Bats and Mines

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Bat Conservation
International, Inc.

Resource Publication No. 3

Revised Edition

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Natural Resources
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Introduction

Many of North America's largest remaining bat populations roost in mines. These include a majority of the 45 bat species living in the continental United States and some of the largest populations of endangered bats. More than half of U.S. bats are already listed as endangered or species of concern, and closure of abandoned mines without first conducting biological surveys could endanger even currently abundant species. Given the key ecological role of bats as primary predators of night-flying insects, which cost American farmers and foresters billions of dollars annually, additional threats to bat survival are cause for serious concern.

Closure or other alteration of old mines without biological assessment can, in single events, eliminate some of America's largest remaining bat populations. This publication will aid resource managers and others involved in decisions to close or reclaim abandoned or inactive subsurface mines, or to permit new mining in historic districts. It provides the basic information required to assess whether a mine is, or could serve as, an important bat roost, and it describes safe and responsible methods for protecting both humans and bats without total closure. Before surveying, closing, or gating mines, experts knowledgeable about bats and mine safety should be consulted. A list of resources is provided at the end of this publication.

Importance of Mines for Bats

Abandoned mines serve as important year-round sanctuaries for bats. Throughout the United States, human disturbance of caves, cave commercialization, deforestation, and urban and agricultural developments have forced many bats from their traditional roosts in search of new homes. Although caves are numerous in some regions, most are now too frequently disturbed by humans to permit bat use. Bats additionally have lost countless traditional roosts in old tree hollows due to logging of old-growth forests. Over the past 100 years or more, many displaced bats have gradually moved into abandoned mines, which often provide microclimates similar to caves. Even in areas where traditional roosting habitat has not been disturbed or altered by man, abandoned mines attract bats due to their often ideal environmental conditions. Bats may now have few alternatives or may be so instinctually committed to certain sites that they cannot change roosts in the time permitted by current rates of mine closure. Loss of a single mine hibernation site can affect a multistate region, eliminating many summer colonies of bats over thousands of square miles.

Of the more than 8,000 mines surveyed by researchers across North America, 30 to 80 percent showed signs of use by bats, with an average of 10 percent containing important colonies. From the Great Lakes region north and eastward in the United States and Canada, up to 70 percent of open, unflooded mines may be used by large bat populations. Moreover, because most mines have not been checked for bats, a large proportion of bats living in them remain undiscovered. For example, in December 1992, an estimated one million little and big brown bats (*Myotis lucifugus* and *Eptesicus fuscus*) were found in the Millie Hill Mine in Iron Mountain, Michigan. It was slated for closure the next spring. These bats constituted the second largest hibernating bat population ever discovered in North America.

In Wisconsin, more than 600,000 bats of four species were saved because just two mines were surveyed and protected from closure. The largest recorded hibernating population of western big-eared bats (*Corynorhinus townsendii pallescens*), another species in decline, was recently destroyed in a New Mexico mine shaft where vandals set old timbers on fire. In New Jersey, the state's largest population of hibernating bats was inadvertently trapped in the Hibernia Mine when it was capped. These bats also would have died had not biologists convinced state authorities to reopen the entrance immediately. Likewise, the

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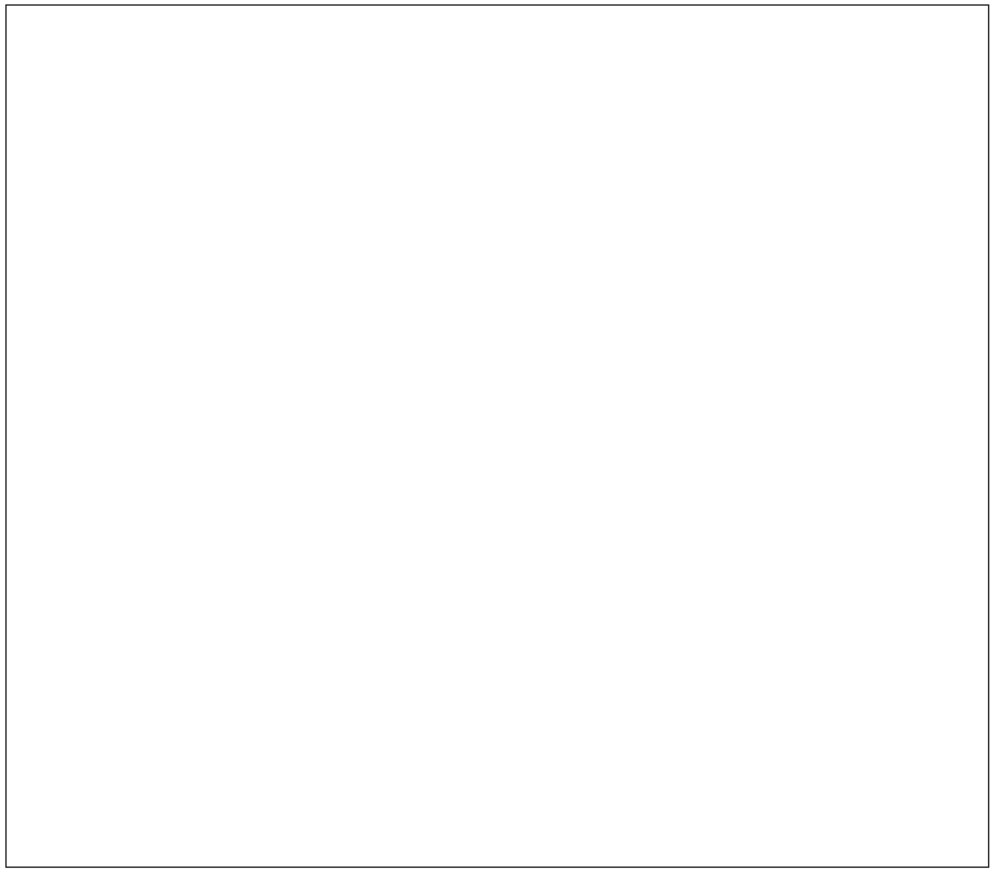
Some of our largest remaining populations of endangered Indiana bats rely on abandoned mines for hibernation. These bats and many other species often have few alternatives as their traditional roosts in caves are lost to human disturbance.



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California leaf-nosed bats are extremely dependent on abandoned mines. Most of their known winter roosts in the Southwest are in mines.

Canoe Creek State Park limestone mine in Pennsylvania was reopened in time to save its bats and now shelters the largest bat hibernating population in the state.

Unfortunately, at the rate at which mines are being closed, such incidents are far more common than recognized. A local mine inspector reported that, of the 12 mines already closed prior to 1993 in Iron Mountain, Michigan, some contained large numbers of bats, perhaps more than were saved in the Millie Hill Mine.

Due to the colonial behavior of most bats, they are especially vulnerable to mine closures. Endangered Indiana bats (*Myotis sodalis*) and cave myotis (*M. velifer*) have each been found in mines in numbers up to 100,000. Similarly, the largest known hibernating populations of the southeastern big-eared bat (*Corynorhinus rafinesquii*), a species of concern, live in abandoned iron and copper mines in small groups ranging from a few dozen to over 500. A majority of the remaining nursery roosts of the endangered lesser long-nosed bat (*Leptonycteris curasoae*) in the United States are also in mines.

In the northern United States, little brown bats, among America's most successful and abundant bats, are now so reliant upon abandoned mines for hibernation that a majority of the entire species overwinters in mines. Closure of mines without first checking for bats could drastically reduce their numbers, needlessly endangering the species. The danger of killing extremely large numbers of these animals is probably greatest in old mines of the northern Midwest, from the Dakotas to Wisconsin and Michigan, as well as farther north into Canada, but it is certainly not restricted to these areas. Populations of over 100,000 bats are also known to live in mines of the northeastern United States and may be discovered wherever bats live near mines cool enough for hibernation.

Other bat species rely heavily on mines for hibernation, even though large proportions of their populations are not normally found in any one mine. These include the eastern small-footed myotis (*Myotis leibii*), western small-footed myotis (*M. ciliolabrum*), California myotis (*M. californicus*), eastern long-eared myotis (*M. septentrionalis*), eastern pipistrelle (*Pipistrellus subflavus*), and big brown bat.

Environmental Consequences of Losing Bats

Mine closures without assessment for bats have potentially serious ecological and economic consequences. Bats are primary predators of vast numbers of insects that fly at night, and many such insects rank among North America's most costly agricultural and forest pests. These include cucumber, potato, and snout beetles; corn-borer, corn earworm, cutworm, and grain moths; leafhoppers; and mosquitoes. A single little brown bat can catch more than 1,200 mosquito-sized insects in an hour, and the 25 million Mexican free-tailed bats (*Tadarida brasiliensis*) that formerly occupied Eagle Creek Cave in Arizona consumed over 250 tons of insects nightly, the majority of which were agricultural pests.

A colony of Mexican free-tailed bats living in the old Orient Mine in Colorado consumes nearly two tons of insects nightly, largely moths. Just one of the many moths that such bats eat, the corn earworm moth, attacks a wide variety of crops, from corn and cotton to tomatoes and pumpkins. Since each female moth is capable of laying hundreds of eggs, as few as 100 can force a farmer to spray a large area of crop lands.

Illustrative of the impact that even small colonies of bats can have, just 150 big brown bats can eat sufficient cucumber beetles each summer to protect farmers from 33 million of these beetles' root worm larvae, pests that cost American farmers an estimated billion dollars annually.

Long-nosed (*Leptonycteris curasoae* and *L. nivalis*) and long-tongued bats (*Choeronycteris mexicana*) are believed to be important pollinators for some 60 species of agave plants and to serve as both pollinators and seed dispersers for dozens of species of columnar cacti, including organ pipe and saguaro, which rank among the southwestern desert's most familiar and ecologically important plants. Loss of these bats could further jeopardize these already declining plants, harming an entire ecosystem.

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Mexican free-tailed bats rank among North America's most valuable wildlife, consuming enormous quantities of insect pests each summer night.

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Bats are primary pollinators and seed dispersers for many of the most ecologically important plants of the desert Southwest. This lesser long-nosed bat is about to pollinate a saguaro cactus.

How and When Bats Use Mines

Mines are key sites for rearing young in summer, for hibernating in winter, and for use as temporary havens. They also can serve as crucial migratory rest stops during spring or fall. Loss of these migratory stopover sites can have serious consequences for an entire population. Old mines are often the only suitable shelters left midway between a bat's summer and winter roosts; without these protected resting places, species' migratory mortality could greatly increase.

Bats also use mines as temporary night roosts, where they can retire to digest an evening meal in safety. Select mines are also frequently used for courtship and mating. Bats need mines for all these reasons, but for many species the most important contribution mines make to their survival is as essential sites in which they can raise their young or hibernate.

Be it a mine or natural cave, the microclimate of a site, especially the temperature, determines if and when bats use it. Roosting habits of different species—whether they tend to gather in small groups or in dense clusters covering thousands of square feet of walls—largely determine the kinds of roosts they can occupy.

Large colonies can share the energy cost of heating a site to the high temperature required for rearing young, and so can tolerate much lower ambient temperatures. Only four U.S. bat species are known to form nursery colonies of many thousands of individuals, and all live primarily in southern areas. Because of their large colony sizes, such species can sometimes raise young in mines with ambient temperatures as low as 56°F, though they prefer temperatures of 66°F or more. Colonies of gray bats (*Myotis grisescens*) and cave myotis sometimes include 100,000 or more individuals. Gray bats were declared endangered in 1976, and the cave myotis is a species of concern. The endangered lesser long-nosed bat also forms colonies of 10,000 or more individuals in mines. In the Southwest, Mexican free-tailed bats form colonies numbering in the millions, and are the largest aggregations of mammals known. However, even these bats have declined to less than one percent of former numbers in several areas where they once were the most abundant species. As colonies become smaller, their ability to share the cost of heating relatively cool roosts diminishes. They are thus forced to choose warmer roosts, decreasing the number of suitable roost sites available to them.

These little brown bats are hibernating in an abandoned Michigan mine. A single site may attract hundreds of thousands of bats from a multistate area each winter.

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Baby Mexican free-tailed bats cluster at densities of up to 500 per square foot. Colonies of up to 100,000 or more may live in a single mine. Because the species concentrates in large numbers in relatively few places, it is extremely vulnerable and has declined alarmingly over the past 30 years.

Bats that roost in smaller groups typically require roost temperatures between 70° and 90°F to raise young successfully. Big-eared bats are an apparent exception. Their nursery roosts have sometimes been recorded in sites where ambient temperatures are as low as 60°F.

The California leaf-nosed bat (*Macrotus californicus*), a species of concern, is incapable of hibernation and does not migrate. It typically selects temperatures close to 90°F in summer and 72° to 80°F in winter, often in mines warmed by geothermal heat. Most colonies of leaf-nosed bats in the United States now live only in mines. Long-nosed bats and most Mexican free-tailed bats that use U.S. mines in summer migrate south to Mexico for the winter.

Nearly half of U.S. bat species live in regions where mines provide suitable temperatures for both summer and winter use (see Table 1, page 28). These bats can sometimes find appropriate temperatures from season to season by moving to different parts of a single mine. As with caves, the configurations of some mines trap air of varied temperatures, and bats can move between areas that provide warm or cold air, depending on their physiological requirements. They may also temporarily move to other mines or caves that provide appropriate seasonal temperatures.

Suitable hibernation sites in all regions must protect bats from freezing and, for most species, should provide temperatures between 40° and 50°F for most of the winter. Big brown bats can survive subfreezing body temperatures, and several bats, including big-eared bats, pipistrelles (*Pipistrellus subflavus* and *P. hesperus*), and a few myotis bats, sometimes hibernate at temperatures between 32° and 40°F. Mines that provide a range of temperatures between 32° and 50°F are not common, and bats often must travel hundreds of miles to reach them. A few bats, especially southeastern and Pacific big-eared bats (*Corynorhinus townsendii townsendii*), are exceptional. They may feed during mild winter weather, enabling them to hibernate for shorter periods of time in locations that are not stable enough for other bats, often at temperatures ranging between 50° and 60° F. This also appears to be true for several other bats in mild coastal areas of the West. The needs of many western species are still poorly known.

Approximately one quarter of U.S. bat species are believed to hibernate almost exclusively in old mines or caves. These bats typically must find roosts where temperatures do not exceed 53°F at the time they enter hibernation between September and November, and that average between 34° and 50°F by midwinter, although a few species can tolerate temperatures as low as 27°F. The greater the range of temperature provided in a single cave or mine, the easier it is for bats to find appropriate temperatures by changing roosts within the site during exceptionally warm or cold winters. In the northern United States and in Canada, species such as the little brown bat and eastern pipistrelle thrive in mines where temperatures often vary only one or two degrees annually, remaining stable between 40° and 50°F.

How Mine Structure, Location, and Human Disturbance Affect Bat Use

Knowledge of seasonal roosting requirements and an understanding of the typical configurations of underground mines is helpful in evaluating them as potential bat habitat. Table 1 (page 28) lists species known to have the greatest reliance on mines as nursery or hibernation sites, and indicates the species' approximate geographical distributions, the kind and timing of mine use, and their current conservation status. Some western species may depend on mines more than is yet documented. Figure 1 is a diagram of an abandoned mine, showing the typical configurations and terminology associated with underground mine workings.

