Blue Heron.
59	
60	
61	
62	
67	
68	
70	
71	
98	
99	
72	
100	
73	
74	
75	
76	
77	
78	
79	
81	Both on W. edge of Yamacraw safety zone, and right on a pack trail.
198	
82	On N. edge of Yamacraw safety zone, W. side of river, on hwy. 92.
83	
84	

Table 5 (concluded)

85	All 3 on N. edge of Worley dev. area safety zone, on the N. side of Worley Branch.
86	
87	
88	Within the Worley dev. area safety zone, southern half.
89	At N. edge of Blue Heron Group Camp, but on N. side of Roaring Paunch Cr.
90	
91	All 4 outside BSFNRRA boundary, but right on RR.
92	
93	
94	Both outside BSFNRRA boundary, but only 0.5 mile N. of Blue Heron Group Camp.
95	
96	
186	
187	
188	
189	
190	All barely within N. edge of Alum Fork development area safety zone.
191	
192	
193	
194	
195	
150	In center of Leatherwood safety zone, on day trail and backcountry road.
151	
152	
153	
154	All 4 on pack trail/backcountry road connecting Leatherwood and Station Camp.
155	
156	
157	Both in heart of Zenith development area.
158	
159	Adjacent to road at Burnt Mill Bridge.

Condition of Mine Openings and Shafts

Most of the abandoned mines in the BSFNRRA could best be described as hazardous. Ceiling and wall collapses were commonly encountered, often preventing further exploration of a given mine due to total or near-total blockage of the shaft. Water of varying quality was also commonly encountered in the mine shafts, and was most frequently found ponded behind berms that had formed at the mine entrance due to natural events. Occasionally water was seen to completely seal a shaft, extending from floor to ceiling. And at eight entrances, water was found to be flowing (> 1 cfs) out of the mine shaft; this flowing water was generally orange-colored due to the presence of iron compounds, and low in pH. All of these factors must be considered when deciding how best to close a mine to human entry.

Table 6 summarizes conditions encountered at each abandoned mine shaft on the day surveyed. It should be noted that mine depths listed do not necessarily mean that the mine ended at this depth. Rather, these figures indicate the depth actually surveyed; a survey was terminated when (1) the end of the mine was reached, (2) a major collapse prevented passage, (3) deep water prevented further exploration, (4) air temperatures exceeded bat thermal preference ranges, (5) shafts were judged to be unsafe for further survey, or (6) the mine was judged much too complex to adequately survey by visual inspection,

Table 6. Condition of each abandoned mine shaft on date surveyed. When no mine depth is listed, the shaft was either closed or judged too unsafe to enter.

Shaft No.	Mine Depth	Water Ponded Behind Berm	Water Seeping From Mine	Water Flowing From Mine	Comments
1-2	200'				
3	200'				
200					This is a powder magazine
4					Closed
6	25'				Stable
7	50'+	12-18"	X		
8		12-18"			
9	120'+	<12"			Connects with 10
10	120'+				
11	75'+	<12"			
12	200'	<12"			
13					
14	50'	<12"			
16	140'				
17					Closed
18	630'				Connects with 19-22
19	100'				
20					Nearly closed
21					Closed
22					Nearly closed
23					Nearly closed
24					Closed
25(a)	150'+	12-18"	X		
25(b)					Closed
26					
27					
28	250'				
29	100'				
30		>18"			Water fills shaft
31	40'+	<12"			
199	30'				
32	100'	*			
33	80'	*			
34	60'	*			Water fills shaft
35	60'+	*			
36	100'+	*			
37	400'+				

Table 6 (cont.)

38	40'				Connects with 39
39	100'+	*			
40	100'+	*			
197		<12"			Nearly closed
42	60'	*			Water fills shaft
43	100'				Connector with 44
44	60'+	*			
45	40'				
46					Nearly closed
47					Closed
48	40'	X	X	X	
49		<12"	X		
50	500'+	<12"	X		
51	50'	*			Water fills shaft
52	50'	*			
53	15'				Punch mine (stable)
54	105'				
56					Water fills shaft
57					Closed
58					Closed
59					Closed
60	200'+	<12"			
61		X	X	X	Strong outflow of water
62	120'+	12-18"	X	X	
67	250'+	<12"			Connects with 68
68		<12"			Nearly closed
70	40'				
71	200'				
98					Closed
99	75'				
72	250'+				
100	1,000'+				
73					Closed
74					A natural cave
75	30'				Punch mine (stable)
76	30'				Closed
77		12-18"			
78	40'				
79	30'				
81	60'				
198			X	X	Entrance collapsed
82		<12"	X		
83	50'+	<12"	X		
84	300'	*			
85					Closed
86				X	Strong outflow of water

