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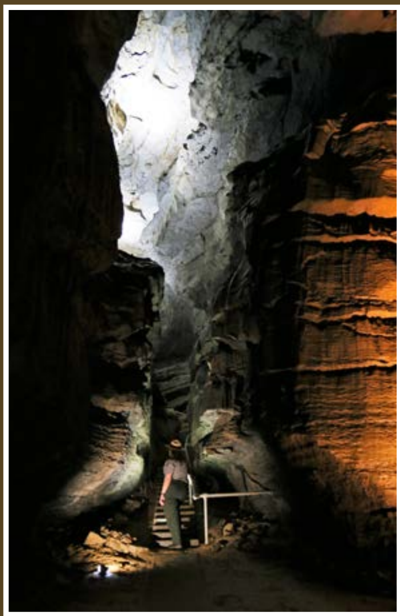

# Cave and Karst Management Plan / Environmental Assessment

## Mammoth Cave National Park
## Kentucky

**July 2019**

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# HOW TO COMMENT ON THIS PLAN

The National Park Service (NPS) welcomes comments on this plan and will accept them for 30 days following the official public release. To respond, please submit written comments by the following means. The preferred method for receiving comments is through the NPS Planning, Environment, and Public Comment (PEPC) system.

## INTERNET WEBSITE

The NPS PEPC website is http://parkplanning.nps.gov/MACA_CKMP.

Click on the "Open for Comment" link on the left side of the page to access the online document.

## US MAIL

Written comments can be mailed to the park at:

Superintendent, Mammoth Cave National Park
Re: Cave and Karst Management Plan
P.O. Box 7
Mammoth Cave, KY 42259

Reviewers are encouraged to use the PEPC website to comment and access the document if possible. Please submit only one set of comments.

Before including your address, phone number, e-mail address, or other personal identifying information in your comment, you should be aware that your entire comment—including your personal identifying information—may be made publicly available at any time. Although you can ask us in your comment to withhold your personal identifying information from public review, we cannot guarantee that we will be able to do so.

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# ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| ASMIS | Archeological Sites Management Information System |
| CCC | Civilian Conservation Corps |
| CEQ | Council on Environmental Quality |
| CFR | Code of Federal Regulations |
| CLR | Cultural Landscape Report |
| EA | environmental assessment |
| GMP | general management plan |
| IVUMC | Interagency Visitor Use Management Council |
| KSNPC | Kentucky State Nature Preserves Commission |
| $m^2$ | square meter |
| MACA | Mammoth Cave National Park |
| NEPA | National Environmental Policy Act |
| NPS | National Park Service |
| PEPC | Planning, Environment, and Public Comment |
| PL | Public Law |
| UNESCO | United Nations Educational, Scientific and Cultural Organization |
| USC | United States Code |
| USFWS | US Fish and Wildlife Service |
| VUM | Visitor Use Management |

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# Chapter 1

## Purpose and Need

**CHAPTER 1 DIVIDER (BACK PAGE)**

# CHAPTER 1: PURPOSE AND NEED FOR ACTION

## INTRODUCTION

Mammoth Cave National Park (MACA) contains 450 significant caves, including Mammoth Cave itself, the longest mapped cave in the world. The park comprises approximately 52,830 acres in Edmonson, Hart, and Barren Counties in the Commonwealth of Kentucky (figure 1 in appendix A). Visitors are drawn to the park by its caves, scenic rivers and valleys, bluffs, forests, and abundant wildlife. The park offers ranger-led cave tours and surface walks, camping, hiking, horseback riding, bicycling, scenic drives, canoeing and kayaking, fishing, accessible trails, and picnicking. This breadth of activities is available because Mammoth Cave National Park is a park on two levels—maturing hardwood forest and winding riverways above, and complex cave systems below (figure 2 in appendix A).

The cultural and natural resources protected in this national park are national treasures. In recognition of these world-class resources, the park has received two international designations. In 1981, the United Nations Educational, Scientific and Cultural Organization (UNESCO) designated Mammoth Cave National Park as a World Heritage Site. In 1990, the United Nations Educational, Scientific and Cultural Organization designated the Mammoth Cave Area as an International Biosphere Reserve (with all park acreage included in a core 112,800-acre area). The Reserve was expanded to 909,328 acres in 1996.

## PURPOSE OF THE PLAN

The purpose of this plan is to provide a consistent framework for managing the world-class cave and karst resources in the park and to work cooperatively with partners in the broader Mammoth Cave Area International Biosphere Reserve. The plan provides direction to protect and conserve all 450 caves in the park and its entire karst groundwater system through the use of science to promote stewardship and understanding. The plan is needed to address resource protection issues and support sustainable public enjoyment, education, and research efforts.

## NEED FOR ACTION

The National Park Service (NPS) is mandated to protect caves through a variety of laws, policies, and regulations. NPS *Management Policies 2006* (NPS 2006a, §4.8.2.2), for example, states: "The Service will manage caves in accordance with approved management plans to perpetuate the natural systems associated with the caves, such as karst and other drainage patterns, airflows, mineral deposition, and plant and animal communities." In addition to *Management Policies 2006*, the Cave Resource Protection Act of 1988 and Archaeological Resource Protection Act of 1979 provide federal direction for managing cave environments and archeological resources for resource planning and management actions.

While Mammoth Cave has a general management plan (GMP) from 1983 (NPS 1983), the park has not completed a formal cave and karst management plan. Currently, the park continues to implement cave resource management efforts through its detailed standard operating procedure guidebook. This internal guidance incorporates best available science and operational direction for the park's cave environment and individual procedures are updated as needed by park managers. However, the guidebook does not provide a comprehensive approach for managing visitor use, establishing tour capacities, or providing desired future conditions for the cave system.

## GOALS AND OBJECTIVES

The goal of the cave and karst management plan is to implement policies and provide a consistent and comprehensive framework for managing the world-class cave and karst resources in the park. The plan will provide direction to perpetuate these complex and sensitive resources through the use of science-based decision-making that promotes stewardship and understanding, while providing for sustainable public enjoyment.