Airflow and temperature are key determinants of how, when, and where bats will use mines. Internal mine temperatures typically approximate the mean annual surface temperature unless the mine's configuration and/or multiple entrances set up chimney-effect airflow patterns or geothermal heating occurs. Thus knowledge of an area's mean annual surface temperature, combined with information on a mine's approximate volume, configuration, elevation, and number and location of connected surface entrances, can help greatly in predicting seasonal bat use patterns. These factors will suggest where, and in which season, bats are most likely to be present. However, it may be difficult or impossible to predict some internal mine configurations from observing only surface workings, and in rare cases internal temperatures can be altered at sites where there is geothermal heating. The following discussion of temperature, airflow, and mine ventilation is provided to help explain how such factors affect bat occupancy.

Temperature

Mines with internal temperatures as low as 55°F are rarely used as summer nursery sites. They are simply too cold. Consequently, bats rarely raise young in mines located at high elevations or in the northern United States or Canada. Exceptions occur in areas of the Northwest where warm climates extend northward or where extraordinarily effective heat traps or geothermal activity exists.

Many northern or high-elevation mines are, however, ideally suited for bat hibernation in winter, because they provide stable, year-round temperatures in the 40° to 50°F range. Some of these harbor North America's largest remaining populations of bats. A few mines may be unacceptable due to radioactivity, flooding, geothermal heat, or toxic gas.

The farther south, or the lower the elevation, the less likely a mine is to provide temperatures suitable for winter use and the more likely it is to be warm enough for summer use, especially by nursery colonies. In areas where internal mine temperatures are predominantly in the 50s, a high proportion may be too warm for winter use and too cool for summer use. Exceptions occur when "chimney effects," created by multiple entrances at different elevations, allow warm air to enter and become trapped in stopes or raises near entrances or when cold air is trapped in the lower sections of a mine. Nursery colonies of southeastern big-eared bats are often found in warm-air traps near the entrances of mines whose temperatures would otherwise be too cool.

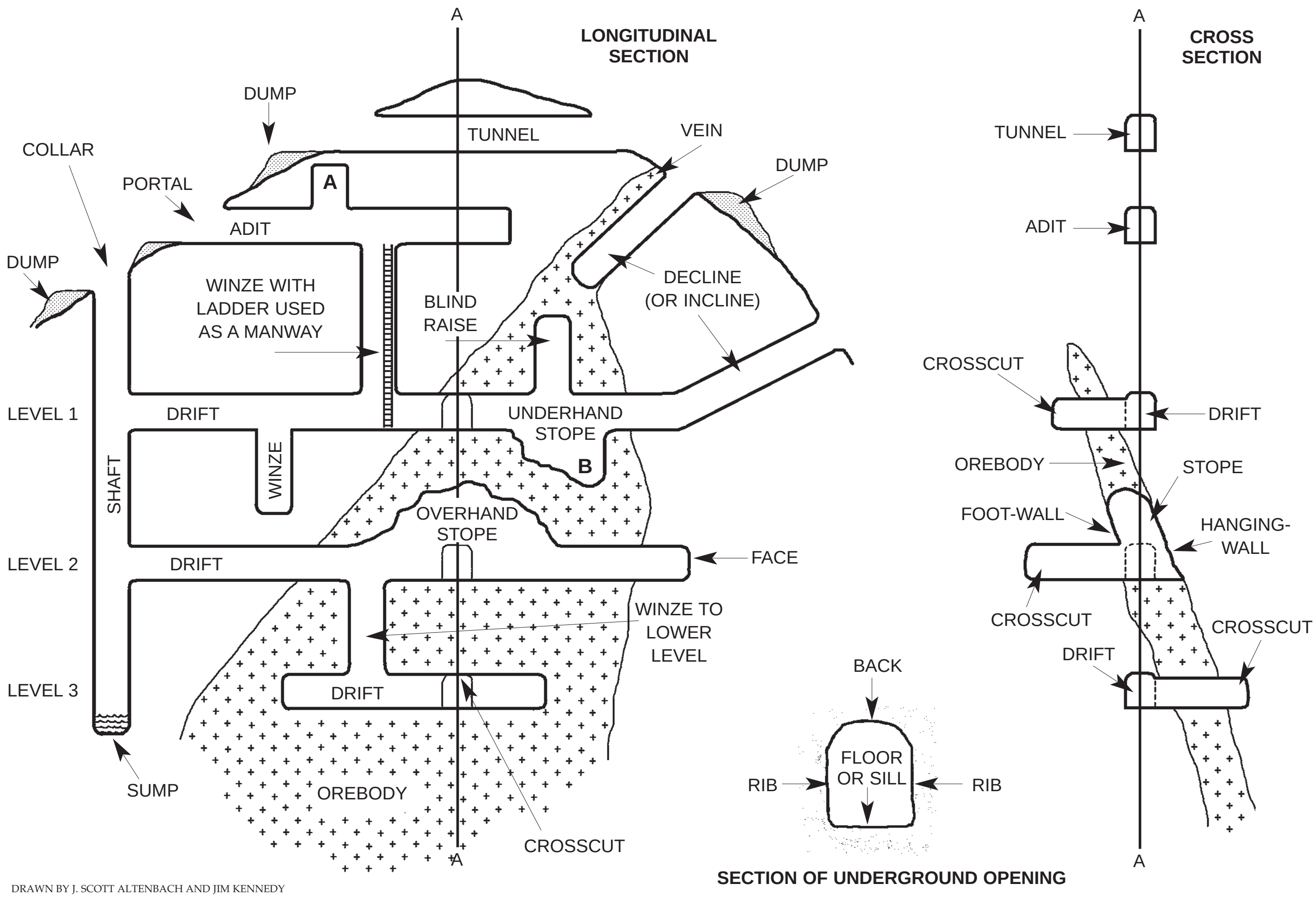
At lower elevations in southern areas, many mines will be warm enough to support bat nursery colonies. However, species that form nursery colonies of hundreds of individuals or less, often must find exceptionally warm areas, even in southern mines. These may be in stopes or raises, especially near entrances through which warm air from outside enters and is trapped.

Where mean annual surface temperatures range between 50° and 60°F, knowledge of cold- or warm-air trap configurations can be especially important. For example, Missouri's Pilot Knob Mine, located in such an area, is critical habitat for an estimated 100,000 endangered Indiana bats. The size and internal contours of this mine allow entrapment of cold air, permitting deviation (at least in some parts of the mine) markedly below the mean annual surface temperature.

Where average surface temperatures range between 40° and 50°F, virtually any mine deep enough to prevent freezing is potentially important as a hibernation site, although the largest and most complex mines are likely to be the most suitable. Some mines in these regions may contain millions of bats and serve as vital refugia for bats from multistate areas. Only a few losses of these critical mines could endanger an entire species.

Mines where average surface temperatures exceed 70°F typically are used only in summer, though some mines in western desert areas are exceptional due to extreme daily and seasonal fluctuations in surface temperatures. Also, both hibernation and nursery sites are used to varying degrees in spring and fall,

Figure 1. Typical mine features and terminology. In this example, the highest and lowest temperature air would be trapped at locations A and B respectively.



Mining Terminology

Adit — A horizontal mine passage driven from the surface.

Back — The ceiling of an underground passage.

Blind — Without lateral workings.

Collar — The entrance to a shaft.

Crosscut — A horizontal underground mine passage driven to intersect an orebody.

Decline — A mine passage driven up or down along the orebody (also called incline).

Drift — A horizontal underground mine passage following an orebody.

Dump — Waste rock removed from a mine.

Face — The termination of an adit or drift.

Foot-wall — The rock below an orebody.

Hanging-wall — The rock above an orebody.

Levels — Drifts at different elevations.

Orebody — A mineral deposit that is being mined for its metals.

Portal — The entrance to an adit or tunnel.

Raise — A mine opening driven upward from inside to connect upper levels or explore areas above a level.

Rib — The side of an underground passage.

Shaft — A vertical mine opening from the surface.

Stope — An underground cavity made by the removal of ore above (overhand) or below (underhand) a drift.

Sump — The bottom of a shaft below all levels; used to collect water.

Tunnel — A horizontal mine passage that is open at both ends.

Vein — A definable linear zone of mineralized rock.

Winze — A mine opening sunk downward from inside to connect lower levels or explore areas beneath a level.

and some warm mines may be used year-round by bats in mild coastal or desert climates of the West.

In general, mines with the largest internal volume and more than one entrance are the most likely to be important for bats, especially when entrances are at even slightly different elevations. However, even a mine with a single entrance can be extremely important, especially if it is located in an area of extra warm or cold climate or is geothermally heated.

Airflow

Airflow rates in mines are typically determined by the difference between external and internal air temperatures due to seasonal or daily weather changes, combined with mine configurations that create, enhance, or restrict airflow. Without airflow from the outside, or geothermal heating, mine temperatures rarely deviate from an area's mean annual surface temperature. The fact that hot air rises and cold air sinks is the driving force behind internal mine temperature deviations above or below mean annual surface temperatures. Other factors, such as the greater weight of moisture-laden air or the pressure created by winds blowing into mine entrances, also can affect airflow in and out of mines, but their impact is typically minor compared to that of temperature. Thus, only temperature will be considered in the following discussion.

Figure 2 provides four examples of how the interior configuration of a mine can affect seasonal airflow and bat roost site choices. Example 1 illustrates a mine configuration that creates a strong "chimney effect," combined with an excellent cold air trap. Little airflow occurs here in summer when external temperatures are above the mean annual surface temperature, allowing relatively cool, heavy air to remain trapped inside. However, as colder air arrives in fall, it sinks inside (A) and warmer air escapes (B), creating a potential hibernating site. Each time the external temperature falls below that of the mine's walls (which approximate the mean annual surface temperature) more cold air is trapped and stored, while warmer air rises and exits. Even when mine entrances are thousands of feet apart, "chimney effects" typically occur if entrances exist at different surface elevations. If there is sufficient volume for cold-air storage below the lowest entrance, the average temperature in the lowest levels may remain 10°F or more below the mean surface temperature. Thus, even though a mine with these configurations may be located at elevations or in mid-latitudes where the mean annual surface temperature averages in the 50s, such a site could still provide the cooler temperatures necessary for bat hibernation. In northern latitudes or at high elevations, such mines might be too cold for bats without reduction of airflow at one of the entrances.

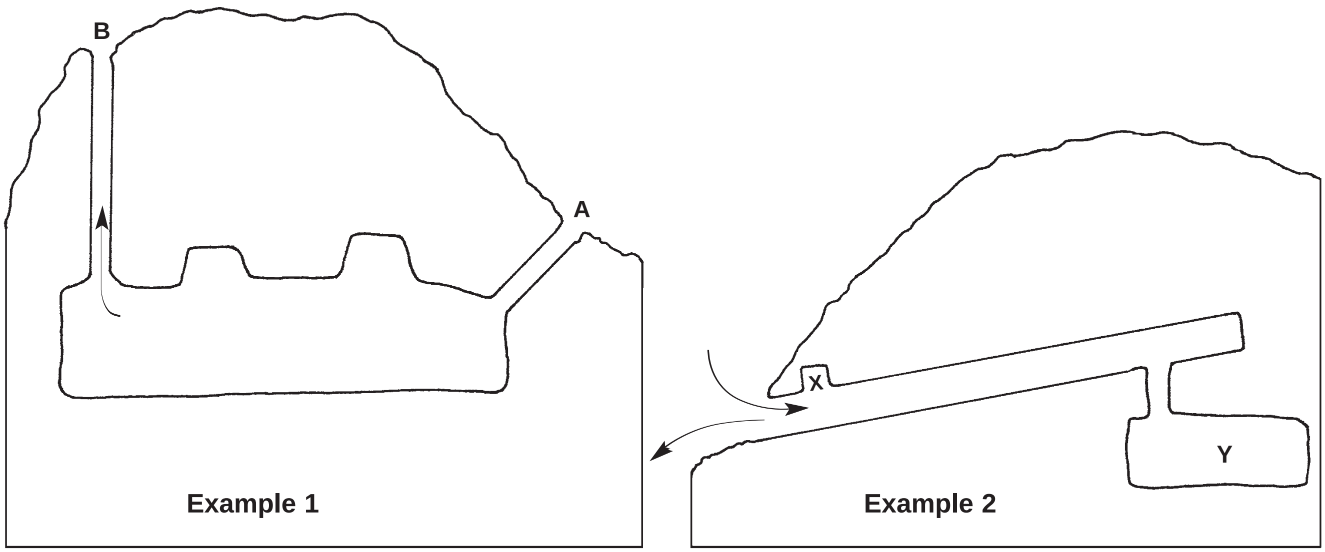
Air circulates in the adit illustrated in Example 2 only when outside air temperatures rise above the mean annual surface temperature, typically in summer. Cool air flows out the lower part of the mine entrance, allowing warm air to enter along its ceiling. If a raise or stope exists above and near the entrance (X), it might trap enough warm air to be used as a bat nursery site, even in an area where temperatures would normally be too low. Entrance and passage diameter have a major impact on how much warm air can enter. The temperature of the lower chamber (Y) remains nearly constant year-round, because it is difficult for the light summer air or the heavy winter air to reach it.

Since this lower chamber always remains at approximately the mean annual surface temperature, the site cannot be used for hibernation in a region where the mean annual temperature averages above the bats' mid-winter temperature needs (usually in the 40s or low 50s, lower for some species). If the mine were located where the mean surface temperature is between 40° and 50°F, however, this chamber might be ideal for hibernation. Due to its shape, it would never be in danger of freezing, since cold air from outside could not move upward to reach it, even during an unusually cold winter.

Example 3 illustrates a restriction near the entrance that blocks most of the airflow year-round. In lowland mid-latitude locations, where mean annual surface temperatures are mostly between 51° and 56°F, such a mine probably would not meet the nursery or hibernation needs of most bats. As one moves south into areas where surface temperatures average closer to 60°F or above, more and more such sites will be used by nursery colonies large enough to share heating of the dome-shaped stoped area (B). In warm-enough locations, even small nursery colonies might find such a site ideal. Conversely, if this site were located in the north, where average surface temperatures would be below 50°F, it could be used for hibernation.

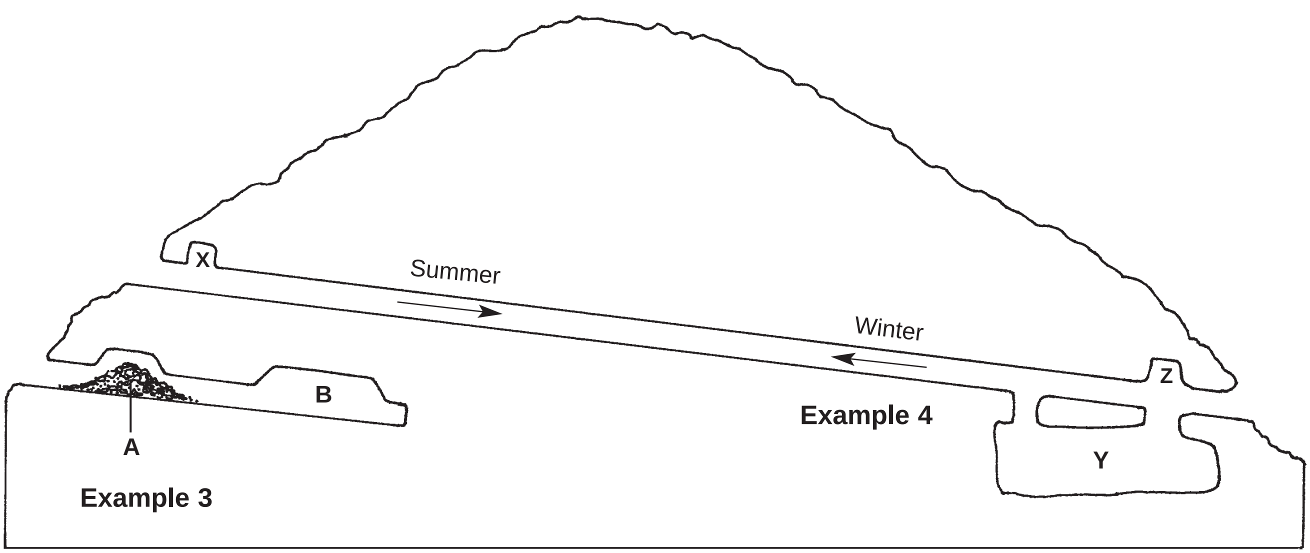
The fourth example illustrates a configuration that permits bats to change their roost sites seasonally within the same mine. In such a mine, airflow directions would reverse between summer and winter. In winter, upward movement of a large volume of relatively warm air creates sufficient suction to draw cold air up hill. In mid-latitudes or at elevations where the mean surface temperature is in the mid-50s, the stoped area (Z) would be unacceptable to most bats year-round. However, cavity (X) might trap enough warm air to permit use by a nursery colony, and loca-

Figure 2. Seasonal airflow and the locations of cold- and warm-air traps play a key role in determining how, when, and where bats use mines.