Table 6 (concluded)

87		*			Water fills shaft
88		>18"		X	Strong outflow of water
89					
90					Nearly closed
91	240'+	<12"			
92	150'+				
93	30'+				
94	80'+				
95	400'+				
96	375'+				
186		>18"		X	Strong outflow of water
187	80'	*			
188	120'	<12"			
189				X	Strong outflow of water
190		<12"	X		
191		<12"	X		
192					Closed
193	75'+	>18"	X		
194	120'				
195					Closed
150	20'				
151	75'	<12"	X		
152	60'+	<12"	X		
153		>18"			Water fills shaft
154	75'+	*			
155					Nearly closed
156	100'+				
157		*			Water fills shaft
158					Closed
159		*			Water fills shaft

Key: * indicates that water was ponded deeper in the shaft, not at the entrance.

necessitating a mist net survey during the period when bats were leaving hibernation.

Methods of Closing Abandoned Mine Openings

Four general techniques are currently in widespread use for closing or reclaiming mine openings. These techniques are backfilling, sealing, blasting, and barrier construction. These techniques are briefly described in the following paragraphs.

1. Backfilling.--This is the most commonly used technique for reclaiming both horizontal and vertical openings. It consists simply of filling the mine opening with available fill materials. Many materials are commonly used including spoil and coal waste, rock and stone, and slurries. Methods employed in backfilling include use of mechanical devices, hand labor, hydraulic pumping, and pneumatic packing. Material from onsite locations (borrow pits, spoil, refuse piles) or offsite locations (commercial aggregate suppliers or nearby mine operators) is used.

2. Constructed seals.--For horizontal mine openings that drain water, seals are usually constructed of some form of masonry material (brick, block, or stone) or of concrete that is poured into forms in the mine opening. Depending upon particular site conditions and requirements, these seals may include provision

for free drainage or be sealed to prevent drainage. Hydraulic seals dam the flow of water from the mine so that the mine floods behind the seal. This creates an oxygen-deficient environment and prevents oxidation of pyrites and the resultant formation of acid. Air seals inhibit oxidation by allowing the mine drainage to pass through a pipe or ditch while preventing air from entering the mine.

3. Blasting.--This technique requires that holes be drilled either horizontally or vertically into the strata surrounding the opening. After placement of the explosives, the holes are packed with noncombustible material and the charges are detonated. Blasting collapses the strata and turns it into rubble. The resultant increase in volume of fractured strata (rubble) is usually sufficient to fill the opening. If not, backfilling is usually employed to complete the job.

4. Barriers.--Barriers include grates, fences, gates, and other similar structures installed either over, in front of, or around the mine opening to impede entry. Placement of barriers is done by securely anchoring the structure to a solid base, usually posts imbedded into the ground and set within concrete.

Additional information on types of seals for closing mine openings has been provided by the Tennessee Department of Conservation, Division of Land Reclamation, and is included herein as Appendix A.

Protecting Bat Habitat and the Public

Methods for impeding human entry into abandoned mines while still permitting free bat movement into and out of these cavelike habitats are generally restricted to gating and fencing. Gating is the more secure of the two alternatives, but it presents unique problems for bats. Improperly constructed gates often impede air flow into and out of a cave or mine shaft. As noted by Tuttle (1977), even the slightest restriction of air flow may cause a rise in temperature that is intolerable for hibernating bats; this is particularly true in caves and mines located south of about the 37 degree north latitude. It is important to understand that gates placed in tight places will cause maximum damage in terms of restricting movement of both bats and air. Gates at bat caves or mines should always be built in the largest possible places in the entranceway or in an inner passage where the diameter is large.

Improper bar spacing is another potential problem of major proportions. In the past, some ill-conceived bat gates have had inadequate space between the bars to permit bats to fly through freely; vertical bars too narrowly spaced have been reported by Tuttle

(1977). Several such ill-conceived gating projects have resulted in the destruction of the very bat populations they were intended to protect. Other restrictive gates have resulted in increased predation by causing the bats to slow down and/or circle in front before entering, thereby increasing their vulnerability to predators (Tuttle 1977).