The plan will consider restructuring cave tour options and permitting within the cave and revising cave zoning created in the 1983 general management plan to better balance visitor opportunities and sustained resource protection. Visitor use indicators and thresholds will be developed to evaluate cave tour visitor capacities and identify future management strategies and mitigation measures.

## VISITOR USE MANAGEMENT

Visitor use management is the proactive and adaptive process of planning for and managing characteristics of visitor use and its physical and social setting, using a variety of strategies and tools, to sustain desired resource conditions and visitor experiences. Visitor use management is important because the National Park Service strives to maximize opportunities and benefits for visitors while achieving and maintaining desired conditions for resources and visitor experiences in a particular area. Managing visitor access and use for visitor enjoyment and resource protection is inherently complex. It requires NPS managers to analyze not only the number of visitors but also where they go, what they do, their impacts on resources and visitor experiences, and the underlying causes of those impacts. Managers must acknowledge the dynamic nature of visitor use, the vulnerabilities of natural and cultural resources, and the need to be responsive to changing conditions.

This plan employs the visitor use management framework and the visitor use management planning process to develop a long-term strategy for managing visitor use in the park (see figure 3 in appendix A). The general planning process used for this plan is described below and is consistent with the guidance outlined by the Interagency Visitor Use Management Council (IVUMC, www.visitorusemanagement.nps.gov). “Indicators and thresholds” and “visitor capacity” are two important pieces of the visitor use management framework being applied in this plan.

### Desired Conditions

Desired conditions are defined as statements of aspiration that describe resource conditions, visitor experiences and opportunities, and facilities and services that an agency strives to achieve and maintain in a particular area. Within the Visitor Use Management (VUM) framework described above, desired conditions are a crucial element that help guide management decisions. In this plan, desired conditions described in previous plans, such as the general management plan, have been considered and provide high-level guidance. To provide guidance for specific actions contained in this plan, desired conditions for visitor use and experience common to all planning alternatives are outlined here and further articulated in chapter 2.

**Common to All.**

- Natural
  - The natural function, diversity, complexity, and resiliency of park caves are protected.
  - Impacts on fragile natural and cultural resources are minimized by locating facilities in areas that are able to support such use without sustaining unacceptable environmental damage.
  - Cave use-related impacts are minimized or mitigated by management strategies.
  - Infiltrating water is protected to ensure good water quality to support cave functions and organisms.
  - Cave habitats and communities, especially cave-obligate endangered species, are maintained and protected.
- Cultural
  - Archeological resources are preserved and protected from unintentional, adverse impacts and/or disturbance associated with cave use.
  - Cultural resources—including archeological sites, historic structures, cultural landscapes, and ethnographic resources—are identified, documented, and protected, to the extent possible.
- Visitor Experience
  - A variety of cave tours are readily available to provide visitors with a high-quality experience, and an opportunity to learn about and enjoy Mammoth Cave’s iconic cultural and natural resources.
  - Visitor congestion and conflict are managed to provide visitors with a high-quality experience.

## Indicators and Thresholds

The National Park Service places a strong emphasis on avoiding, minimizing, and mitigating potentially adverse environmental impacts. To help ensure the protection of natural and cultural resources and the quality of the visitor experience, protective measures would be implemented as part of the action alternatives to minimize potential environmental impacts from actions associated with this plan. The National Park Service would conduct an appropriate level of monitoring throughout implementation of the chosen alternative to help ensure that protective measures are properly applied and achieve their intended results.

Monitoring is the process of routinely and systematically gathering information or making observations to assess the status of specific resource conditions and visitor experiences; it is a critical step in successfully implementing any VUM plan. A monitoring strategy is designed and implemented to generate usable data to periodically compare existing and desired conditions, assess the need for management actions, and evaluate the efficacy of management actions. A well-planned monitoring strategy provides for transparency, communication, and potential cost savings through efficiencies and possibly cost sharing. A monitoring strategy includes the selection of indicators, along with the establishment of thresholds or objectives, and any needed triggers. It also includes routine, systematic observations or data collection of the indicators over time, as well as associated documentation and analysis.

Indicators, thresholds, monitoring protocols, management strategies, and mitigation measures would be implemented as a result of this planning effort. Indicators would be applied to the action alternatives described in this plan. Indicators translate desired conditions of the MACA Cave and Karst Management Plan into measurable attributes (e.g., linear extent of visitor-created trails) that when tracked over time, evaluate change in resource or experiential conditions. These are critical components of monitoring the success of the plan and are considered common to all action alternatives. Thresholds represent the minimum acceptable condition for each indicator and were established by considering qualitative descriptions of the desired conditions, data on existing conditions, relevant research studies, professional judgement of staff from management experience, and scoping on public preferences. A trigger is defined as a condition of concern for an indicator that is enough to prompt a management response to ensure that desired conditions continue to be maintained before the threshold is crossed.

After considering the central issues driving the need for the MACA Cave and Karst Plan, the interdisciplinary planning team developed related indicators to help identify when the level of impact becomes a cause for concern and management action may be needed. The indicators described below were considered the most critical, given the importance and vulnerability of the resource or visitor experience affected by types of visitor use. The planning team also reviewed the experiences of other park units with similar issues to help identify meaningful indicators. Not all of the strategies related to the indicators, thresholds, and visitor capacity would be implemented immediately, but would be implemented as thresholds are approached or exceeded. Those strategies identified for use as needed are labeled as adaptive management strategies in each of the appendixes. The impact analysis is included in chapter 3 so the park can employ those as necessary to achieve desired conditions.

The following are indicators park staff identified to be the most important to maintain desired conditions for visitor experience and natural and cultural resources. Thresholds, rationales, monitoring guidelines, and management strategies are included in appendix B.

1. *Indicator:* Number of incidents of vandalism on tour routes per year.
2. *Indicator*: Number of illegal cave entries per year resulting from break-ins (evidence of broken or removed locks and gates, unauthorized entries into the cave by the public) or visitor trespass (unattended access points left open and crossed, intentionally or unintentionally, and caves without gates). Sometimes, damage to cave resources may be the only evidence of illegal entry.
3. *Indicator*: Number of visitor concerns related to tour size and crowding on park cave tours.