Example 1 illustrates any mine situation where adits, raises, winzes, or stopes are located below the lowest entrance and are connected to one or more additional entrances located even a few feet above the lowest one. This sets up chimney-effect airflow, as indicated. The strongest flow occurs on the coldest winter days. The larger the volume of chambers below the lowest entrance, the more effective the cold-air trapping.

Airflow in **Example 2** is strongest when the adit is tall and extensive and at times when the outside temperature is highest.



Example 3 illustrates how cold- or warm-air “dams” can restrict airflow. The temperature in this sample mine will approximate the mean annual surface temperature for the same reason that location Y in Example 2 does.

Example 4 is similar to Example 1, except for drawing cold air uphill and for illustrating how greater complexity enhances a site for bats. Because it provides extensive tunneling, in addition to both warm- and cold-air traps, it will have strong airflow through both upper and lower portals whenever the outside temperature deviates far above or below the area’s mean annual surface temperature.

tion (Y) might trap enough cold air to permit hibernation. Larger spaces trap more warm or cold air and therefore provide the most reliable conditions for bat use.

Predation

Entrance and passage size also affect a bat's vulnerability to predators. Species that form nursery colonies of fewer than 1,000 individuals sometimes use entrances less than three feet in diameter or roost on ceilings less than eight feet above floors. However, only mines with larger entrances and high-roofed passages are suitable for species that form nursery colonies numbering in the tens of thousands of individuals.

Bats tend to be more tolerant of varied entrance and roost dimensions in hibernation sites. Colonies numbering more than 1,000 bats rarely overwinter in places with ceilings less than six feet high unless otherwise protected from predators by deep pits, shafts, or other obstacles. Small groups, or scattered individuals, may roost within three feet of the floor, simply relying on not being discovered. Such bats may also tolerate entrances as small as two feet or less in diameter. Since bats about to enter hibernation often arrive and exit a few at a time, they have fewer problems with predators. Entrance size is therefore not as critical a factor as it is in choosing a summer site.

Proximity to food and water

A major consideration in bat choice of summer roosts is their proximity to feeding habitat and water. Distances to drinking or feeding sites can be severely limiting factors for nursery colonies of insectivorous bats. Most species prefer sites located less than a half mile from water and feeding habitat. However, fast, long-distance flyers, like Mexican free-tailed bats, can live much farther from key resources, and long-nosed and California leaf-nosed bats may not require water at all. Long-nosed bats typically live within 40 miles of the nearest agave, saguaro, or organ pipe cactus plants, on which they feed. California leaf-nosed bats normally roost within five miles from their feeding habitat over desert-wash vegetation.

Human disturbance

Mines that humans can easily enter may be ideal for bats, but may lack bats due to high levels of disturbance. Human exploration of abandoned mines is increasing, both for recreation and extraction of minerals and historic mine artifacts. To avoid disturbance, many of the most important bat hibernation populations now live in mines that are especially dangerous for humans to enter. By using these sites, bats avoid potentially lethal disturbances that exhaust their limited fat supplies before spring. One of North America's largest remaining hibernating populations of endangered Indiana bats is in a mine that is too dangerous to be entered by people. An estimated million little brown bats were discovered hibernating in a mine with a nearly vertical entrance 300 feet deep. In either case, bats are difficult to detect except as they enter and exit in fall and spring. Bat biologists can be alerted to the potential importance of a site too dangerous to enter, or which currently has no bats due to human disturbance, based on knowledge of mean annual surface temperatures, combined with information on mine entrance types and locations.

Summary

Understanding how mean annual surface temperature, "chimney-effects," and thermal traps affect mine temperatures can greatly enhance the probability of identifying mines or locations inside mines that will be most important to bats. Assessments of predator pressures on the bats and whether the surrounding area meets foraging requirements, especially for a summer-use site, are additional factors to consider. Such knowledge also can be used to identify ideal sites where bats would live if protected from human disturbance. *In some cases protecting a mine where no bats now live can do much more good for the conservation of bats than protecting one nearby where bats are barely surviving marginal conditions in order to avoid human disturbance*. Knowing bat roost needs may also indicate the season in which a mine should be checked for bats and certainly is helpful when dealing with sites that are too dangerous to enter.

Assessing Mines for Bats

THERE ARE TWO PRIMARY TECHNIQUES for surveying mines for bats: internal and external surveys. As implied, internal surveys involve a thorough search of a mine's interior for bats or bat sign, while external surveys involve observing or capturing bats from outside a mine entrance as they exit or enter. For both methods, it is critical that surveys be conducted at the proper time of year, since the types of use and seasons of use differ widely. While an internal mine survey is generally the more thorough and accurate method for determining bat use, it is also more hazardous and requires the most training and experience.

The exploration of abandoned underground mines may be regulated in some states by the federal Office of Safety and Health Administration (OSHA), Mine Safety and Health Administration (MSHA), or the state mine inspector's office. Appropriate authorities in each state or region should be contacted before conducting or contracting for underground abandoned mine surveys. Underground surveys should not be attempted without appropriate training and experience. Human and financial resources, and the level of expertise available to natural resource managers, will likely play a major role in determining the method of survey used.

When time permits, an external presurvey of abandoned mine sites should first be conducted to determine if mines have potential as bat roosts. An initial site visit, and knowledge of how mine environments determine bat use, will help determine if additional surveys are necessary and if so, how and when surveys should be conducted. Sample survey forms are provided on pages 47 through 50.

External presurveys

Safety training is recommended even for those conducting external mine surveys. There are several safety issues to be aware of when conducting external surveys. Mine openings are often the most dangerous part of an old mine. The rock around entrances is often weakened by weathering and fractured from explosives. Care should be taken to approach the edges of shafts and other vertical openings with great caution, as edges can break away unexpectedly.

An internal survey of a mine is the most thorough and accurate method of determining whether bats use a site and in which season they are present. This method, however, requires training and experience.

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Furthermore, sudden collapse and falling rocks represent potential hazards even at horizontal openings.

Presurveys can be conducted anytime the site is accessible, but should be planned well before scheduling of mine closures, providing adequate time if additional internal or external surveys are warranted. Information to be collected during presurveys should include: (1) number, dimension, location, and description of all entrances; (2) airflow direction, if any, through entrances; (3) outside air temperature; (4) the presence of any restrictions at or near entrances (vegetation, old timbers, trash, loose piles of rock, etc.); (5) the presence of standing water or evidence of prior flooding; (6) internal features that can be safely determined from outside, such as depth, side passages, ventilation shafts; and (7) visual signs of bats, such as droppings, roosting bats, carcasses, or piles of insect parts.

The information from the presurvey should then be evaluated by a person experienced in working with bats and mines. If all mine entrances are completely blocked by debris, rock, soil, or dense vegetation, the site is unlikely to be used by bats. *However, in some cases, especially where mine or cave habitat may be limited, these sites could be further evaluated for their potential value as habitat if the entrances were to be cleared and secured*. If the mine is shallow (generally less than 50 feet for adits and shafts) and all sides are visible when viewed from outside, confirming there are no drifts, internal shafts, etc., it probably has low potential as a roost site. Mine adits flooded to the ceiling or within a foot of the ceiling, or vertical shafts that fill with water can also be eliminated, unless there is a drift above the waterline. If there is a possibility of bat use, a more detailed evaluation should be considered.

Mines that can be entered

An internal survey is often the quickest and least time-intensive survey method. Winter surveys typically can detect summer use, since guano piles from active bats remain visible. However, summer surveys cannot detect winter use, since hibernating bats leave very little guano. Paying close attention to airflow patterns and a mine's temperature can save much time by focusing searches for bats in places where they are most likely to be during the season of inspection.

Abandoned mines can be dangerous, with cave-ins and falling rock, rattlesnakes, deadly gases, oxygen deficiency, hidden shafts, and old explosives all posing potentially serious threats to human safety. Thus, internal mine surveys should be conducted only by individuals trained in bat biology and mine safety. As an additional safety precaution, a minimum of two people should participate in all surveys. For information on mine safety and training, contact the state mine inspector's office.

When internal surveys fail to reach all potential areas where bats might live, they should be backed up by entrance observations made in the appropriate seasons (see "Mines that cannot be entered"). Since bats usually emerge nightly to feed, warm-season surveys do not typically require mine entry to detect bat use. Furthermore, entrance observations avoid the risk of disturbing nursery colonies, which can cause loss of young.

When conducting warm-season internal surveys, listen for the sounds of bat squeaks and chatter, and when approaching a roost area, move quietly along a wall, staying as low as possible. Make counts and collect data as quickly as possible, reducing talking and other sounds to a minimum. Speak softly in low tones if talking is necessary. A red light may help, but if clustered bats begin to take flight, immediately back away. Do not attempt to capture active bats at their roost. Identification and reproductive status can be checked through trapping or netting at entrances.

Most non-hibernating bat colonies deposit piles of droppings beneath their roosts. These are easily observed in any season, though they can be missed in complex mines. The droppings of insectivorous bat species are simple to distinguish from those of rodents. Bat guano is easily crushed and is composed mostly of shiny bits of insect exoskeleton. By comparison, rodent fecal pellets are usually hard to crush and are composed mostly of plant matter. Furthermore, bat droppings are typically deposited near the middle of passages where ceilings are highest and where the bats have stained the rock surfaces. In contrast, rodent droppings are more likely to be concentrated along walls or in low places too small for bats to use. With experience, some species identification of insectivorous bats is possible from the size, color, odor, inclusion of insect parts (such as wings, carapace, or legs), and deposit pattern of the guano. Nectar-feeding long-nosed and long-tongued bats may produce formed droppings, but characteristically leave yellow or reddish "splat" marks on mine floors and walls, colored by pollen or cactus fruit.

Since even large numbers of hibernating bats often leave very few droppings or other evidence, internal surveys for hibernating bats must be conducted in the winter, preferably between December and February. Because mines with deep vertical shafts often provide the best cold air traps and protection from disturbance by humans and predators, these can be especially important resources for hibernating bats.

Such sites may attract many thousands, or even millions, of bats from thousands of square miles around. Those too dangerous to enter require entrance sampling in late summer or early fall (see "Mines that cannot be entered").

It is extremely important to minimize disturbance when inspecting the interior of a bat hibernation site. Once in hibernation, each arousal forces a bat to burn from 10 to 60 days' worth of its limited fat, which must last until spring. Repeated arousal can easily kill bats. Visits into hibernation areas should be brief and never repeated more than once in the same winter.

Mines that cannot be entered

Many mines will be too dangerous for humans to enter. However, because these receive the least disturbance, they often shelter the largest bat populations. *In fact, some such mines are so predictably ideal for bats that they should be assumed crucial bat sites unless proven otherwise*.

Entrance observations, made between mid-June and early August, are often the best method for verifying summer use of mines. Since bats usually emerge each night to feed, determining their presence at dusk is reasonably simple. Surveys should be conducted for at least two hours after dark, beginning at sundown on nights that are free of rain and excessive wind or low temperatures. Observers should be ready at least 30 minutes before sunset and should keep noise to a minimum. Noise may alter or inhibit emergence behavior.

Observers should be seated at least 15 feet away to one side of the entrance, ideally positioned so that emerging bats are silhouetted against the evening sky. All entrances associated with the mine (if known) should be surveyed at the same time, if possible. A night-vision device with an infra-red light source will provide the most accurate observations, but if unavailable, a dim red light (aimed across, not into, the entrance) can be used to assess the approximate

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In mines that cannot be entered, external surveys at appropriate times of year can determine whether bats are using the site and may also aid in assessing the approximate population size. A bat trap placed over the entrance is a reliable method.

colony size. Flights of even relatively small colonies typically can be detected by an observer positioned low enough to both listen and watch the skyline. Even after dark, listening for wingbeat sounds of emerging bats normally can aid in assessment. An ultrasonic bat detector may be used to help detect emerging bats. Night-vision devices are especially helpful for detecting some bats, such as big-eared bats, which are difficult to hear on a bat detector and which may exit after dark and at slow rates.

The best time to check mines for winter use is usually when bats begin arriving to inspect a site for hibernation. This is typically in August and September in the eastern and northern United States or Canada, extending into October in the Southeast. In warmer southwestern areas, arrivals are more likely to peak in October or November. Spring emergence also can be observed, but is less reliable, since activity then is often less predictable or detectable. Entrance observations at potential hibernation sites are best made between a half hour after sunset and midnight. Bats entering a hibernation site may arrive all night long each night for a month or more. Within that period, arrival rates vary considerably, but a flow of even a few dozen bats per hour on a given night could suggest a hibernating population of thousands or more. Sometimes, large groups of bats arrive together within just a few minutes.

Bats at many important hibernating sites exhibit “swarming” behavior, which is believed to be related to breeding and selection of hibernation sites. Swarming consists of many bats flying in and out and around the entrance of a mine or cave, with peak activity occurring between two to three hours after sunset. In the eastern United States, north into Canada, this behavior is intense in August and September and is easily used to detect hibernation sites. Such behavior sometimes occurs in the West, but can be more difficult to detect since greater numbers of mines are used for hibernation and are occupied by smaller numbers of bats. Swarming activities in the West, therefore, may be missed during early winter surveys.

Bat traps or mist nets can be used to capture and identify bats at mine entrances. Persons conducting capture surveys must have appropriate state and federal permits and have previous experience handling bats or be accompanied by someone who does. Although bats bite only in self-defense if handled, people who plan to handle bats should receive rabies pre-exposure vaccine, now relatively painless and highly effective.

A bat trap is effective in checking horizontal mine entrances for emerging or arriving bats. These traps, weighing as little as five pounds, can be made with capture areas as small as four feet high and three feet wide. If a mine entrance is considerably larger than the area covered by the trap, inexpensive cloth, plastic, or netting can be used to block alternate access. Removing bats with gloved hands is quick and efficient. Traps can rapidly capture hundreds of bats without entangling them, but they must never be left unattended, since traps can quickly fill with bats that may then suffocate. Also, traps containing bats readily attract predators.

Mist nets also can be used to capture bats and may be useful in checking difficult-to-reach locations. The disadvantage is that each bat must be individually disentangled from the net, which is time consuming and requires experience. Never set a net across an unfamiliar mine entrance before first observing the level of bat activity. A net over a busy entrance will quickly catch more bats than can be removed effectively, destroying the net and needlessly injuring severely tangled bats.