> A "good gate" for a bat cave is one that minimizes restriction of air flow and that does not cause bats to reduce their speed of entry or exit. In order to minimize interference with the bats, a gate should have the least number of vertical bars possible and the greatest width possible between horizontal bars. These considerations unfortunately must be balanced carefully against the increased possibility of vandals breaking or squeezing through the gate when spaces are too large. Consequently, the greatest allowable distance between horizontal bars is about 6 inches. Distance between vertical bars can be as much as 3-4 feet (never less than 2 feet), depending on strength of construction materials. (from Tuttle 1977, page 80)

Chain link or cyclone fences built around but not directly in front of (or over) cave or mine entrances provide a good means of protecting bat populations while impeding human entry. When constructed well back from the entrance, fencing does not hinder the exit or entry of bats. Other advantages are that fences are relatively inexpensive, easy to install, and easy to repair when vandalized. Easily read signs can be placed inside, explaining reasons for protecting the shaft and safety hazards of entry. Disadvantages include the fact that they are more easily breached than gates, that they are fairly conspicuous, and that they are not very aesthetically pleasing.

A final consideration regarding gating versus fencing: Tuttle (1977) recommends that gates be restricted to caves with entrances at least 5 feet or more in height and preferably of even greater width. He concludes that fencing may prove to be the only alternative for protecting bats in many cases with entrances of less than 5 feet in diameter. Fortunately, a cage-type gate has recently been designed for use with small cave and mine openings (LaVal and LaVal 1980), and it has been successfully tested in Missouri. Consequently, smallness of entrance size need no longer eliminate the use of gates for protecting bat populations in mines and caves while impeding human entry.

Categorization of BSFNRRA Mine Openings

Since no endangered species were encountered during the course of this study (and only one specimen of an endangered species--the Indiana bat--has ever been identified from BSFNRRA abandoned mines), there are apparently no endangered species limitations on selecting methods for closing these abandoned mines to human entry. This is not to imply that these mines are not important to bats, but only that there appear to be no legal constraints from an endangered species standpoint to closing the BSFNRRA mines. The data, however, clearly indicate that some of these abandoned mines are being used as wintering habitat by non-endangered species of bats; some mines exhibited relatively high species diversity, while a few others contained relatively high numbers of only one species.

Decisions on closure methodologies for abandoned mines in the BSFNRRA should be made on the basis of the following considerations: (1) human safety, (2) mine drainage and water quality, and (3) maintenance of natural diversity in the BSFNRRA through protection of bat habitat. To aid in the decisionmaking process abandoned mine openings have been categorized based on the three factors listed above. In this categorization, relative significance to bats is based on species diversity (3 or more species encountered is considered significant mine usage), number of individuals of a species (20 or more individuals found in a mine is considered significant), presence of a cluster of *Plecotus rafinesquii*, or interconnecting mine openings at least one of which contained significant bat populations based on the above factors (potential significance to bats is based on air circulation). Any action involving mines with drainage problems should include further studies of the quality of waters draining from these mines; extreme care should be taken to insure that mine closure actions do not exacerbate water quality problems. On the basis of these considerations, BSFNRRA mine openings can be categorized as follows:

Category 1.A.--Significant bat use, high public use area, no mine drainage problems:

3	18	44
9	33	54
10	43	

Category 1.B.--Significant bat use, low public use area, no mine drainage problems:

67	72	100
68	99	

Category 2.A.--Low bat use, high public use area, no mine drainage problems:

1	14	27
2	25(b)	37

Category 2.B.--Low bat use, high public use area, but with mine drainage problems:

25(a)	40	191
32	51	193

Category 2.C.--Low bat use, low public use area, no mine drainage problems:

28	92	
70	95	188
71	96	

Category 2.D.--Low bat use, low public use area, but with mine drainage problems:

62	84

Category 3.A.--No bat use, high public use area, no mine drainage problems:

4	16	23	47	81	158
6	17	24	53	85	192
8	19	26	57	89	194
11	20	38	58	150	195
12	21	45	59	155	197
13	22	46	60	156	200

Category 3.B.--No bat use, high public use area, but with mine drainage problems:

7	36	49	82	153	189
30	39	50	86	154	190
34	42	52	87	157	198
35	48	56	88	159	

Category 3.C.--No bat use, low public use area, no mine drainage problems:

29	74	77	90	94
31	75	78	91	98
73	76	79	93	199

Category 3.D.--No bat use, low public use area, but with mine drainage problems:

61	151	186
83	152	187

Recommended Alternatives

Given the physical, financial, and manpower constraints that would be associated with the treatment (closure or otherwise) of all abandoned mine openings in the BSFNRRA, it is likely that such treatment will occur in a step-by-step progression over some reasonably lengthy period of time. The following ranked listing of alternatives should aid in the selection of both timing and methodologies for treatment of these abandoned mine openings. This ranking utilizes the previously described categorization of mine openings, with public safety receiving the primary consideration.