4. *Indicator Topic*: Algae growth.
    a. Indicator 4(a): Number of lights that show visible algae growth
    b. Indicator 4(b): Total area (coverage) of algae
5. *Indicator Topic*: *E. coli* in select springs and cave discharges.

### Visitor Capacity

Visitor capacity is a component of visitor use management and is defined as the maximum amount and types of visitor use that an area can accommodate while sustaining desired resource conditions and visitor experiences, consistent with the purpose for which the area was established. Visitor capacity is used to inform and implement the management strategies selected as part of the plan.

The primary goal of this planning effort is to preserve the fundamental resources and values of Mammoth Cave National Park while still achieving the plan purpose and need—and visitor use management is one component. By establishing and implementing visitor capacities, the National Park Service can help ensure that resources are protected and visitors have the opportunity for a range of high-quality experiences. Through this planning effort, the park has an important opportunity to proactively safeguard the highly valued experiences and resources throughout the park unit.

The full identification of visitor capacity and implementation strategies is included in appendix B.

### Scope of the Environmental Assessment

The extent and nature of environmental issues and alternatives that should be considered during the National Environmental Policy Act (NEPA) review were considered early in the process. Issues were identified to help emphasize the important environmental concerns related to the proposal and to help identify impact topics and focus the impact analysis.

Determination of topics for impact evaluations were identified based upon the following:

- federal laws, regulations, and executive orders, including NEPA guidance documents;
- NPS Management Policies (NPS 2006a);
- public scoping input; and
- relevance of proposed actions to park resources.

When an alternative is selected and approved, implementation of that alternative will depend upon future funding. The approval of a plan does not guarantee that the funding and staffing needed to carry out the plan will be forthcoming. Full execution of the approved plan could occur many years in the future.

Implementation of the approved plan could also be affected by other factors. Once the plan has been approved, additional feasibility studies and more-detailed planning and environmental documentation may need to be completed before any proposed actions can be carried out.

## ISSUES AND IMPACT TOPICS RETAINED FOR FURTHER ANALYSIS

"Issues" can be problems, concerns, conflicts, obstacles, or benefits that would result if the proposed action or alternatives, including the no-action alternative, are implemented. Issues may be raised by the National Park Service, other agencies, tribal governments, adjacent communities, or the public.

The analysis in this plan focuses on significant issues (meaning pivotal issues, or issues of critical importance). During scoping for this plan, the interdisciplinary team identified a number of visitor use management issues at the park. The following issues were retained for a more detailed analysis in chapters 3 and 4 if

- the environmental impacts associated with the issue are central to the proposal or of critical importance;
- a detailed analysis of environmental impacts related to the issue is necessary to make a reasoned choice between alternatives;

- the environmental impacts associated with the issue are a big point of contention among the public or other agencies; or
- there are potentially significant impacts to resources associated with the issue.

An important part of effective planning is understanding the consequences of making one decision over another. Environmental assessments (EAs), such as this document, identify the anticipated impacts of actions on resources, park visitors, and neighbors. Impacts are organized by topic, such as impacts on visitor experience or impacts on vegetation. Impact topics focus the environmental analysis and ensure the relevance of impact evaluation. The following section summarizes the issues and impact topics that are discussed in Chapter 3: Affected Environment and analyzed in Chapter 4: Environmental Consequences.

### Biological Resources

Biota in Mammoth Cave—including bats, woodrats, amphibians, fish, cave crickets, spiders, beetles, crayfish, springtails, and a variety of other cave-adapted animals—are subject to disturbance and displacement from past, present, and future visitor use, trail maintenance, cave exploration, and research activities. They are also subject to habitat loss due to changes in water quality, water quantity, climate, or airflow, or changes to entrances that affect flow of food into the cave. As recent issues caused by white-nose syndrome in bats has indicated, cave species may also be impacted by accidental introduction of exotic diseases and species. Lint, as well as factors such as changes to airflow, pH, and temperature, disrupts the delicate balance that exists in a cave environment, and there is potential for damage to communities from introduction of lint and other materials.

### Rare, Threatened, and Endangered Species

Listed species and species of special interest are subject to disturbance and displacement from past, present, and future visitor use, trail maintenance, cave exploration, and research activities. For example, surface activities in the park vicinity affect water infiltrating into the cave. Similarly, chemicals and other toxins occurring in cave water adversely affect the three species of cave fish, the Kentucky cave shrimp (*Palaemonias ganteri*), and species that may drink the water, such as the three special status bats. Changing cave climates because of alterations of cave entrances, may also improve or degrade hibernation sites for endangered bats.

### Cave Climate

The park faces numerous issues related to the condition of its natural systems and the overall cave environment. Airflow, temperature, relative humidity, and condensation can affect cave conditions, natural and cultural resources, and park infrastructure. Cave atmospheric conditions are also altered by visitor activities, modifications of entrances, surface activities, and changing climate.

### Physical Cave Features

Mammoth Cave is a nonrenewable resource that lacks natural regenerative processes; therefore, potential impacts from management activities can be permanent. For example, damage to irreplaceable cave features, including graffiti and the physical degradation of cave surfaces, have occurred and continue to occur. Similarly, extremely fragile speleothems are vulnerable to accumulated dust and lint, which can also negatively affect cave aesthetics. Current and previous tour infrastructure has impacted numerous cave surfaces, mostly near trails. Electric lighting along trails has encouraged the unnatural growth of algae and other lamp flora in some areas. Although some changes in lighting have occurred to reduce the growth of such lamp flora, it continues to grow (more slowly) and continues to require monitoring and mitigation.

### Water Resources

Activities adjacent to and within park boundaries (e.g., industry, agriculture, infrastructure development, transportation corridors, sewers, stormwater runoff, increasing impervious cover) can threaten water quality, which affects sensitive karst formation, cave habitats, and threatened and endangered species. Changes to surface and groundwater quantity and flow regimes connected to dams, development, and oil and gas production can also disrupt habitats and affect natural and cultural resources found in the park's caves.

### Paleontological Resources

Accidental or intentional damage from travel off trail, trail construction, and modification of cave surfaces impact cave paleontological resources. Lint and dust accumulation may impact surface cave paleontological resources (such as mummified bats) and also make them more difficult to see and avoid off trail. Natural degradation in the cave environment is also likely to continue impacting paleontological resources.