Neither nets nor traps should be used over vertical shafts. However, by observing the flight paths of emerging bats, they may be set effectively nearby. For some such sites, combined use of bat detectors and dim red lights or night-vision devices may be required. Since western big-eared bats are often active periodically throughout the winter, electronic counting devices may be helpful in documenting their use at sites that cannot be entered by people.

Protection of Bats in Mines

Bats that live in mines face three primary human threats: closure of mine entrances for reclamation or safety reasons, human disturbance due to recreational entry, and loss of old mines and surrounding habitat if mining is renewed. Since mines are now essential habitats for many of America's most important remaining bat populations, they always should be assessed for bat use prior to any of these activities.

Reclamation and safety closures

If a biological survey reveals bat use of a mine, there are alternatives to total closure that provide for public safety and allow bats to continue using the site. Often the most effective solution is a steel gate placed over or across the entrance, which can include a small, lockable door or removable horizontal cross member for official access. Many bat species respond well to such structures. Bat gates must meet the land manager's objective of protecting the public from a hazardous situation, while ensuring safe access to bats. In areas where favorable roost temperatures require cold or warm-air traps (see "How Mine Structure, Location, and Human Disturbance Affect Bat Use"), it is essential that gates not obstruct normal airflow through entrances. Proper design and placement is extremely important; bat colonies have often been driven from a site because of an inappropriate gate.

Modern gate designs are both difficult for vandals to breach and often less costly than traditional closure methods, such as capping mines with concrete or bulldozing entrances shut. A primary purpose of a gate is obviously to keep unauthorized visitors out. This requirement results in further limitations on the type of materials used, as well as the spacing of horizontal and vertical members of the gate. The *minimum* distance between vertical gate supports should be 24 inches (anything less may restrict bat movement). The ideal spacing for vertical gate supports is between 4 and 10 feet, depending upon the design and strength of material used.

The widest vertical and horizontal spacings are always preferred by bats, but in no case should human safety be compromised. Horizontal members should normally be spaced no less than 5 3/4 inches apart. Near heavily populated areas or recreation sites where small

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Siebert Cowley (Unimin Corp.), Ray Smith (US Forest Service), and Sheryl Ducummon (Bat Conservation International) demonstrate the removable bar on this angle-iron gate at Unimin Corporation's Magazine Mine, an abandoned silica mine on the Shawnee National Forest in Southern Illinois. The gate protects humans as well as a growing population of endangered Indiana bats. This design has proven highly successful and difficult to breach.

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This protective cage at the Neda Mine in Dodge County, Wisconsin, ensures human safety while also protecting one of North America's largest hibernating bat populations. It cost less than alternative methods of closure and was built through collaboration of the Wisconsin Department of Natural Resources, the University of Wisconsin at Milwaukee, and the Friends of the Neda Mine—a private group led by Bat Conservation International Chairman Emeritus Verne (pictured) and Marion Read.

children might attempt to gain entry, expanded metal grating can be used on the bottom third of the gate, or the spacing of the horizontal members on the bottom third can be reduced slightly. Spacing horizontal gate members less than 5 $^{3}/_{4}$ inches apart can severely restrict bat movement, while distances greater than 5 $^{3}/_{4}$ inches may permit small children to squeeze through.

Gates constructed of 4 x 4 x $^{3}/_{8}$-inch angle iron, reinforced by stiffeners (see Appendix III, Design A, for plans), have been successfully used to protect bats in caves and mines throughout North America. This design is extremely strong; hundreds of these gates have been installed thus far, and very few have been breached. When located properly, the gate has minimal effect upon airflow because of the orientation of the angle iron.

Gates should not constrict mine openings more than absolutely necessary, especially along floors and ceilings. Whenever possible, construction should occur during the time of year when bats are not using a mine, in order to avoid disturbance. If construction must take place while bats are present, it should not occur within two hours of dusk or dawn. Furthermore, care must be taken so that welding fumes are not drawn into areas where bats are roosting.

Where either horizontal or vertical mine entrances are unstable, they often can be secured by use of galvanized or concrete sections of highway culvert. Vertical shafts further require specially designed cage-type gates, since horizontal gates over shaft entrances can easily become blocked by debris and also force bats to slow down or land, greatly increasing mortality from predation. All cage-type closures should be high and wide enough to provide adequate flight space (minimally 6 to 10 feet square) for bats to maneuver safely through the bars without being caught by predators. Cage-type closures have been used successfully at many sites across the country. Because cage-type gates and vertical shafts entail special bat and engineering considerations, individuals or agencies familiar with their construction, such as Bat Conservation International or the American Cave Conservation Association, should be consulted (see Appendix II).

A cage-type design was built over a vertical entrance at the Neda Mine in Dodge County, Wisconsin. The foundation was constructed of poured concrete reinforced with steel. The cage was constructed from 4 x 4 x $^{3}/_{8}$-inch steel angle iron, with a roof of expanded metal grating (see Appendix III, Design B, for plans). An expanded metal collar can be used at the base of cage closures to prevent small children from climbing up to the bars. A solid steel collar can be used in lieu of expanded metal where the entry of surface water is a concern, but should be avoided where cold-air trapping is especially important, as it may inhibit airflow.

When carefully installed to avoid alterations of roost temperatures, bat-friendly angle-iron gates have proven highly successful in ensuring both human and bat safety at numerous locations throughout North America. Available evidence suggests that all hibernating North American bat species will accept gates at overwintering sites. Big-eared bats have accepted gates at both hibernation and nursery sites and California leaf-nosed bats accept gates during all seasons. However, gates often are not suitable for protecting nursery colonies of more than 1,000 individuals of other bat species, and are not tolerated at all by some. Bat tolerance of gates is roughly proportional to gate size, larger gates allowing more bats to exit through a larger area with less risk of being caught by predators. Gray bat nursery colonies rarely tolerate gates, and this is probably due to the fact that they typically number in excess of 10,000 individuals. Small to medium-sized nursery colonies of several species of the genus *Myotis* have accepted gates. Gates are never acceptable to Mexican free-tailed bats, and little is known regarding gate tolerance of long-nosed or long-tongued bats, ghost-faced (*Mormoops megalophylla*), Allen's lappet-browed (*Idionycteris phyllotis*), or pallid bats (*Antrozous pallidus*).

Experimentation has shown that at nursery sites,

Galvanized highway culvert can be used to stabilize vertical mine entrances.

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This horizontal entrance was stabilized with a concrete culvert. Attachment of the gate to the inner end of a culvert reduced predation risk to the bats. The Homestake Mining Company in northern California reopened and gated this previously closed adit to provide an alternate home for a colony of western big-eared bats, which would otherwise have been displaced when mining was renewed nearby. The bats successfully moved into their new roost.

myotis bats may more readily tolerate gates located inside an entrance, beyond the twilight zone. Such positioning reduces the danger from visually orienting predators, but in some cases may not meet human safety needs or may make gate inspection and monitoring more difficult. This approach warrants further testing. When using culverts to stabilize entrances, gate attachment to the inner end of the culvert can also help bats avoid predation.

Other options exist for summer sites that cannot be protected by gates. Cyclone fences can be placed at least 12 feet back from an entrance to provide adequate space for bats to fly over, and half-gates have been used successfully in unusually large entrances, where sufficient space can be left for bats to fly over. Silent alarm systems can provide suitable backup.

Gates located in small entrances can greatly increase predation, especially where large nursery colonies are involved. They also are the most likely to restrict airflow, forcing bats to abandon even a protected mine if inside temperatures are raised or lowered beyond those they require (see "How Mine Structure, Location, and Human Disturbance Affect Bat Use"). When entrances are smaller than four feet in diameter, consideration should be given to use of cage-type designs that do not further restrict either airflow or the bats' space for negotiating the gate.

The largest nursery colonies attract the most predators which may be one reason they are least tolerant of gates. In these cases, fences or silent alarm systems may be the only option. All signs of access for gate or fence construction should be eliminated, or access blocked, so that additional human activity is not attracted.

It is impossible to predict how untested species will react to gates constructed at their roost sites. Therefore, it is essential that any gates used in unusual situations, or to protect untested species, be carefully monitored after they are installed. Consultation should be sought when questions arise (see Appendix II). At a minimum, the following steps should be taken before and after gate construction:

(1) If possible, estimate the number of emerging bats, and make observations of their emergence and return behavior before constructing a gate (include times that emergence begins and ends, location of flight paths through the entrance, and the amount of circling at the entrance).

(2) Repeat the preliminary observations immediately after construction is completed. Periodically repeat these observations through the first season of use, and once again a year later, to ensure that the bats are not suffering adverse effects from the gate.
(3) Utilize the information gained in the post-construction observations to modify future gate designs and correct any mistakes revealed during monitoring, if necessary.

All protective barriers require appropriate signage and periodic monitoring to ensure structural integrity. Signs should be clearly visible and attached to mine walls, not to gates, where they might obstruct airflow or bat movement and be accessible to vandals. Once a site is protected, no one should be allowed to enter during periods when bats are present, except to perform official surveys or for clearly justified research. Hibernation site surveys should not be repeated more than once every two to five years.

Federal, state, or private assistance is often available to help plan and fund gate construction or other protective measures at key sites that must be saved. Federal and state governments also can assist immeasurably through passage of legislation limiting owner liability. When mining companies or private-land owners are asked to cooperate in conservation-relevant activities involving inactive mines, every possible effort should be made to protect them from increased liability exposure.

Renewed mining

Contemporary mining operations usually occur in historic mining districts and can have major impact on bats, either positive or negative. New sampling methods, such as drilling, often detect ore deposits missed by previous miners and the ore is typically extracted with open-pit mining techniques. When this happens existing adits and shafts are often destroyed. Exploratory operations can have a major impact on bats due to disturbance from mine personnel entering bat roosts for ore samples or bulldozers burying historic mine openings during road construction for drilling equipment. Today, underground mining methods are seldom employed, except where high-quality ore is located deep beneath the surface.

In addition to roost destruction, other aspects of renewed mining can have adverse impact on bats, even bats not living in mines. Destruction of riparian vegetation and other foraging habitat can threaten the survival of bat species that rely on this habitat for feeding. Open cyanide leaching ponds, or other water in which toxic chemicals accumulate, can poison large numbers of bats. New roads may lead to increased recreational visitation, and nearby blasting associated with mine construction and operation can disturb roosting bats. When current mining operations cease, reclamation requirements and liability often require a company to close any remaining historic workings.

Mitigation for bats during mining or mine reclamation fall into two major categories: safe exclusion of bats from the mine, and the identification and protection of replacement roosting and foraging habitat. If a bat roost must be destroyed, this should be done during a season when bats are not present or only after exclusion of bats. Where large colonies of bats are at risk, a bat biologist with the necessary experience and equipment should be consulted. As already noted, many bats use mines only in certain seasons. If there is a maternity colony occupying a mine, then no closure should be made between late April and August. Closures should not be scheduled for the winter months at mines that may contain hibernating bats. If bats live in a mine year-round, then exclusion should occur in spring or fall to reduce harm, which would be most intense during summer nursery or winter hibernation use. Exclusions should not be attempted during severe weather, as bats may not emerge to forage or may die before finding alternate roosts.

Exclusion is best achieved by covering the mine entrance with one-inch chicken wire soon after most of the bats have exited to feed on a warm evening. Chicken wire can be molded to create a funnel shaped one-way escape door so that bats inside the mine detect a window, while those on the outside of the mine perceive a barrier. Bats still trapped inside can be allowed to escape by partially removing the chicken wire just before sundown on the following evening, then re-closing it after sundown once any remaining bats have left. One or two repetitions on warm evenings should successfully exclude most members of any summer colony. Other bat species may enter a mine to night roost before, during, and after the emergence of the resident bat colony. In these cases the creation of funnels as one-way escape valves in the chicken wire closure is especially important. If a mine contains multiple entrances that connect or could potentially connect, then all of the openings should be systematically closed as above. If the covered mine is not destroyed or permanently sealed within a few weeks of the bat exclusion, then chicken wire closures should be checked periodically to ensure that they are still effective.

It is sometimes possible to mitigate for the loss of evicted bats, either by protecting nearby mines or, in some cases, by reopening ones already closed. Abandoned mines within a radius of approximately five miles of the mine to be destroyed should be surveyed.

Mines housing the same species or with microclimates similar to the mine to be closed should be prioritized for protection. These should be protected by gates or fences prior to the eviction of bats from their current roosts. This was successfully accomplished by the Homestake Mining Company at its McLaughlin Mine in northern California. When a nursery colony of big-eared bats had to be evicted from a mine about to be destroyed by expansion of an open-pit mine, two nearby mines were reopened and gated. The bats were excluded from their original roost in spring and now live in one of the alternate sites where they are permanently protected. At the American Girl Mining Joint Venture in southern California, some of the newly mined underground areas were gated and left open to create new bat habitat when recent mining ceased.

The creation of artificial roosts

A new approach for mitigating the loss of underground bat habitat or enhancing habitat at active mining operations is the construction of artificial underground roosts that mimic habitat conditions found in mines and caves. Several mining companies have already constructed experimental roosts by burying surplus mining materials such as large diameter culvert or mine truck tires beneath waste rock.

The Homestake Mining Company used old mine truck tires configured to create four separate adit "arms" connecting to a central precast concrete bunker at their McLauglin Mine in Northern California. The entire structure was buried under waste rock, which was then re-contoured and planted with native vegetation. A concrete flange with a steel bat gate was inserted into two of the entrances. At Solutia's (formerly Monsanto Corporation) Enoch Valley Mine in Soda Springs, Idaho, two steel culverts measuring eight feet in diameter and forty feet long were modified, connected, and buried in such a way as to trap warm air in the upper culvert for summer use and cool stable air in the lower culvert for hibernation. As part of a bat conservation program to mitigate for the loss of underground mine bat habitat, Canyon Resource's Briggs gold mine constructed an artificial

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At Homestake Mining Company's McLaughlin Mine in California, surplus truck tires were buried beneath waste rock to create an innovative and cost-effective bat roost. If careful consideration is given to design and construction, artificial structures can provide important roosts for bats.

underground roost using surplus drums from cement mixing trucks buried beneath waste rock. Four drums were used, connected by an adit constructed of used mine truck tires. Environmental managers at Echo Bay Mineral's McCoy Mine in Nevada are constructing an artificial roost in a mine waste rock dump consisting of two rectangular metal bunkers connected by old mine truck tires, with an entrance on each side of the 200-foot-long structure at different elevations to promote airflow.

In order to be successful, artificial roosts must be designed to create an internal roost microclimate that meets the life history needs of the target bat species. First, information must be obtained on which species are likely to be present in the vicinity and how and when these species use underground roosts. Next, the artificial roost structure must be designed with an understanding of how airflow, mean annual surface temperatures, and seasonal and daily climate patterns will affect the internal climate conditions of the completed roost. Special consideration must also be given to factors such as ensuring that places within the structure where the bats will roost are not accessible to predators. They must also have a rough nonmetallic surface for the bats to hang on (see "How Mine Structure, Location, and Human Disturbance Affect Bat Use"). When possible, the actual site where the artificial roost will be located should be safe from flooding and be as near as possible to water and foraging habitat. While bats needs are often predictable, it is highly recommended that companies attempting to create new or alternate habitat should seek expert advice.

In summary, bats are a key natural resource, which now rely heavily on old abandoned mines for their survival. Installing a bat gate that protects both humans and bats often costs less than traditional mine-closure methods. By checking mines for bats prior to closure we can avoid unnecessary and costly endangered species problems and contribute greatly to ecosystem health. Artificial bat roosts show great promise for economically creating or enhancing bat habitat where it has been destroyed.