First Priority (category 3.A. and 3.B. openings)

Preferred alternative.--Seal all 3.A. openings; seal all 3.B. openings either with hydraulic seals or with air seals and suitable water treatment to insure good water quality.

Second Priority (category 1.A., 2.A., and 2.B. openings)

Preferred alternative.--Gate all 1.A., 2.A., and 2.B. openings.

Second alternative.--Gate all 1.A. openings; seal all 2.A. openings; and seal all 2.B. openings either with hydraulic seals or with air seals and suitable water treatment to insure good water quality.

Third Priority (category 3.C. and 3.D. openings)

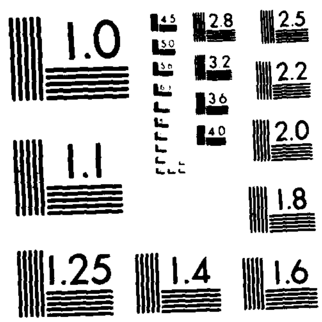
Preferred alternative.--Seal all 3.C. openings; seal all 3.D. openings either with hydraulic seals or with air seals and suitable water treatment to insure good water quality.

Fourth Priority (category 1.B., 2.C., and 2.D. openings)

Preferred alternative.--Leave all 1.B. and 2.C. openings in their current, unsecured condition; leave all 2.D. openings in their current, unsecured condition, and treat mine drainage to insure that only high quality waters enter the Big South Fork of the Cumberland River.

Second alternative.--Fence or gate all 1.B. and 2.C. openings; fence or gate all 2.D. openings, and treat mine drainage to insure that only high quality waters enter the Big South Fork of the Cumberland River.

Third alternative.--Fence or gate all 1.B. openings; seal all 2.C. openings; and seal all 2.D. openings either with hydraulic seals or with air seals and suitable water treatment to insure good water quality.



Preferred alternatives are summarized in Table 7.

The technical specifications for gates intended to permit ingress and egress of bats must, of necessity, be highly site specific. Technical assistance in designing such gates or fences can be obtained from the Endangered Species Field Office, U.S. Fish and Wildlife Service, Plateau Building, 50 South French Broad Avenue, Asheville, North Carolina 28801.

Technical assistance in closing other abandoned mine openings is available from any of the following three agencies:

Office of Surface Mining Reclamation
and Enforcement
Eastern Technical Center
Ten Parkway Center
Pittsburg, PA 15220

Division of Abandoned Lands
Department of Natural Resources
and Environmental Protection
Capital Plaza Tower
Frankfort, KY 40601

Table 7. Summary of preferred alternatives for treatment of abandoned mine openings in the Big South Fork National River and Recreation Area.

Location	FWS Preferred Alternative	FWS Priority	Number of Sites
Blue Heron Rec. Area	(1) Seal	1	16
	(2) Seal w/drains	1	1
	(3) Gate	2	10
Blue Heron Group Camp	(1) Seal	1	1
Alum Ford Rec. Area	(1) Seal	1	3
	(2) Seal w/drains	1	2
	(3) Gate	2	2
Yamacraw Rec. Area	(1) Seal	1	1
	(2) Seal w/drains	1	2
Worley Rec. Area	(1) Seal	1	1
	(2) Seal w/drains	1	3
Leatherwood Rec. Area	(1) Seal	1	1
Zenith Rec. Area	(1) Seal	1	1
	(2) Seal w/drains	1	1
Burnt Mill Rec. Area	(1) Seal w/drains	1	1
Adjacent to Proposed Trails	(1) Seal	1	12
	(2) Seal w/drains	1	13
	(3) Gate	2	8
Backcountry	(1) Seal	3	15
	(2) Seal w/drains	3	6
	(3) Leave open	4	12
	(4) Leave open, treat drainage	4	2

Division of Land Reclamation

Tennessee Department of Conservation

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LITERATURE CITED

Barbour, R.W. and W.H. Davis. 1974. Mammals of Kentucky. Univ. of Kentucky Press, Lexington. 322 pages.

Beer, J.R. and A.G. Richards. 1956. Hibernation of the big brown bat. Journal of Mammalogy, 37(1):31-41.