### Cultural Resources

The Mammoth Cave Historic District, listed on the National Register of Historic Places in 1991, includes trails and cave passages as contributing resources, with some historic routes dating back to the 19th century. Other portions of the historic tour routes contain infrastructure constructed by the Civilian Conservation Corps in the 1930s and the National Park Service during the Mission 66 initiative. Some cave trails, particularly those with a dirt surface, are prone to dust deposition, which negatively impacts natural and cultural resources in certain areas. Cave use by visitors, park staff, cooperators, and researchers, have cumulative effects to the cave's natural and cultural resources. The introduction of foreign material and moisture on organic archeological remains have resulted in rapidly increased decomposition after centuries of stable preservation. Activities that occur off cave trails have a potential to adversely affect the condition and context of archeological materials. Vandalism (including graffiti) and cave trespass from designated tour trails have the potential to adversely affect the built features within the caves.

### Appropriate Access, Visitor Use, and Visitor Experience

The park is challenged to provide adequate opportunities for visitors, researchers, and staff to experience cave resources in a sustainable and appropriate manner. With increasing visitation, it becomes more difficult to meet visitor demand. Current cave use and tour routes may be unable to meet future visitation levels in a manner that provides a meaningful visitor experience and adequate resource protection. Challenging topics related to this issue include the following:

- tour size, seasonality, variety, and frequency
- providing adequate visitor facilities in the cave
- maintaining an environment for visitors and staff that reduces harmful interactions
- resource protection
- park-sponsored, large-scale special events
- cave zoning and acceptable uses in caves
- gating caves as appropriate to control non-authorized visitation
- evaluating requests of non-NPS special-use permits for activities in the caves
- managing exploration and mapping of park caves
- managing access for research

## IMPACT TOPICS CONSIDERED BUT DISMISSED FROM FURTHER ANALYSIS

The following impact topics are not analyzed because they do not exist in the cave, they would not be affected by the proposal, the likelihood of impacts are not reasonably expected, or mitigation measures would ensure there would be minimal adverse effects from the proposal.

### Air Quality

The federal Clean Air Act (42 United States Code [USC] 7401 et seq., as amended), stipulates that federal land managers have an affirmative responsibility to protect a park's air quality from adverse air pollution impacts. Air quality is currently monitored throughout the park and would not be affected by any of the proposed actions in this environmental assessment, so this topic was dismissed from consideration.

## Soils

In the context of impacting cave and karst resources and processes, soils along cave tour routes addressed in this plan have not been subjected to soil-forming processes and would therefore not be impacted by proposed management actions. Impacts to related cave sediments are considered under the Physical Cave Features impact topic.

## Wetlands and Floodplains

Executive Order 11990, Protection of Wetlands, requires an examination of impacts to and protection of wetlands. Executive Order 11988, Floodplain Management, requires all federal agencies to take action to reduce the risk of flood loss; to restore and preserve the natural and beneficial values served by floodplains; and to minimize the impact of floods on human safety, health, and welfare. The NPS Director's Order 77-1 (Wetland Protection) implements Executive Order 11990, and Director's Order 77-2 (Floodplain Management) implements Executive Order 11988. Proposed project actions are not located near or in any wetlands or floodplains; therefore, this topic was dismissed from consideration.

## Soundscape

While the cave soundscape could be impacted by additional visitor-created noise and management activities from reopening cave tours, impacts would be of low intensity. Some surface types (e.g., boardwalks) that could be installed in future efforts outside the scope of this plan, would be noisy when large tour groups walk over them, but there are other noises from tour groups that also occur. The proposed action would not substantially affect natural ambient sound in the long term; therefore, soundscape was dismissed as an impact topic in this environmental assessment. The impacts of noise on macrobiota, special status species, and visitor experience are discussed under each of those topics.

## Socioeconomic Environment

Management activities associated with the proposed action would have negligible impacts on the local economy as there would be no definitive changes in employment opportunities or revenues for local businesses. No long-term impacts on the local economy would occur as a result of the project. Therefore, this topic was dismissed from further analysis in this environmental assessment

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# Chapter 2

## Alternatives

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# CHAPTER 2: ALTERNATIVES

## INTRODUCTION

The Council on Environmental Quality (CEQ) regulations for implementing the National Environmental Policy Act requires that federal agencies explore and objectively evaluate all reasonable alternatives to the preferred alternative, and briefly discuss the rationale for eliminating any alternatives that were not considered in detail. This chapter describes the no-action alternative, and an action alternative that would meet the purpose and need of this management plan.

The no-action alternative would continue current management and provides a basis for comparing the effects of the other alternatives. The action alternative—which is also the preferred alternative for this plan—is based on recommendations of an interdisciplinary planning team and from public feedback. The action alternative presents the park's preferred approach to address the plan's purpose and need.

In addition, this chapter includes strategies for managing the cave system's natural and cultural resources, and for developing mitigation measures.

## NO-ACTION ALTERNATIVE

The no-action alternative represents current conditions and management of the park's cave and karst system. This alternative provides a baseline comparison for the action alternative.

### Cave Tours and Routes

There are currently a number of tour options that seek to meet visitation levels from recent years. Under the no-action alternative, the park would follow current management guidance regarding the number of visitors it can serve for each tour, while providing a range of cave opportunities that accommodate large tours as well as more immersive experiences. Managers would focus efforts on larger tours and peak seasons to meet public demand and maintain the current level of resource protection.

A list of cave tours currently available at the park is provided below. Further details on the tour lengths and capacities are provided in chapter 3.

- Historic
- Domes and Dripstones
- Frozen Niagara
- Mammoth Passage
- Discovery
- Gothic
- Grand Avenue
- Accessible
- Great Onyx
- Broadway
- River Styx
- Cleaveland Avenue
- Violet City Lantern
- Wild Cave
- Introduction to Caving
- Trog
- Star Chamber
- Focus
- Extended Historic

### Cave Management Zones

Under the no-action alternative, the direction established in the 1983 general management plan would continue. For example, the park's six cave zones established in the general management plan would continue to guide which routes are available for public tours, scientific study, and exploration. These zones are described in this section.