Table 1. Species List of Bats that Use Mines

Species	Group Size	Range	Use Time	Status
Ghost-faced bat *Mormoops megalophylla*	Dozens to hundreds	AZ & TX	Year-round	Species of Concern[1]
California leaf-nosed bat[2] *Macrotus californicus*	Dozens to over a thousand	AZ & southern CA & NV	Year-round	Species of Concern[1]
Mexican long-tongued bat *Choeronycteris mexicana*	A dozen or fewer	AZ & southern CA	Summer	Species of Concern[1]
Lesser long-nosed bat[2] *Leptonycteris curasoae*	Hundreds to thousands	AZ & NM	Summer	Endangered
Greater long-nosed bats *Leptonycteris nivalis*	Hundreds to thousands	TX & NM	Summer	Endangered
Southeastern myotis *Myotis austroriparius*	Hundreds to thousands	Southeastern U.S.	Year-round	Species of Concern[1]
California myotis *Myotis californicus*	Up to a hundred	Western U.S.	Year-round	Unknown
Western small-footed myotis *Myotis ciliolabrum*	Up to hundreds	Western U.S.	Year-round	Species of Concern[1]
Long-eared myotis *Myotis evotis*	Dozens	Western U.S.	Year-round	Species of Concern[1]
Gray bat *Myotis grisescens*	Hundreds to 50,000 or more	Southeastern U.S.	Year-round	Endangered
Eastern small-footed myotis *Myotis leibii*	Dozens	Eastern U.S.	Winter	Species of Concern[1]
Little brown bat[2] *Myotis lucifugus lucifugus*	Hundreds to a million +	Northern U.S.	Year-round	Unknown
Arizona myotis *M. l. occultus*	Hundreds	Southwestern U.S.	Year-round	Species of Concern[1]
Eastern long-eared myotis *Myotis septentrionalis*	Hundreds to thousands	Eastern U.S.	Winter	Unknown
Indiana bat[2] *Myotis sodalis*	Hundreds to 100,000 or more	Eastern U.S.	Winter	Endangered

[1] Formerly known as Category 2, candidate for federal threatened or endangered listing.
[2] Bats known to be especially dependent on abandoned mines.

Species	Group Size	Range	Use Time	Status
Fringed myotis *Myotis thysanodes*	Dozens to hundreds	Western U.S.	Year-round	Species of Concern[1]
Cave myotis[2] *Myotis velifer*	Hundreds to 100,000 or more	Southwestern U.S.	Year-round	Species of Concern[1]
Long-legged myotis *Myotis volans*	Hundreds	Western U.S.	Year-round	Species of Concern[1]
Yuma myotis *Myotis yumanensis*	Hundreds to thousands	Western U.S.	Year-round	Species of Concern[1]
Western pipistrelle *Pipistrellus hesperus*	Dozens	Western U.S.	Year-round	Unknown
Eastern pipistrelle *Pipistrellus subflavus*	Dozens to thousands	Eastern U.S.	Winter	Unknown
Big brown bat *Eptesicus fuscus*	Dozens to hundreds	North America	Year-round	Stable
Allen's lappet-browed bat *Idionycteris phyllotis*	Dozens to about two hundred	Mostly AZ, also parts of NV, CO	Year-round	Species of Concern[1]
Southeastern big-eared bat *Corynorhinus rafinesquii*	Dozens to several hundred	Southeastern U.S.	Year-round	Species of Concern[1]
Pacific big-eared bat[2] *C. townsendii townsendii*	Dozens to hundreds	Western U.S.	Year-round	Species of Concern[1]
Ozark big-eared bat *C. t. ingens*	Dozens to hundreds	Ozark Mountains	Year-round	Endangered
Western big-eared bat[2] *C. t. pallescens*	Dozens to thousands	Western U.S.	Year-round	Species of Concern[1]
Virginia big-eared bat *C. t. virginianus*	Dozens to thousands	KY, VA & WV	Year-round	Endangered
Pallid bat *Antrozous pallidus*	Dozens to hundreds	Western U.S.	Year-round	Declining
Mexican free-tailed bat *Tadarida brasiliensis*	Hundreds of thousands	Southwestern U.S. north to OR	Summer	Declining

[1] Formerly known as Category 2, candidate for federal threatened or endangered listing.
[2] Bats known to be especially dependent on abandoned mines.

Appendix I

Helpful Literature

General Bat Identification, Behavior, and Distribution

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Appendix II

Available Resources

Training Opportunities and Educational Materials

Bat Conservation International

P.O. Box 162603, Austin, TX 78716, 512-327-9721. BCI provides several Bat Conservation and Management Workshops annually, including some specifically devoted to bats and mines issues. BCI also produces a wide variety of slide and video programs, posters, and other educational materials about bats. For more information, or for a free catalogue, write or call BCI

Bat Conservation International Web Site

Visit our web site at **www.batcon.org** for up-to-date information on bat conservation workshops, available grants, on-line library of bat resources, and more.

Consultation Resources

American Cave Conservation Association

P.O. Box 409, Horse Cave, KY 42749, 502-786-1466. The ACCA is a leader in development of vandal-resistant, bat friendly gate designs and can provide information on gate design and construction.

Bat Conservation International

BCI maintains a list of bat experts throughout North America who are knowledgeable about bat ecology and behavior and who are willing to consult on bat conservation issues. The Director of BCI's North American Bats and Mines Project, founded in partnership with the U.S. Bureau of Land Management, is also available for consultation.

U.S. Fish and Wildlife Service, Asheville Field Office

160 Zillicoa Street, Asheville, NC 28801-1038. 704-258-3939. Available for consultation, either on endangered species issues or on gate designs, use of gates, and alarm systems to protect bats. Also contact the Asheville Field Office for locations of the nearest Fish and Wildlife Offices responsible for formal or informal consultation under the Endangered Species Act.

Bat Line.

An international electronic information forum for the exchange of research ideas, questions, and information on bat ecology, management, and conservation. Information about subscribing to BATLINE can be found at gopher://gopher.unm.edu: 70/00/academic/biology/batline/about/BATLINE (or through a link at BCI's web page: www.batcon.org)

Equipment Sources

Alarm Systems

Light sensitive systems for detecting and recording mine/cave visitation.

Ozark Instruments, Route 2, Box 322, Russelville, AR 72801

Onset Computer Corporation, P.O. Box 3450, Pocasset, MA 02559-3450, Tel: 508-759-9500, FAX: 508-759-9100

Bat Detectors

Anabat2 Ultrasound Detector; Titley Electronics, P.O. Box 19, Ballina, NSW 2478, Australia, FAX/Tel. 066-86-6617

Batbox III, Stag Electronics, 1 Rosemundy, Saint Agnes, Cornwall TR5 OUF., United Kingdom, Tel: [+44](0) 872-553441, FAX: [+44](0) 872-553074

Eco-Tranquility, by David J. Bale, 3 Suffolk Street, Cheltenham, Glouchestershire GL50-2DH, United Kingdom, Tel/FAX: [+44](0) 1242-570123

Mini-3 Bat Detector, by Ultra Sound Advice; available from Bat Conservation International, P.O. Box 162603, Austin, TX 78716, Tel: 1-800-538-BATS

Pettersson Ultrasound Detector D 100; available from Bat Conservation International, P.O. Box 162603, Austin, TX 78716, Tel: 1-800-538-BATS

Ultra Sound Advice: 23 Aberdeen Road, London N5 2UG, U.K., Tel: 44 171 359 1718, FAX: 44 171 359 3650

Bat Traps

May be individually constructed from plans—see Appendix I - Detecting and Censing Bats and Protecting Sites: Tidemann, et al. 1978 and Tuttle 1974 or available from:

Ausbat Research Equipment, 32 Longs Road, Lower Plenty, Victoria, 3093, Australia, Tel/FAX: [+61] (0) 3-9435-7004

General Gear for Underground Work

Headlamps, opaque lenses, red filters, helmets, ropes, and more.

Bob and Bob, P.O. Box 441, Lewisburg, WV 24901, Tel: 800-262-2283, FAX: 304-772-3076

Guadalupe Mountain Outfitters, P.O. Box 2429, Carlsbad, NM 88220, Tel: 505-885-9492

Inner Mountain Outfitters, R1, Box 263, Greenville, VA 24440-9727, Tel: 540-377-2690

Speleobooks, P.O. Box 10, Schohaire, NY 12157, Tel: 518-295-7978

Mine Safety Equipment

Including headlamps, gas detectors and respirators (be sure to order the correct size respirator and have it fitted to properly seal completely against the face prior to using in a hazardous environment).

Mine Safety Appliances, 600 Penn Center Boulevard, Pittsburgh, PA 15235

National Mine Safety Service Co., 4900/600 Grant Street, Pittsburgh, PA 15216

Nite Lite: P.O. Box 8300, Little Rock, AR 72222, Tel: 1-800-648-5483

Forestry Suppliers, Inc., P.O. Box 8397, Jackson, MS 39284-8397, Tel: 800-430-5566

Mist Nets and Poles (permit needed)

Avinet, Inc., P.O. Box 1103, Dryden, NY 13053-1103, Tel: 607-844-3277 or 800-340-6387

Spotlights — Quartz Halogen

Rechargeable 500,000 (or more) candle power lights.

Cabela's, One Cabela Drive, Sidney, NE 69160-9555, Tel: 800-237-4444, FAX: 800-496-6329

Lectro Science Incorporated, 6410 West Ridge Road, Erie, PA 16506, Tel: 814-833-6487

Plow and Hearth, P.O. Box 5000, Madison, VA 22727-1500, Tel: 800-627-1712

Night-Vision Equipment

Night-vision devices should be equipped with bi-ocular eyepieces. A wide angle or normal lens is best for observing mine entrances. Most night viewing devices also require additional illumination for optimum bat viewing. A headlamp with an opaque lens and a Wratten 89B photographic filter or any red or infra-red filter is suitable.

Night Vision System Noctron VI or night goggles available from:

Aspect Technology and Equipment Inc., 811 East Plano Parkway, Suite 110, Plano, TX 75074

Electrophysics Corporation, 48 Spruce Street, Nutley, NJ 07110, Tel: 201-882-0211

Meyers & Co., Inc., 17525 NE 67th Court, Redmond, WA 98052, Tel: 800-327-5648 or 425-881-6648, FAX: 425-687-1759

Varo, Inc., Electronic Devices Division, 2203 W. Walnut Street, P.O. Box 469014, Garland, TX 75046

Thermometers — Digital

Davis Instruments, 4701 Mount Hope Drive, Baltimore, MD 21215, Tel: 410-358-3900 or 800-368-2516, FAX: 410-358-0252 or 800-433-9971

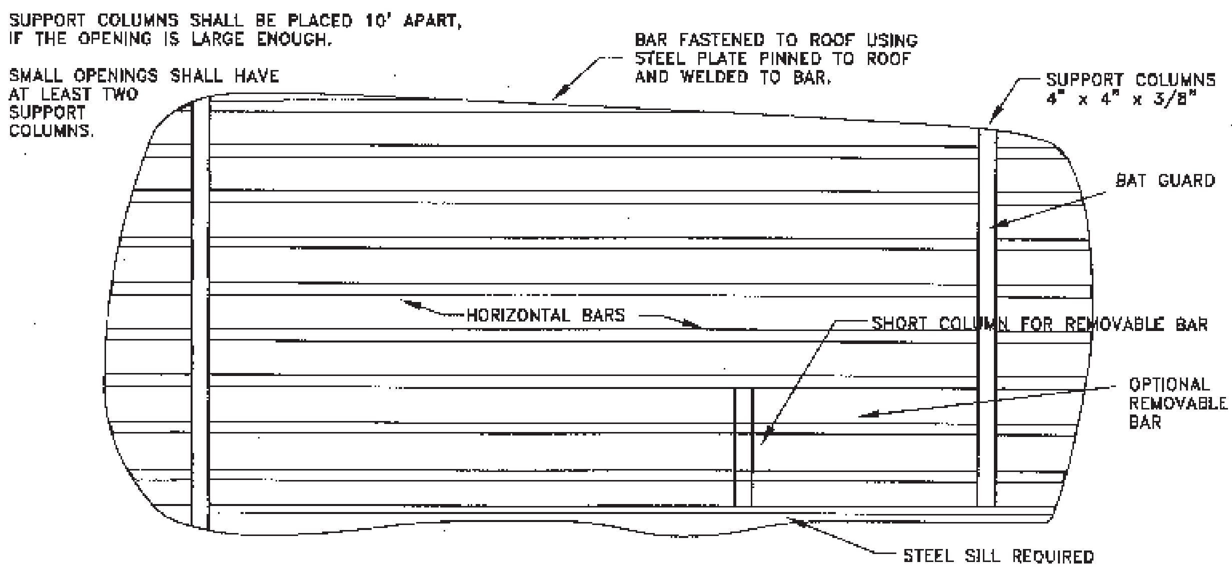
IMC Instruments, Inc., 14434 Kaul Avenue, Menomonee Falls, WI 53051, Tel: 414-252-4620

Programmable Temperature Dataloggers

Onset Computer Corporation, P.O. Box 3450, Pocasset, MA 02559-3450, Tel: 508-759-9500, FAX: 508-759-9100

Appendix III
Design A

These plans are provided courtesy of the American Cave Conservation Association and are revised annually. Contact the ACCA for current construction specifications or for consultation on special needs (see Appendix II).