Caire, W., R.K. LaVal, M.L. LaVal, and R. Clawson. 1979. Notes on the ecology of Myotis keenii. American Midland Naturalist, 102(2):404-407.

Clawson, R.L., R.K. LaVal, M.L. LaVal, and W. Caire. 1980. Clustering behavior of hibernating Myotis sodalis in Missouri. Journal of Mammalogy, 61(2):245-253.

Davis, W.H. and H.B. Hitchcock. 1965. Biology and migration of the bat, Myotis lucifugus, in New England. Journal of Mammalogy, 48(2):296-313.

Elder, W.H. and W.J. Gunier. 1978. Sex ratios and seasonal movements of gray bats (Myotis grisescens) in southwest Missouri and adjacent states. American Midland Naturalist, 99(2):463-472.

Geiger, R. 1965. The microclimate of caves. Pp. 462-467 in The Climate Near the Ground. Harvard Univ. Press, Cambridge, Mass.

Gray Bat Recovery Team (GBRT). 1982. Gray Bat Recovery Plan. U.S. Fish and Wildlife Service, Washington, DC 120 pages.

Hall, J.S. 1962. A life history and taxonomic study of the Indiana bat, Myotis sodalis. Reading (PA) Public Museum and Art Gallery, Scientific Publications, No. 12. 68 pages.

Hall, J.S. and N. Wilson. 1966. Seasonal populations and movements of the gray bat in the Kentucky area. American Midland Naturalist, 75(2):317-324.

Humphrey, S.R. 1978. Status, winter habitat, and management of the endangered Indiana bat, Myotis sodalis. Florida Scientist, 41(2):65-76.

Humphrey, S.R., A.R. Richter, and J.B. Cope. 1977. Summer habitat and ecology of the endangered Indiana bat, Myotis sodalis. Journal of Mammalogy, 58(3):334-346.

Indiana Bat Recovery Team (IBRT). 1976. Draft Recovery Plan for the Indiana bat. U.S. Fish and Wildlife Service, Washington, DC 34 pages.

LaVal, R.K., R.L. Clawson, M.L. LaVal, and W. Caire. 1977. Foraging behavior and nocturnal activity patterns of Missouri bats, with emphasis on the endangered species Myotis grisescens and Myotis sodalis. Journal of Mammalogy, 58(4):592-599.

LaVal, R.K. and M.L. LaVal. 1980. Ecological studies and management of Missouri bats, with emphasis on cave-dwelling species. Missouri Dept. of Conservation, Terrestrial Series No. 8, 53 pages.

Mills, R.S. 1971. A concentration of Myotis keenii at caves in Ohio. Journal of Mammalogy, 52(3):625.

Mumford, R.E. and J.O. Whitaker, Jr. 1974. Seasonal activity of bats at an Indiana cave. Proc. *Indiana Academy of Science,* 84:500-507.

Pearson, E.W. 1962. Bats hibernating in silica mines in southern Illinois. Journal of Mammalogy, 43(1):27-33.

Rabinowitz, A. and M.D. Tuttle. 1980. Status of summer colonies of the endangered gray bat in Kentucky. Journal of Wildlife Management. 44(4):955-960.

Tuttle, M.D. 1975. Population ecology of the gray bat (Myotis grisescens): factors influencing early growth and development. Occasional Papers of the Museum of Natural History, Univ. of Kansas, 36:1-24.

Tuttle, M.D. 1976(a). Population ecology of the gray bat (Myotis grisescens): Philopatry, timing and patterns of movement, weight loss during migration, and seasonal adaptive strategies. Occasional Papers of the Museum of Natural History, Univ. of Kansas, 54:1-38.

Tuttle, M.D. 1976(b). Population ecology of the gray bat (Myotis grisescens): factors influencing growth and survival of newly volant young. Ecology, 57(3):587-595.

Tuttle, M.D. 1977. Gating as a means of protecting cave dwelling bats. Pp. 77-82 in National Cave Management Symposium Proceedings, 1976. Speleobooks, Albuquerque, NM.

Tuttle, M.D. 1979. Status, causes of decline, and management of endangered gray bats. Journal of Wildlife Management. 43(1):1-17.

Tuttle, M.D. and D.E. Stevenson. 1978. Variation in the cave environment and its biological implications. Pp. 108-121 in

National Cave Management Symposium Proceedings, 1977. Adobe Press, Albuquerque, NM.