**GMP Zone A.** This zone includes developed areas and facilities that can accommodate concentrated uses, events, and interpretive opportunities for a large number of visitors. Areas are designed to provide important visitor services and amenities.

*Examples:* Snowball Room, Grand Central Station, comfort stations, elevator portal, Methodist church, and Rafinesque Hall.

**GMP Zone B.** This zone includes electrically lighted and fully developed passages. Developments include trails, bridges, steps, stairways, and handrails. Guides accompany all parties, which have a maximum of 120 visitors.

*Examples:* Cleaveland Avenue and Broadway.

**GMP Zone C.** This zone includes partially developed passages and passages that were once developed and are now abandoned. Trails range from "good condition" to "somewhat primitive." Overall development is limited to infrastructure essential for visitor safety; there is no electric lighting. Such passages provide a "wild cave" experience for visitors without training in caving techniques. Lighting is by handheld lanterns and tour sizes are limited to 25 to 40 visitors per guide, depending on the passage.

*Examples:* Nickerson Avenue; Fox Avenue; old commercial routes in Colossal, Crystal, Great Onyx, and Proctor Caves; and the back part of Salts Cave.

**GMP Zone D.** Passages in Zone D are defined as "natural." Only those visitors with requisite caving experience and equipment are permitted to explore this zone. Caves are not improved with the exception of known hazardous areas. Small party sizes are required.

*Examples:* Columbian Avenue, Pohl Avenue, and the front part of Salts Cave.

**GMP Zone E.** Zone E includes portions of the cave systems reserved for scientific study and exclusively approved for exploration. The zone includes "pristine" passages that would be irreparably damaged by heavy use. Temporary access to Zone E may be obtained in specific passages by scientists conducting approved projects.

*Examples:* Paradise passage in New Discovery; portions of Upper Turner Avenue, White Cave, and Long Cave (in winter).

**GMP Zone F.** Cave areas containing highly sensitive, fragile, rare natural and/or cultural features are in Zone F. They may also be located in Zones B through E. Special measures should be taken to ensure their protection and preservation, including strict limits on visitation. In general, any entry into these areas should be rare, infrequent, and by the minimum number of people necessary to accomplish specific goals of an approved trip. All entry must be closely supervised by NPS personnel or designated partners who are intimately familiar with the fragile nature of resources in these areas. Great care must be exercised to stay on designated, previously used paths. Permitted entry into Zone F areas must be specifically and explicitly authorized by the superintendent, and only after careful consideration.

## ACTION/PREFERRED ALTERNATIVE

The preferred alternative is defined in U.S. Department of the Interior NEPA regulations as the alternative that the National Park Service determines "would best accomplish the purpose and need of the proposed action while fulfilling its statutory mission and responsibilities, giving consideration to economic, environmental, technical, and other factors" (43 Code of Federal Regulations [CFR] 46.420(d)). Identification of a preferred alternative is within the discretion of the National Park Service. The recommended preferred alternative is the action alternative because it would best address the purpose and need for the proposed action.

When identifying a preferred alternative, it is important to note that no final agency action is being taken. The purpose of identifying a preferred alternative is to let the public know which alternative the agency believes would best meet the purpose and need for the plan at the time an environmental assessment is released.

## Cave Tours and Routes

Under the preferred alternative, the park would provide a range of visitor opportunities that highlight various resources and cave areas. Management actions would include the following:

- Evaluate expanding the types of tour options available by making infrastructure improvements to certain tour routes.
- As possible, provide a variety of guided cave opportunities that range from no previous experience to advanced caving opportunities using current and previous routes.
- Present cave tour options in a manner that would make trip planning less confusing for visitors and help ensure they choose a tour that is aligned with their desired experiences and skill level.
- Provide permitted opportunities for scientific study, exploration, and special uses.
- Increase available tour routes at various times of the year (e.g., off-peak visitation periods during spring and fall shoulder seasons) and non-peak times of day.
- Consider offering tours that explore different portions of the cave system.
- Optimize appropriate use levels (e.g., visitor capacity) for tour routes and cave areas that provide visitor opportunities and protect resources.
- Enhance regional partnerships to improve how visitors gain information on additional cave tour opportunities in the park and in the area if their desired experience is not available at Mammoth Cave National Park.
- Revise cave zoning (from that of the 1983 general management plan) to best protect cave resources while sustaining public enjoyment and educating visitors.

The following seven cave tours are proposed to be reopened:

- Wondering Woods
- Crystal Cave
- Colossal
- Colossal to Bedquilt
- Marion Avenue
- All day (Option A: Historic Tour Route to Violet City to Carmichael to Frozen Niagara; Option B: Historic Tour Route to Bridge [inflatable rafts] over River to Frozen Niagara)
- Cathedral Domes

## Cave Management Zones

Revising cave zoning would assure that park activities occur in the areas where they are most suited. The 1983 general management plan includes a cave zoning system that is designated by the letters "A" through "F" in descending order of intensity of use and development (see figure 4 in appendix A). These zones, as outlined and defined in the general management plan, would be retained under the no-action alternative, while proposed zoning in the preferred alternative zones would be condensed into three zones with an overlay to better capture areas with similar management approaches (see figure 5 in appendix A).

Proposed Zone A would include current Zones A and B (from the 1983 general management plan). Proposed Zone B would be largely the same as current Zone C. Proposed Zone C would cover approximately the same area as current Zone D. The Restriction Overlay in the proposed zoning would be fundamentally similar to combining current Zones E and F. Newly discovered caves and passages would be classified as Zone C, unless resources in the area indicate that a "Restriction Overlay" designation is warranted. A more detailed description of the proposed zones is provided below.

**Proposed Zone A.** Proposed Zone A includes public tour areas of the cave that have major development for walking (or accessible) tours and electric lights and could include a telephone communication system. It supports concentrated use designed for visitor comfort and convenience. This zone contains infrastructure that can accommodate events and interpretive opportunities for a large number of visitors. It would accommodate users with varying experience and physical abilities, including large groups, and areas for large gatherings. Visitors in this zone would be immersed in the sights and sounds of the cave; however, at times the sounds of other people may dominate, and visitor-caused impacts may be visible to cave resources. In appropriate areas, opportunities for special events would be available in this zone with a permit.