TYPICAL BAT GATE
BACK ELEVATION VIEW

NOT TO SCALE

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Appendix III
Design A

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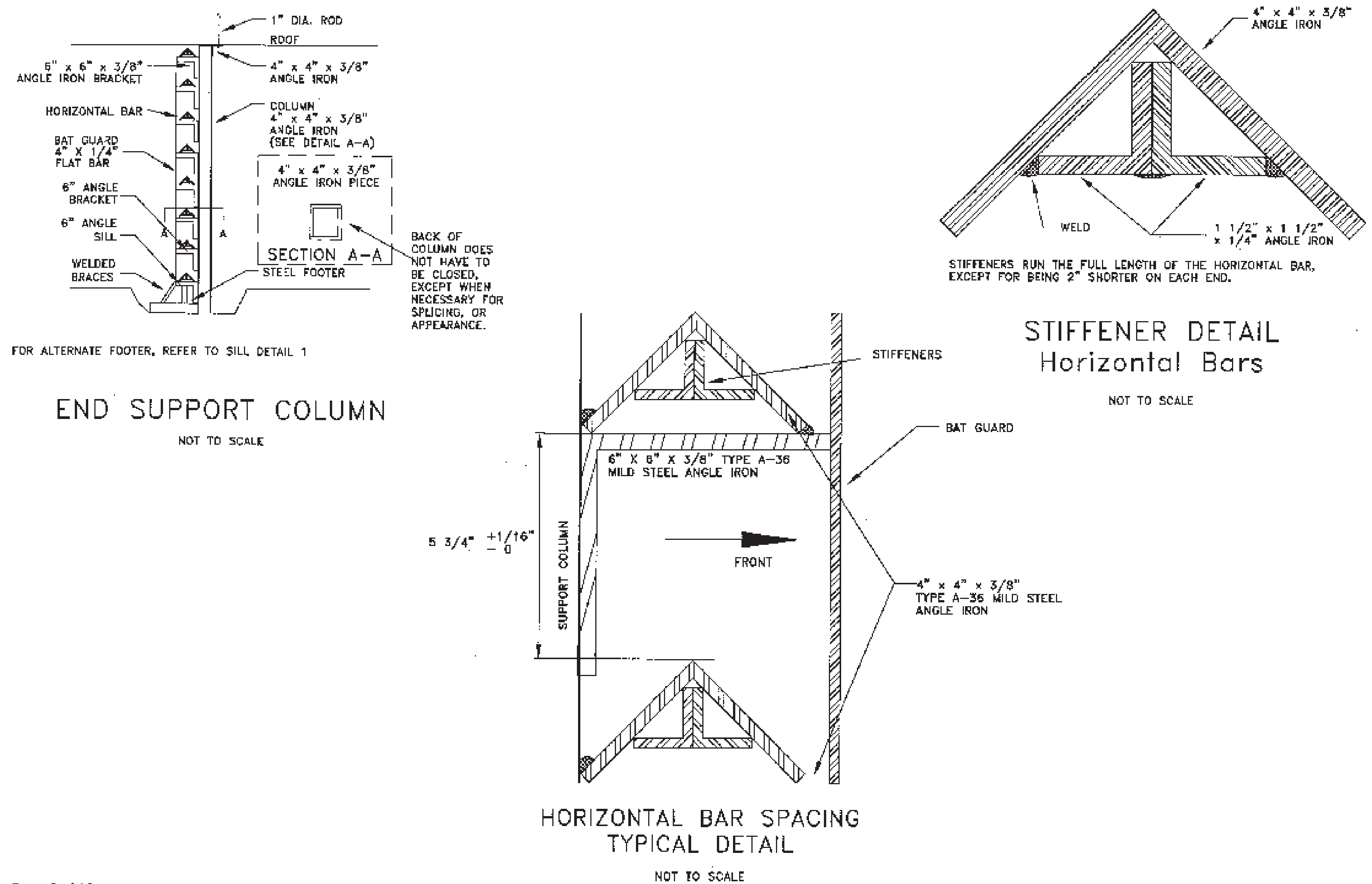

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Appendix III
Design A

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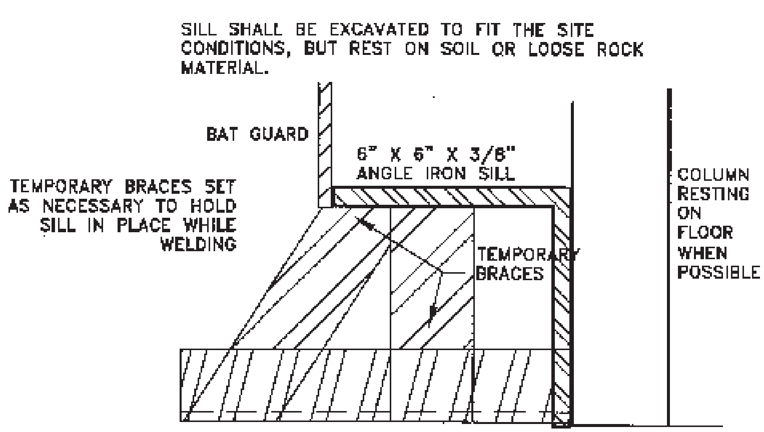
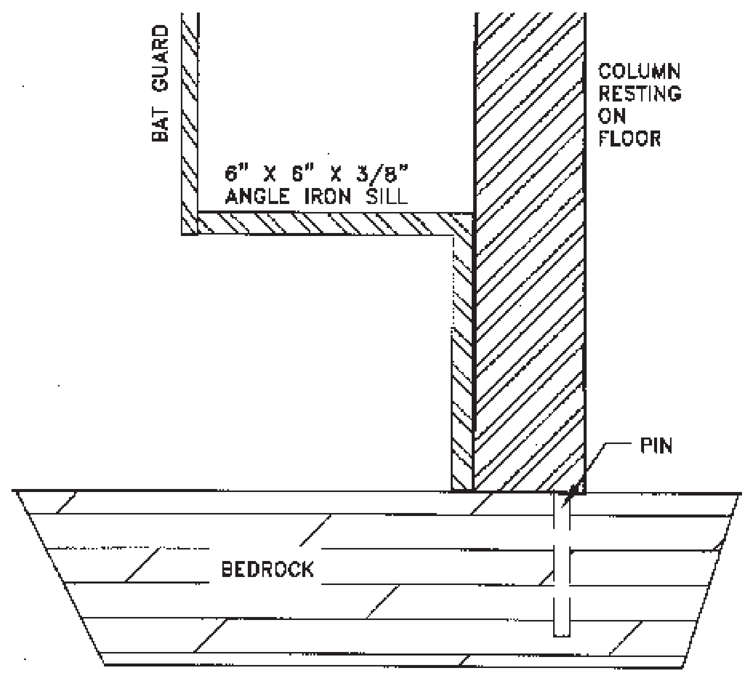


SILL DETAIL 1

NOT TO SCALE



SILL DETAIL FOR BEDROCK FLOOR

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Appendix III
Design A

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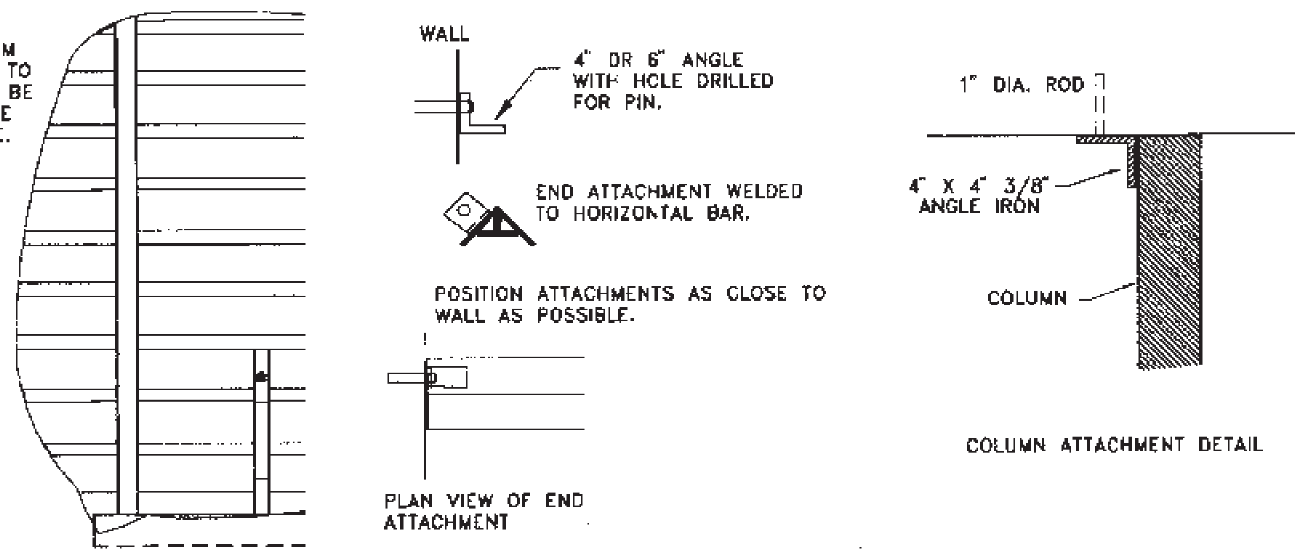
NOTE 1
EACH END SHALL HAVE A MINIMUM OF TWO OF THE BARS ATTACHED TO THE WALL. ATTACHMENTS SHALL BE SPACED AT 25% AND 75% OF THE HEIGHT, AS A GENERAL GUIDELINE.

NOTE 2
END ATTACHMENT MUST BE USED ON BARS WHICH EXTEND MORE THAN 30" BEYOND COLUMNS.



ATTACHMENT DETAILS
NOT TO SCALE

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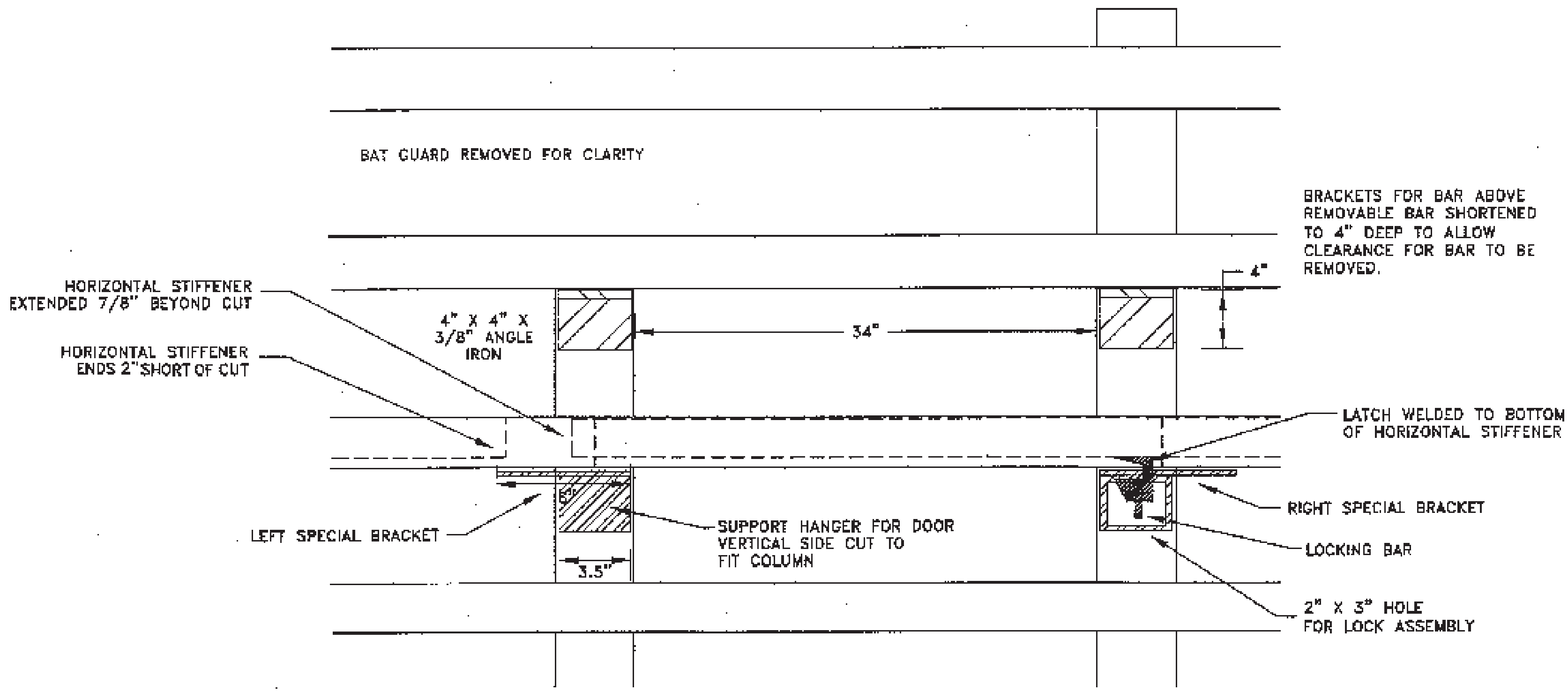

DOOR DETAIL
FRONT ELEVATION VIEW

NOT TO SCALE

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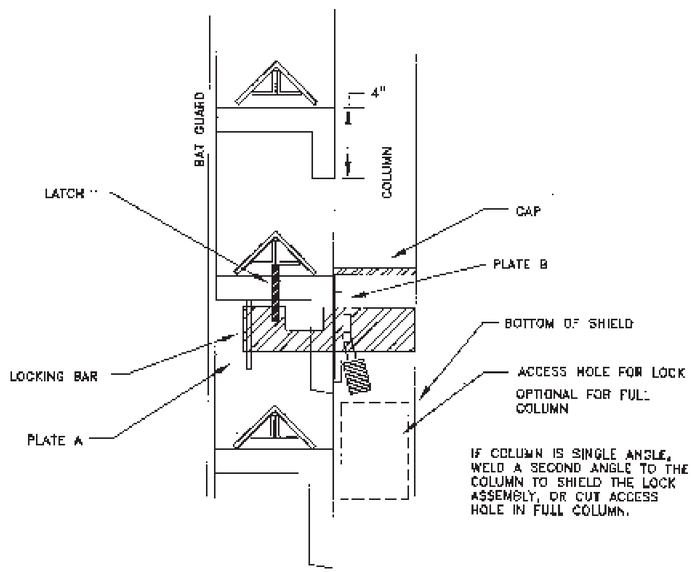
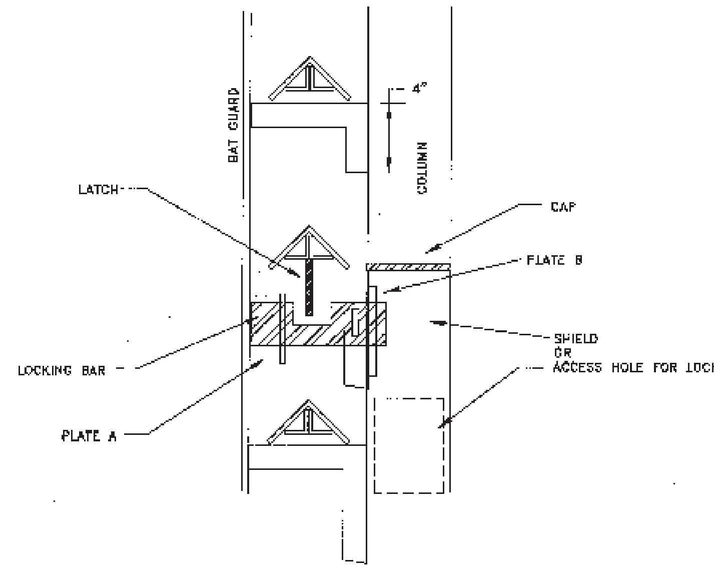
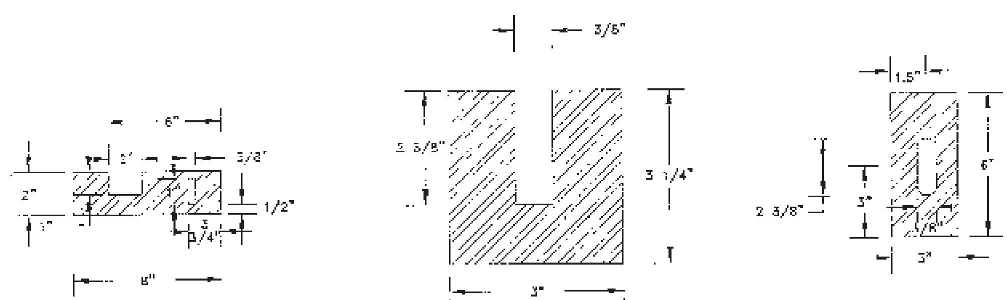