Twente, J.W., Jr. 1955. Some aspects of habitat selection and other behavior of cavern-dwelling bats. Ecology, 36:706-732.

Whitaker, J.O., Jr. and R.E. Mumford. 1971. Notes on a collection of bats taken by mist-netting at an Indiana cave. American Midland Naturalist, 85(1):277-279.

Whitaker, J.O., Jr. and F.A. Winter. 1977. Bats of the caves and mines of the Shawnee National Forest, Southern Illinois. Transactions of the Illinois State Academy of Science, 70(314):301-313.

APPENDIX A

Underground Mine Seals

I. Any seals will be determined by the condition of the tunnels, entryway and the material to be used must be able to withstand very low pH conditions.

Other determining factors:

1. Geology - The geologic structure of the mined area will determine whether a mine tunnel can be effectively sealed. Geologic structure of the mine can be determined by boreholes (strike and dip, folding, anticlines, synclines, fractures and faults, and the composition of the seam and associated strata).

2. Hydrology - Ground water quantity, flow and the height of the ground water table. Factors affecting ground water flow are rock type, joints, faults, fracturing, and dip of beds.

   The elevations of all springs and swamps above the outcrop line and water levels in boreholes and nearby wells should be recorded.

3. Condition of the mine opening - The mine opening or portal from which the drainage originates may either be open so that the seal may be constructed from within by entering the portal, or the portal may be closed due to caving or flooding and the seals will have to be placed from above through boreholes.

II. Types of seals:

1. Dry seals - Dry seals are constructed in the tunnel, shaft, or slope utilizing impermeable materials such as soil, clay, cement block, crushed rock or any combination of these.

2. Air seals - This is the sealing of a mine entry or portal to prevent the penetration of air. The seal is constructed of impermeable materials. Water is usually allowed to drain at a particular point where air cannot enter.

3. Hydraulic seals - Hydraulic seals entail the inundation of the underground mine with water by the construction of seals which will be impervious to and withstand extreme water pressure.

4. Double bulkhead seals - This is the construction of two bulkhead seals with a space in between for the impermeable seal. These bulkheads are usually constructed of quick setting cement and grouted course aggregate. More grouting may be necessary to prevent leakage.

5. Single bulkhead seals - Single bulkheads are constructed of poured concrete, grouted aggregate, quick setting cement, masonry block, rock (crushed), soil, or clay. These bulkheads can be constructed from above through boreholes although they are usually constructed through the entryway.

6. Permeable limestone seals - This is the placing of a permeable material of an alkaline nature such as crushed limestone so that any acid drainage will pass through the seal and become neutralized. This aggregate material may in time become filled with precipitates and become impermeable.

7. Gunite seals - This type of seal is formed by the placement (pneumatically) of low slump concrete (gunite) into the mine opening or tunnel until it is filled. Usually, the roof, floor, and sides of the tunnel are cut so that the seal will be more complete. An initial bulkhead, usually constructed of wood or block is used to support the seal.

8. Clay seals - In this type of seal a plastic impermeable clay placed into the portal or tunnel in layers and compacted to fill cracks and boids to form a tight seal. The seal is usually placed from the entrance and backfilled with earth material.

9. Grout bag seals - This seal is formed by placing layers of grout filled containers into the open portal until the portal is closed. This grout material expands and hardens producing a tight seal.

10. Shaft seals - Shaft seals are formed using a mixed earth and rock (or other material) fill in connection with concrete plugs to seal water discharges.

11. Gel material seals - This type of seal is formed in th open tunnel by pumping a chemical grout and filler material throu borehole(s which forms a gel-like plug without retainers. This type is also permeable.

12. Regulated flow seals In this type seal a pipe drain is inserted to maintain an acceptable discharge into receiving streams.

13. Curtain grouting - This is the process of sealing the pore spaces and voids in permeable soil or rock formations by the injection of grout material through boreholes. There are two types of mixtures:

(A) True solutions - A mixture of soluble monomeric material in water or other solvent which may be injected into the permeable zone without initially fracturing the material.

(B) Slurries - Suspensions of very fine cementing material in a fluid medium. Slurries are more vicious than true solutions and cannot be pumped into pores smaller than the grout particle

III. Alternatives to sealing

1. Treatment - A bituminous fiber pipe should be used to direct the discharge to a drainage ditch (lined with crushed limestone) leading to a holding pond lined with impervious clay and/or crushed limestone. Once in the holding pond the drainage can be treated mechanically and then released, or allowed to evaporate.