*Examples:* Cleaveland Avenue, Snowball Room, Kentucky Avenue, Grand Central Station, Frozen Niagara, Boone Avenue, Rafinesque Hall, Houchin's Narrows, Broadway, Main Cave, Blacksnake Avenue, Fat Man Misery, Great Relief, Sparks Avenue, Mammoth Dome, Little Bat Avenue, and Audubon Avenue.

**Proposed Zone B.** Proposed Zone B would provide for a more primitive cave experience and would require handheld lanterns or flashlights, and/or headlamps. Moderate development including formalized trails may also occur in this zone in order to improve resource conditions; however, visitors may need to prepare for potentially challenging conditions. Approved educational groups and activities may occur in this zone. This zone could provide visitors with an opportunity to learn basic caving skills and necessitate the use of appropriate caving gear. Use would be managed to protect and enhance the natural function, diversity, complexity, and resiliency of the cave. Sights and sounds of the cave, along with personal interpretive opportunities, should dominate this experience. This zone could provide for a more intensively primitive cave experience; however, at times some visitor-caused impacts or developments may be experienced. In appropriate areas, opportunities for research would be available in this zone with a permit.

*Examples:* Main Cave from Star Chamber to Violet City, Great Onyx Cave, Clark Avenue, Cathedral Domes, Becky's Alley, Nickerson Avenue, Big Break, Ganter and Jessup near Wooden Bowl, El Ghor-Silliman Avenue, Woodbury Pass, Colossal Entrance to Bedquilt Route, Historic Crystal Cave Trails, Historic Proctor, Long Cave, Upper Salts Cave, Olive's Bower, Briggs Avenue, Black Chambers, Blue Spring Branch, Echo River (end of Styx Catwalk to Minnehaha), Pensacola Avenue, Sylvan Avenue, Emily's Avenue, Wondering Woods Cave, Dixon Cave, Pohl Avenue, Turner Avenue, New Discovery (main passage to end of trail development with potential extension to Big Paradise), Owl Cave, Fort's Way, and Roaring River.

**Proposed Zone C.** Proposed Zone C would provide for a more intensively primitive cave experience, which is reflective of the conditions experienced by earlier cave explorers. These caves/passages are undeveloped and entered less frequently. It would encompass most of the Mammoth Cave system in the park as well as most of the other caves in the park. Minimal development would occur in this zone, mostly limited to narrow trails for traversing areas or minimal modifications for safe exploration, mapping, research, or management. The result would be a more physically demanding and challenging experience. Trail routes would not necessarily be marked. The primary users of this zone would be NPS resource managers and researchers with caving skills and experience. Most human modifications would not be authorized, except those needed for resource protection or safety. This zone would afford opportunities to study areas of the cave systems that have been minimally impacted by human activity. A permitting process would be used to determine appropriate uses and exploration activities in this zone and would not generally be available to the public. It would include newly discovered caves/passages that would be surveyed and assessed by highly skilled cavers and resource experts. In appropriate areas, opportunities for research would be available in this zone with a permit.

Newly discovered caves and passages would be classified as Zone C, unless resources in the area indicate that a "Restriction Overlay" designation is warranted.

*Examples:* East Bransford Avenue, Carlos Way, River Acheron, Miller Avenue, Proctor Cave (from Proctor Crawl), Logsdon River, Bridge Avenue, Colossal River, Candlelight River, Lower Salts, Ball Trail, The Overlook, Waterfall Trail, Gravel Avenue, Lee Cave, Wilson Cave (other than historic section), Running Branch Cave, Little Beauty Cave, Dennison Cave, Smith Valley Cave, Sand Cave, Bat Cave (other than A-survey), Luna Cave, Fort's Funnel, and Silent Grove Springhouse Cave.

**Proposed Restriction Overlay Zone D.** This overlay is necessary to designate exceptional areas that require seasonal and/or special conditions for entry. This overlay would be managed to restrict resource impacts and is designed to protect pristine caves/passages with highly sensitive resources or specific resources that require additional safeguards and would be tailored to specific areas. This overlay could also designate areas where protection is needed from dangerous conditions. As environmental conditions change within the caves/passages, the overlay areas or restrictions may be modified.

Note: Caves/Passages could move zones if conditions and/or technology changes allow.

*Examples:* Seasonal bat closures, bat restrictions all year (summer negotiable), archeological restrictions, historic resources, delicate formations or minerals, **and areas with** safety concerns.

## Desired Conditions for Updated Cave Zones

As noted in chapter 1, desired conditions are defined as statements of aspiration that describe resource conditions, visitor experiences and opportunities, and facilities and services that an agency strives to achieve and maintain in a particular area. In this plan, desired conditions described in previous plans (such as the general management plan) have been considered and provide high-level guidance. To provide specific guidance for cave zone updates in the proposed action for this plan, desired conditions for visitor use and experience are further articulated by zone (A through D), below.

**Cave Zone A.**

- Provide visitors with opportunities for a variety of experience levels and physical abilities while also being immersed in the sights and sounds of the cave where social recreation experiences are appropriate.
- Provide opportunities for special events and interpretive tours for large groups of people.

*Example Cave Areas:*

- Cleaveland Avenue, Snowball Room, Kentucky Avenue, Grand Central Station, Frozen Niagara, Boone Avenue, Rafinesque Hall, Houchin's Narrows, Broadway, Main Cave, Blacksnake Avenue, Fat Man Misery, Great Relief, Sparks Avenue, Mammoth Dome, Little Bat Avenue, and Audubon Avenue.

**Cave Zone B.**

- Provide visitors with a cave experience where the sights and sounds of the cave would dominate the experience.
- Provide opportunities for research, in appropriate areas.