PROFILE VIEW OF LATCH IN LOCKED POSITION



PROFILE VIEW OF LATCH IN OPEN POSITION

NOT TO SCALE



LOCKING BAR DETAIL

PLATE A

PLATE B

LATCH DETAILS

NOT TO SCALE

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Appendix III
Design A

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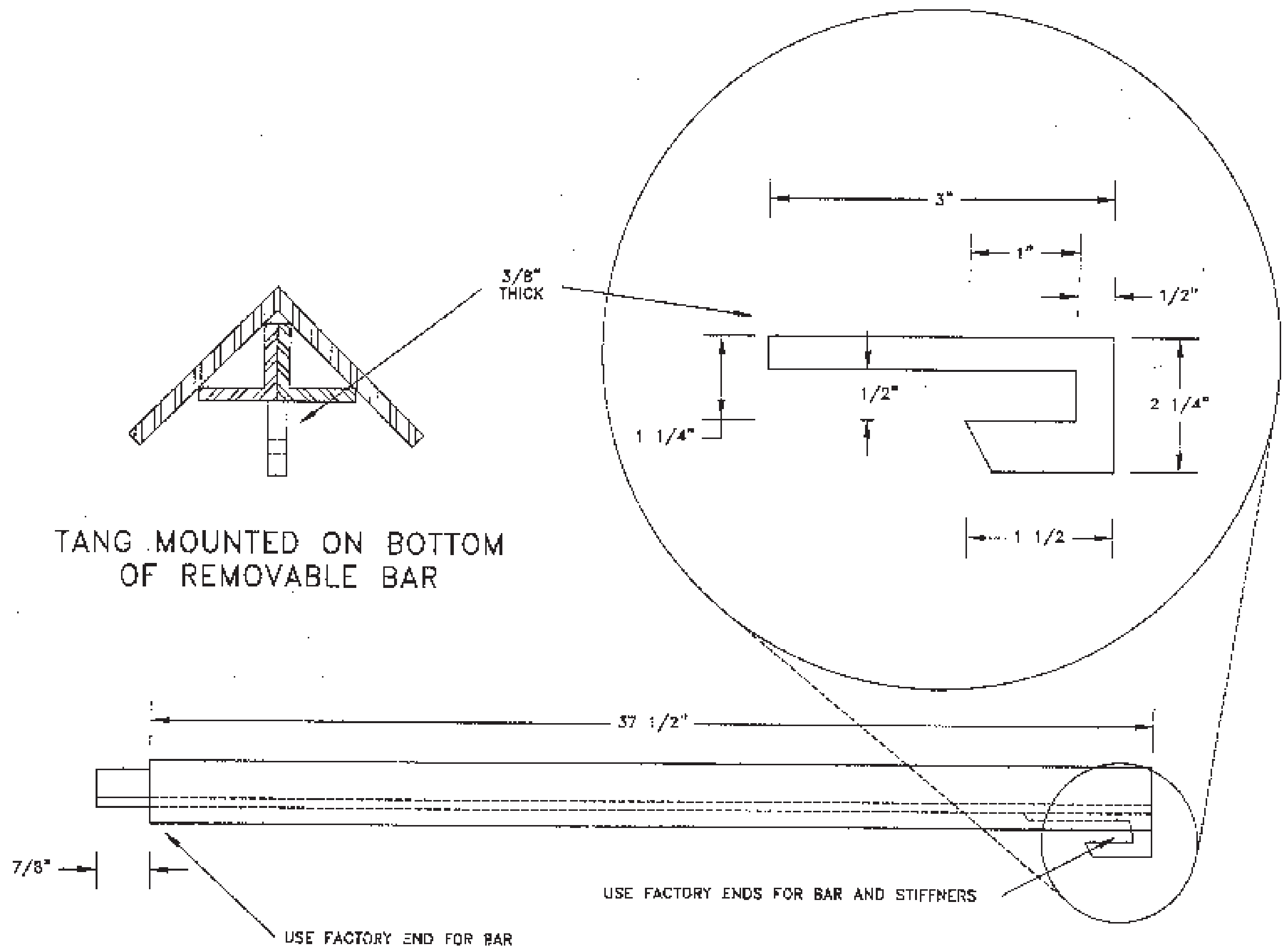

REMOVABLE BAR DETAIL
NOT TO SCALE

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Appendix III
Design A

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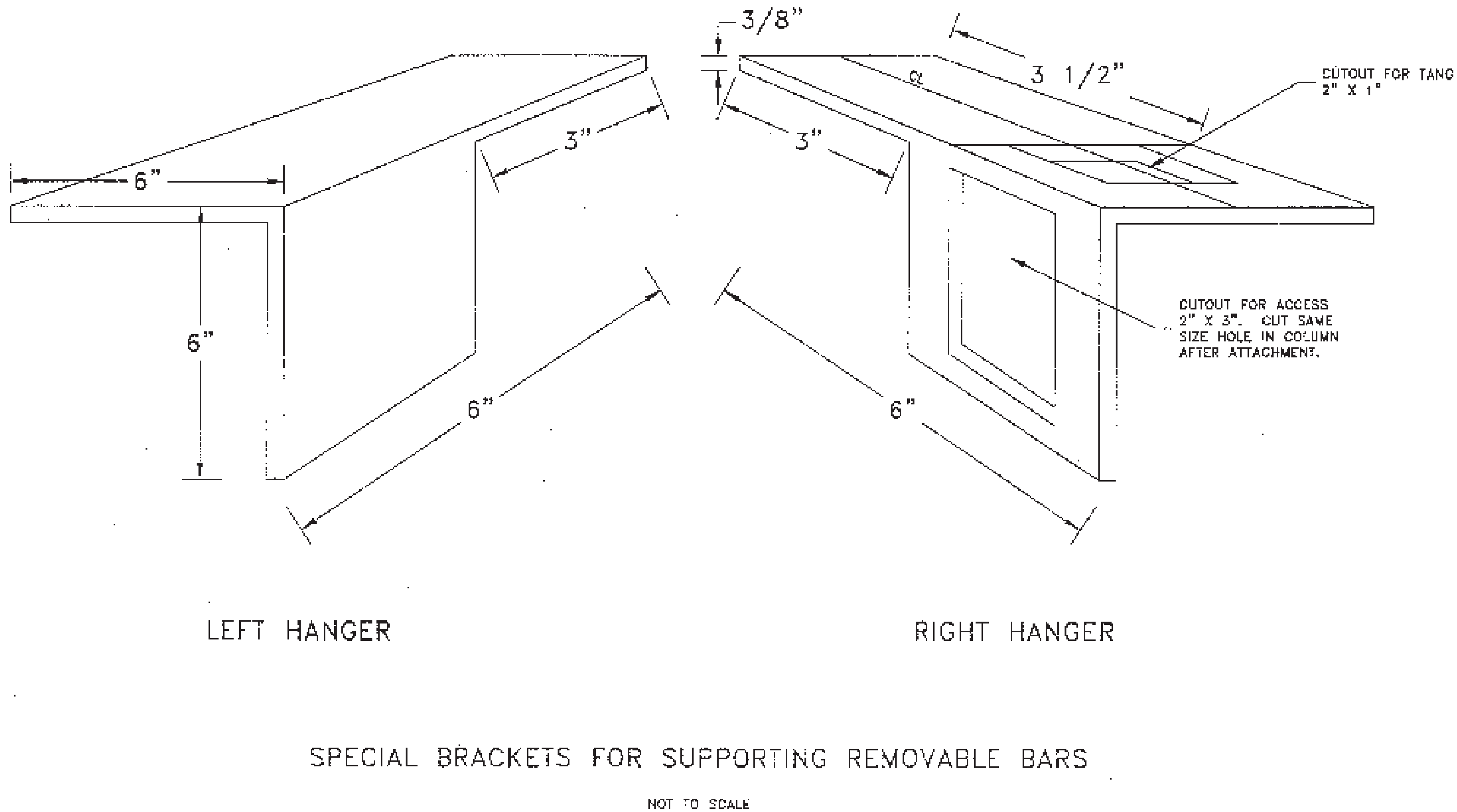

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Appendix III
Design A

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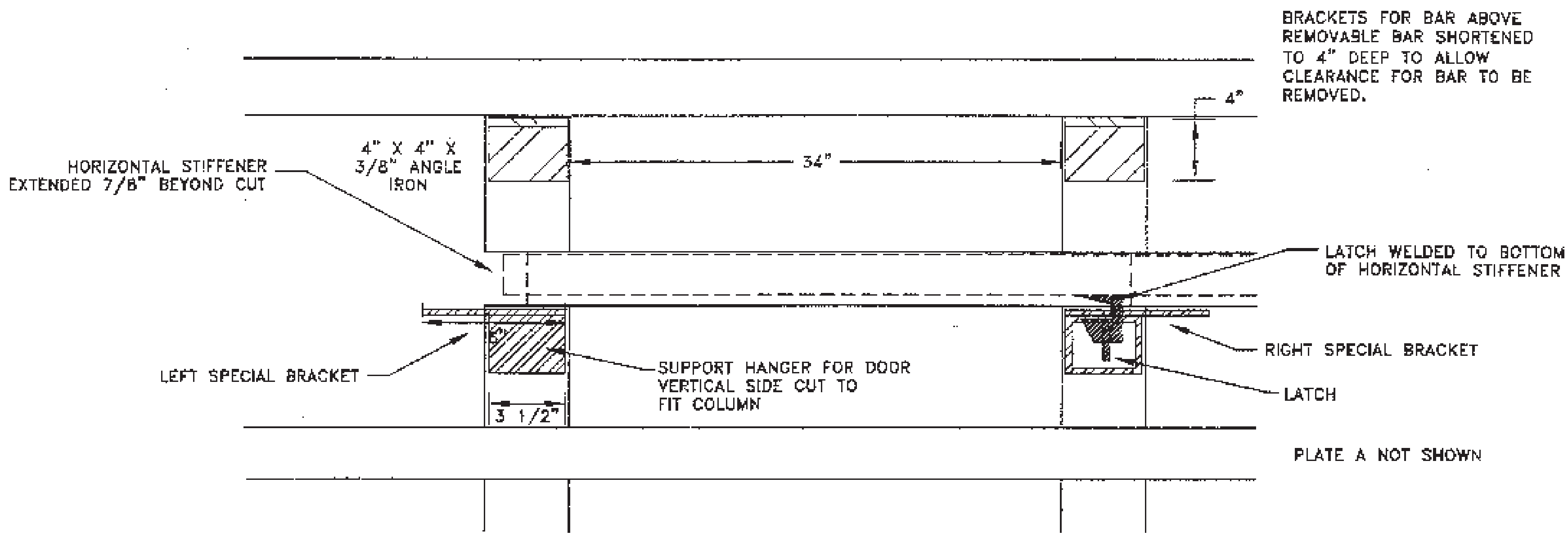

1. PLACE REMOVABLE BAR ON BRACKETS AND CHECK LOCATIONS FOR LATCH, PLATES A AND B.
2. SET RIGHT SIDE HORIZONTAL BAR TO FIT AGAINST RIGHT SIDE OF REMOVABLE BAR.
3. SET LEFT SIDE HORIZONTAL BAR TO FIT AGAINST LEFT END OF REMOVABLE BAR.

ASSEMBLY SEQUENCE FOR REMOVABLE BAR
FRONT ELEVATION VIEW

NOT TO SCALE

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Appendix III
Design A

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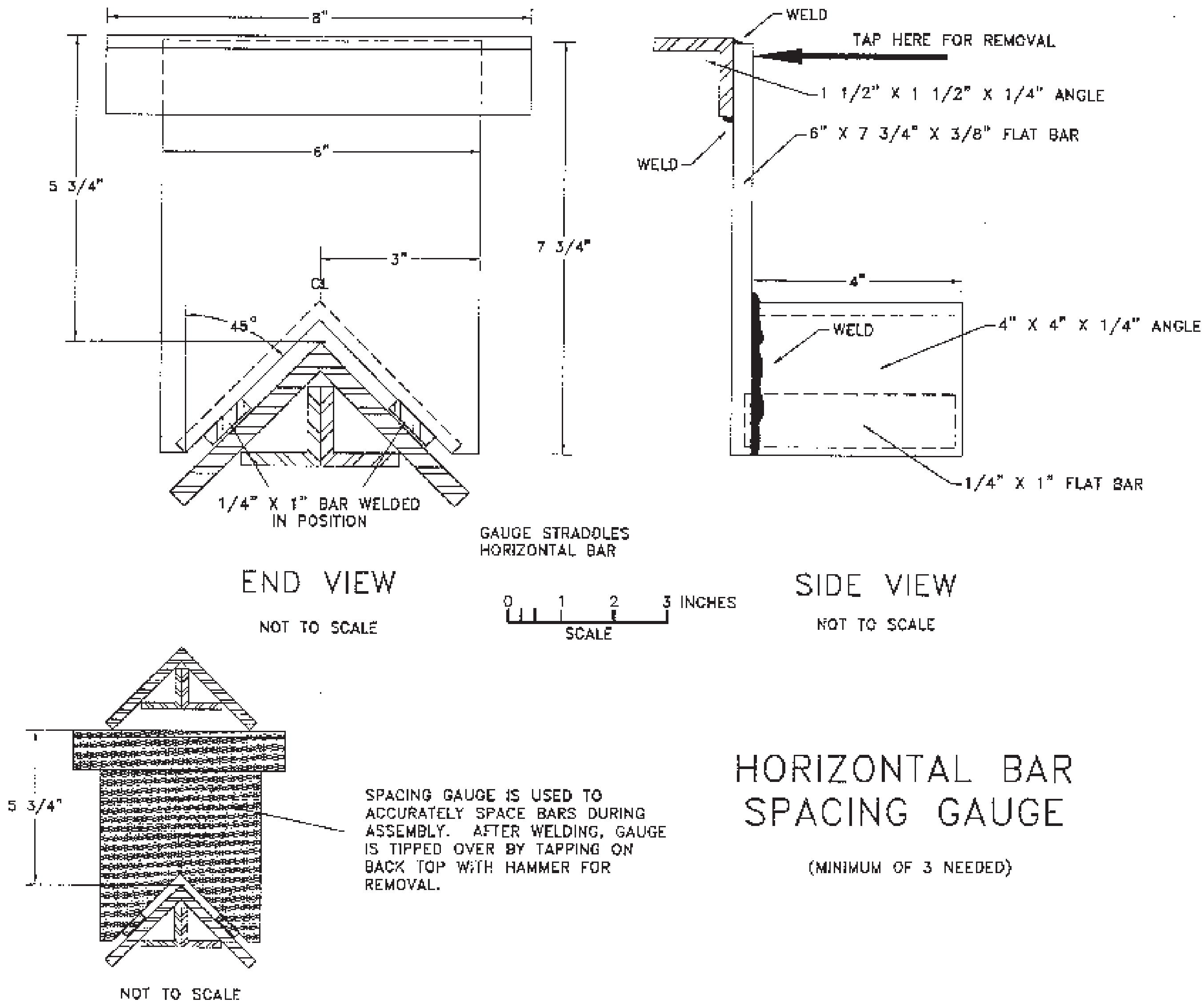

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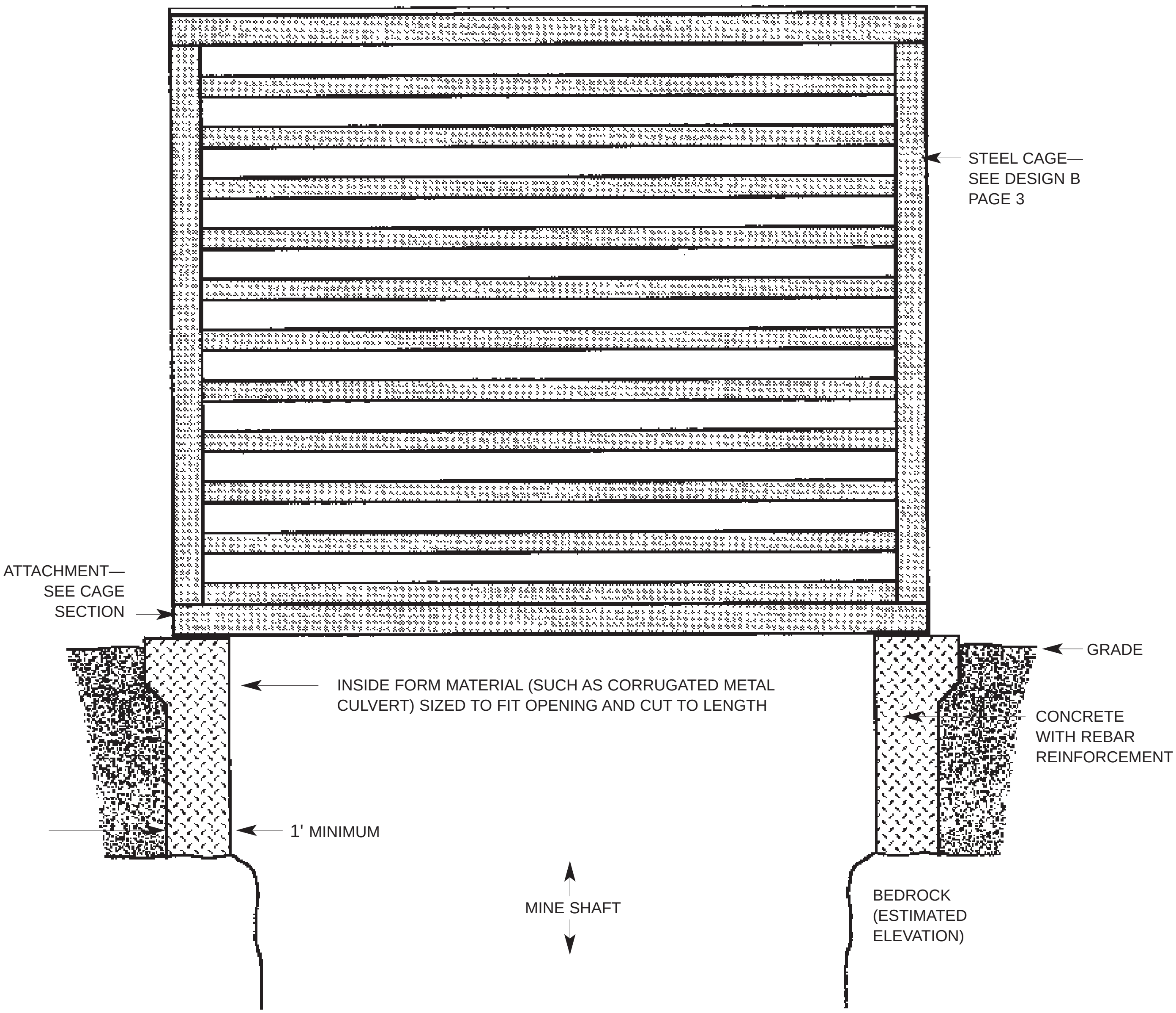
Appendix III

Design B



VERTICAL SHAFT & CAGE CROSS-SECTION

NOT TO SCALE

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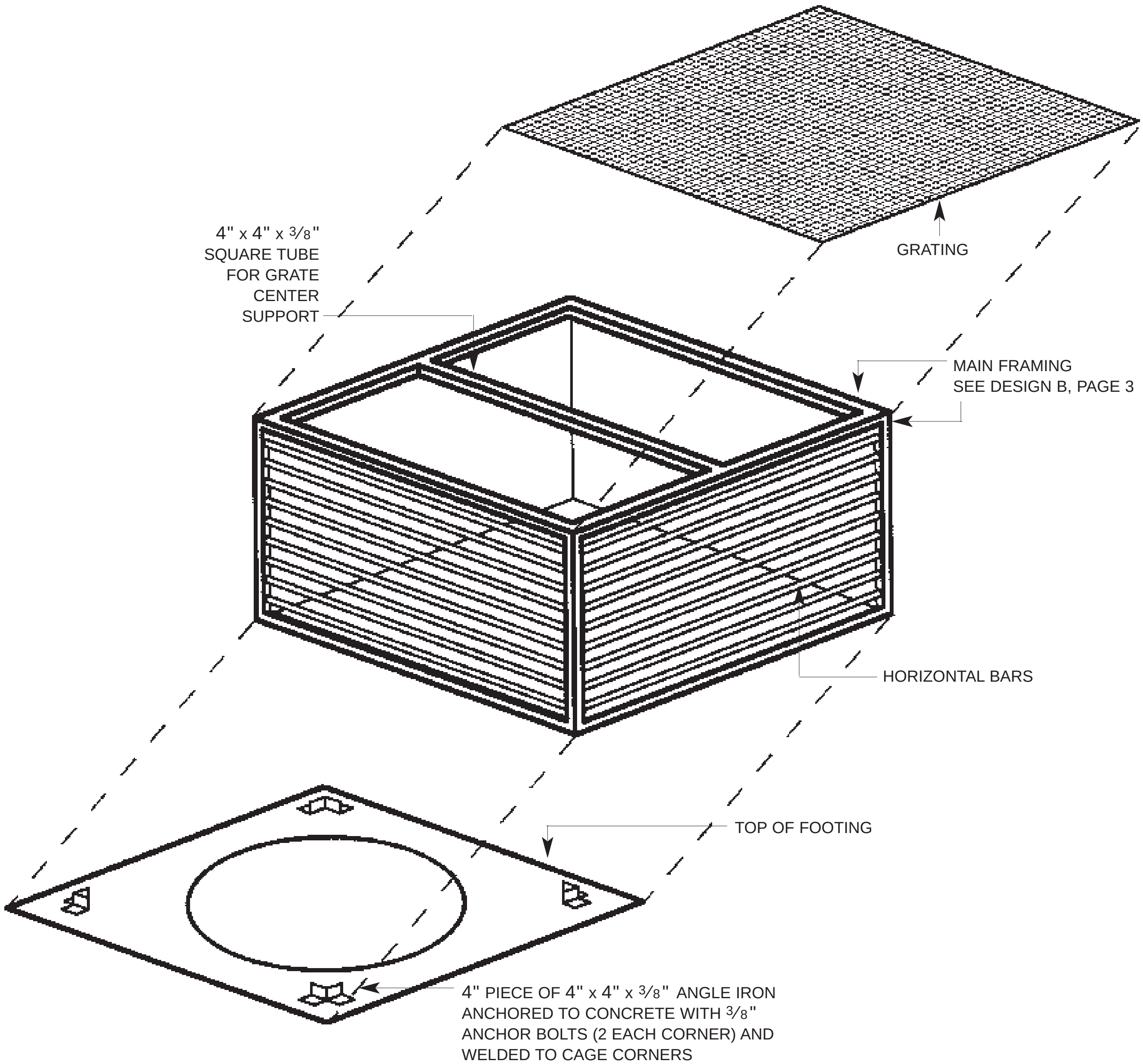
Appendix III

Design B



CAGE ASSEMBLY SCHEMATIC

NOT TO SCALE

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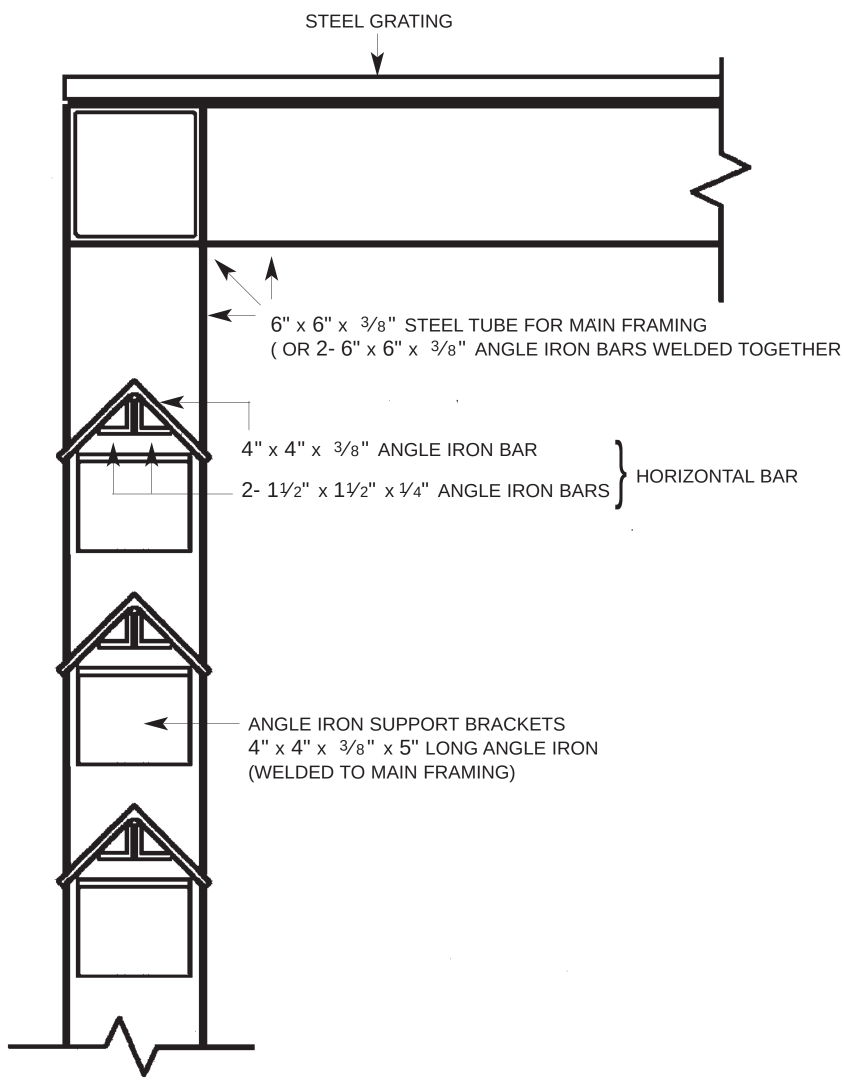
Appendix III

Design B



CAGE SECTION

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Bats in Mines External Survey Form

Mine name (if known):______________________________________

Location:______________________________________

____

Observers:______________________________________

Date:__________________ Time:____________________ Temperature (outside at sunset):______________

Estimated frequency of human disturbance: ❑ Low ❑ Moderate ❑ High

Number of known entrances:____________ More suspected: ❑ Yes ❑ No

Estimated elevational difference between highest and lowest entrances:_____________

Entrance descriptions:

Entrances	**Opening**		**Size**		**Adit Slope**		**Entrance Stability**			**Access**		**Airflow**			**Flow direction**			
	Shaft	Adit	Height x Width	Diameter or Height x Width	Up	Down	Stable	Moderate	Unstable	Mostly blocked	Mostly open	Slight	Moderate	Heavy	None	In only	Out only	In and out

Continue on back if necessary

Lowest temperature of exiting air (any entrance, near ground):_____________, Entrance No._______________

Highest temperature of exiting air (any entrance, near ceiling):_____________, Entrance No._______________

Mine apparently ❑ dry, ❑ damp, or ❑ believed to contain standing water

Greatest length visible through any entrance:_______________

Estimated distance to: nearest riparian habitat:________________ and nearest open water:_______________

Comments:______________________________________

____

Use reverse side for any descriptive sketches and additional information as necessary.

Bats in Mines Emergence Observations

Mine name (if known):____

Location:____

____

Observers:____

Date:__________________ Time:____________________ Temperature (outside at sunset):______________

Number of entrances observed, trapped, or netted:__________________ More suspected: ❑ Yes ❑ No

Start time:___________________________________ End time:______________________________________

Wind: ❑ None ❑ Light ❑ Moderate ❑ Strong

Techniques: Kind of light used: ❑ Ambient ❑ Red light ❑ Night-vision device

Bat detector used: ❑ Yes ❑ No Frequency setting:_____________

Number of bats: Visually counted:______________________, passes heard on detector:___________________

or estimated from length and density of emergence_________________

Total bats caught in: trap____________ or net______________

Percent of mine entrance left open: ____________

Bat Identities/Reproductive Status (include number caught for each species):

Confirmed:____

____

____

Suspected:____

____

Comments:____

____

____

All entrances sampled must be clearly identified; illustrate on reverse if necessary.

Bats in Mines Internal Survey Form: Active Season

Mine name (if known):____________________ Elevation:__________

Location:______________________________

Observers:______________________________

Date:__________ Time:__________ Temperature (outside in shade):__________

Human disturbance is: ❑ Low ❑ Moderate ❑Heavy

Mine is: ❑ Single-level ❑ Multi-level ❑ Simple ❑ Moderate ❑ Complex

Percent of mine included in survey: __________

Number of entrances: __________ Height of largest: __________ Width of largest: __________

Mine length is: ❑ < 50 ft. ❑ 50-100 ft. ❑ 100-200 ft. ❑ 200-500 ft
❑ 500-1000 ft. ❑ 1000-5000 ft. ❑ > 5000 ft.

Dimensions of largest passage: Length__________ Height__________ Width__________

Dimensions of largest room: Length__________ Height__________ Width__________

Mine is: ❑ dry ❑ damp ,or ❑ contains standing water

Temperature in warmest area:__________ Temperature in coolest area:__________

Bat droppings are: ❑ Scattered ❑ In piles ❑ Not present

Total number of guano deposits observed: __________ Measurements of four largest guano deposits:

1. Length __________ Width __________ Depth __________
2. Length __________ Width __________ Depth __________
3. Length __________ Width __________ Depth __________
4. Length __________ Width __________ Depth __________

Number of individual bats counted:__________ or total area covered by clusters:__________

Total estimated number of bats in mine (by species if known):__________

____

Comments:______________________________

____

A sketch on the reverse, showing approximate mine dimensions, numbered roost locations, and sites of temperature readings, may prove helpful.

Bats in Mines Internal Survey Form: Hibernation Season

Mine name (if known):________________________________ Elevation:________________

Location:____

Observers:____

Date:______________ Time:________________ Temperature (outside in shade):____________

Human disturbance is: ❑ Low ❑ Moderate ❑Heavy

Mine is: ❑ Single-level ❑ Multi-level ❑ Simple ❑ Moderate ❑ Complex

Number of Entrances: __________ Height of largest: ____________ Width of largest: ____________

Mine length is: ❑ < 50 ft. ❑ 50-100 ft. ❑ 100-200 ft. ❑ 200-500 ft
❑ 500-1000 ft. ❑ 1000-5000 ft. ❑ > 5000 ft.

Dimensions of largest passage: Length______________ Height____________ Width______________

Dimensions of largest room: Length______________ Height____________ Width______________

Mine is: ❑ dry ❑ damp, or ❑ contains standing water

Temperature in warmest area:__________________ Temperature in coolest area:__________________

Percent of mine's potential bat habitat included in survey: ____________ and total bats counted by species,

followed by the predominant temperature where each was found: ________________________________

____

In very large, complex, or hazardous mines, it may be necessary to search only part of the total mine. In such cases, use the reverse side of this sheet to sketch the mine. Roosting areas should be arbitrarily defined according to identifiable rooms or particular sections of passages between intersections. These should be measured for height, length, and width and numbered on the map, and bat numbers (by species if possible) and air temperatures should be recorded for each area. Where many or large clusters are encountered, record either cluster sizes or the average proportion of wall covered by clusters. Also note whether clusters are loose, moderately dense, or very tightly packed. Most hibernation clusters will range from 150 to 300 bats per square foot, depending on bat size and clustering density. Such knowledge will permit rough extrapolation to determine a mine's total population size if the extent and approximate temperature profile of the mine can be estimated. Match data, as follows, with roost numbers from the mine sketch on as many pages as required.

1. Length _______, Width _______, Height _______, and Temperature ______ of designated roosting area

Number of each species present____

____

2. Length _______, Width _______, Height _______, and Temperature ______ of designated roosting area

Number of each species present:____

____

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