*Example Cave Areas:*

- Main Cave from Star Chamber to Violet City, Great Onyx Cave, Clark Avenue, Cathedral Domes, Becky's Alley, Nickerson Avenue, Big Break, Ganter and Jessup near Wooden Bowl, El Ghor-Silliman Avenue, Woodbury Pass, Colossal Entrance to Bedquilt Route, Historic Crystal Cave Trails, Historic Proctor, Long Cave, Upper Salts Cave, Olive's Bower, Briggs Avenue, Black Chambers, Blue Spring Branch, Echo River (end of Styx Catwalk to Minnehaha), Pensacola Avenue, Sylvan Avenue, Emily's Avenue, Wondering Woods Cave, Dixon Cave, Pohl Avenue, Turner Avenue, New Discovery (main passage to end of trail development with potential extension to Big Paradise), Owl Cave, Fort's Way, and Roaring River.

**Cave Zone C.**

- Preserve a minimally traversed cave environment—one that is reflective of the conditions experienced by earlier cave explorers and where the cave system has been minimally impacted by human activity.

*Example Cave Areas:*

- Examples from within the Mammoth Cave system include East Bransford Avenue, Carlos Way, River Acheron, Miller Avenue, Proctor Cave (from Proctor Crawl), Logsdon River, Bridge Avenue, Colossal River, Candlelight River, Lower Salts, Ball Trail, The Overlook, Waterfall Trail, and Gravel Avenue.
- Other notable caves include Lee Cave, Wilson Cave (other than historic section), Running Branch Cave, Little Beauty Cave, Dennison Cave, Smith Valley Cave, Sand Cave, Bat Cave (other than A-survey), Luna Cave, Fort's Funnel, and Silent Grove Springhouse Cave.

**Overlay Zone D.**

- This zone overlays the appropriate zone assigned to a passage. It is intended to protect specific resource conditions and may require special conditions for entry. Such restrictions or conditions in Overlay Zone D can be seasonal or occur throughout the year and may vary depending on the level of protection needed to protect a specific resource. The following is a list of some justifications for closures and a few examples of passages with special conditions. Neither the reasons for closure nor the examples represent an exhaustive list. The park maintains a list of passages with restrictions and discusses those restrictions with those seeking to enter those areas under appropriate permits.

*Reasons for Closure and Examples:*

- Seasonal Bat Closure (hibernation or maternity use) – Colossal Cave (Grand Avenue and Colossal Entrance), Bat Cave, Cathedral Cave, and Blight Cave.
- Bat Restrictions All Year (summer negotiable) – Long Cave and Dixon Cave.
- Archeological Resources – Watson Trace and Salts Trunk.
- Historic Resources – TB Huts, Saltpeter Vats, and New Discovery (CC trail).
- Delicate Formations or Minerals – Little Paradise.
- Safety Concerns – Sand Cave.

## RESOURCE MANAGEMENT

High-priority resource management strategies in this plan would address critical needs to more comprehensively manage visitor access, improve research, protect water quality, sustain natural airflow, protect cultural resources, and maintain cave biotic communities in the cave environment. Strategies would be implemented to protect natural and cultural resources by reducing illegal cave entry; reduce humidity, condensation, and algal growth; encourage improved hydrologic practices above ground to protect subsurface resources; maintain cave protection during construction, maintenance, survey, and research; and decrease trespass and vandalism. Strategies would also be implemented to mitigate and restore areas where cave and karst resources have been previously degraded.

One of the primary needs for responsible management is developing and implementing a comprehensive algae management program. Such a program would include a systematic monitoring plan to incorporate indicators and thresholds, and a mitigation plan for remediated and ongoing algae control.

Protecting water quality and quantity is a vital step to properly protecting a karst landscape. The plan seeks to provide a strong basis for such protection. Park operations would attempt to minimize impacts on water quality by—among other actions—maintaining and improving stormwater management, upgrading sanitary sewer, and limiting the use of hazardous chemicals in situations where they could get into the groundwater. Where appropriate, artificial entrances may be modified to limit inappropriate water flow. Because much of the drainage basin for Mammoth Cave is located outside of the park boundaries, the park would continue its broader efforts to work with the Federal Highway Administration, railroads, and state and county agencies to incorporate efforts along interstates and roadsides to maintain or improve stormwater management practices and protect the regional groundwater from contamination. Continuing the parks dye-tracing and research programs to further understand hydrology within the karst environment is another resource management effort.

Sustaining natural airflow to caves is an overarching resource management necessity the plan addresses by acknowledging the need for future airflow restoration actions such as airlock installations or reopening older areas that provided historical airflow at specific cave entrances. Monitoring cave airflow and climate are important tools for determining appropriate airflow restoration projects.

As noted, protecting resources by managing access is a need the plan would address. The plan would define appropriate access pathways and provide information on how to manage access when it is permitted. For example, illegal cave entry/trespass would be reduced by placing gates at the cave passages most vulnerable to trespass. Gate installations would follow the park's rigorous gating standards and guidelines that include "bat-friendly" gate designs and materials and would be considered within the context of broader resource protection tools (permits, law enforcement patrols, special use permits, etc.)

Similarly, vandalism and other visitor-caused impacts that negatively impact natural and cultural resources would be limited by implementing visitor capacities on park-guided cave tours and controlling access with park-approved permits. Improving trail boundaries and continuing to harden certain sections of walking surfaces would reduce off-trail activities and inadvertent damage to resources.

Other management strategies—including several that have shown success in their initiation—comprise installing lint curbs to trap lint and improving orientation of best cave management practices for park staff, contractors, and research permittees.

To protect resources in cave areas that are not toured, the plan would provide guidelines for determining appropriate activities in areas off of tour trails. These areas include some portions of Zone B and Zone C. The plan includes guidelines and standard operating procedures for use of these areas.

## MITIGATION MEASURES RELATED TO PROJECT IMPLEMENTATION

For the action alternative, best management practices and mitigation measures would be used to prevent or minimize potential adverse effects associated with cave and karst management activities proposed in this plan. Mitigation measures undertaken during project implementation would include, but would not be limited to, those listed below. The impact analysis in Chapter 4: Environmental Consequences was performed assuming that these best management practices and mitigation measures would be implemented as part of the action alternative.

- To the extent possible, construction and maintenance activities (such as those involving structural upgrades to mitigate impacts due to water infiltration or gate maintenance and construction) in areas with sensitive wildlife would be timed to avoid sensitive wildlife periods, such as breeding seasons and bat hibernation periods.
- Lint and dust mitigation measures, such as periodically removing lint and other foreign materials from some of the heavily traveled tour routes, would continue to be implemented and these areas would be monitored for accumulation. Where applicable, lint curbs and railing would be maintained or installed to control the migration of potentially harmful dust, lint, and other small debris distributed by visitors.
- Dust abatement measures would be implemented to minimize the spread of dust during cave-enhancement activities. Where applicable, continue to install hardened surfaces to help control dust. Where appropriate, older dust can be removed to limit on-going damage to cave resources and aesthetic values.
- Where applicable, old lighting in algae-prone sections of the cave would continue to be replaced with advanced lighting intended to limit the growth of lamp flora. Lamp flora would continue to be routinely removed, where necessary.
- Park staff would coordinate with the regional sewer system operator to implement mitigation measures and reduce threats to water quality.
- To minimize the possibility that construction equipment (limited to propane or electric powered equipment) could leak fluids, introduce noise pollution, or emit pollutants, equipment would be checked frequently to identify and repair any leaks, mufflers would be

checked for proper operation, and only equipment that is within proper operating specifications would be used.

- All excess debris and foreign material resulting from construction, maintenance, and research activities would be removed from the cave for legal and proper disposal.
- Cave personnel and equipment would be subject to stringent decontamination protocols as needed to prevent the introduction and spread exotic species into the cave.
- All visitors and staff using non-electric lanterns would be trained in their operations and follow an approved job hazard analysis. Those using liquid fuels would be required to take extreme care not to spill any fuel in the cave system. All fueling would take place outside the cave. All users would take appropriate steps to mitigate safety and environmental hazards associated with their use and report any fuel spills in the cave to the park's Chief of Science and Resources Management according to the park's Spill Prevention, Control, and Countermeasure Plan (NPS 2006b).
- The park's Spill Prevention, Control, and Countermeasure Plan would be updated to prevent the discharge of hazardous substances near cave resources. The plan's countermeasures for managing a discharge would be updated as well.
- Infrastructure needed for cave-enhancement projects—such as curbs, railings, signs, and stairs—would be designed and located to minimize adverse impacts on the character and features of the cultural landscape. Similarly, new facilities would be compatible with the historic character and material of the landscape and would be designed and located to minimize adverse impacts on cave biotic communities.
- Materials needed for cave-enhancement or maintenance projects—such as curbs, railings, signs, stairs, and lighting fixtures—would be chosen to minimize adverse impacts to the cave (through outgassing, decomposition, or leaching of toxic substances)
- Chemical used in the cave or near cave entrances for cleaning, maintenance, or construction would be selected and used to minimize impact to the cave. Appropriate precautions would be taken to avoid spills. All chemicals would be disposed of properly and safely to protect cave organisms. All spills would be promptly cleaned up and reported to Resource Management for further evaluation and potential remediation.
- Check dams, stormwater filters, or water control structures would be installed to reduce potential for impacts on water quality in areas prone to spills, sewer breaks, or other water quality issues

## General

- Resource management staff would provide all contractor employees with an orientation/briefing that would inform them of relevant natural and cultural resource issues and the importance of minimizing impacts. The resource management division would be notified and consulted when wildlife, cave features, or artifacts must be disturbed or handled.
- To the extent possible, any construction, development, or other enhancement activities would be scheduled to minimize construction-related impacts on visitation and wildlife behavior.
- All staging and stockpiling areas would use existing laydown areas to the extent possible and be rehabilitated to natural conditions following any construction or enhancement activities.
- All tools, equipment, surplus materials, and trash would be removed upon project completion. Any construction debris would be sanitized to prevent potential spread of disease from the cave and hauled from the park to an appropriate disposal location.

## Natural Resources

- Access to the park's caves would be provided to the following user groups:
  - visitors with tour tickets (approved for on-trail visitation in the area and time indicated by the tickets)
  - approved educational tours and activities

  - researchers working under approved permits, cooperative agreements, contracts, or park administrative actions
  - people under approved special use permits
  - contractors working in the cave (access allowed for areas needed for specific contracted project)
  - park staff and approved cooperators working under park administrative actions
- Exploration, mapping, and research activities would be pursued in a manner that minimizes impacts to the cave and cave resources. Activities would minimize unnecessary disturbance of cave floors and walls. Modifications needed for research or exploration (such as placing permanent mounts for equipment, bolting, or digging) would be considered on a case-by-case basis. Permanent station markers and cave brass caps should be placed to avoid impacting cultural resources. Other than small amounts of exploration needed for reconnaissance, newly discovered cave areas would be surveyed as they are explored.
- Newly found caves would be reported to Science and Resource Management for evaluation.
- Per NPS standards, NPS managers would coordinate and supervise any construction and maintenance activities. Specifically, park staff would monitor or direct proposed maintenance and mitigation activities in particularly sensitive portions of the cave; proposed enhancement activities such as stairway and handrail maintenance; where to obtain fill and other materials for enhancements; and how to apply fill materials such as soil, gravel, and rocks. Park staff would be responsible for ensuring that crews perform the necessary work in accordance with NPS instructions and standards.
- Surface trail enhancements would avoid excessively steep slopes to minimize erosion. To provide for soil stability and prevent movement of soils, erosion control features such as rock walls and rolling dips would be used where appropriate.
- On the surface, where runoff might impact the cave, soil erosion would be minimized by limiting the time soil is left exposed and by applying erosion control measures such as erosion matting, silt fencing, and catchment basins in construction areas to reduce erosion, surface scouring, and discharge to drainages.
- Within the cave, only clean fill (dense grade, sand, etc.) would be used as fill. Fill derived from deposits in the cave would only be used with project-specific approval detailing amount of fill to be used, specific areas approved for use, and specific areas approved as the source of fill.
- Pest and pathogen monitoring and treatment would be conducted prior to and following any construction or enhancement efforts.
- Native materials would be salvaged and reused during project implementation.
- All equipment entering the park would be cleaned and pressure washed if necessary to remove foreign soil or outside debris
- When construction or other activities requiring ground disturbance occur in cave entrances, plant and wildlife surveys would be conducted by qualified biologists prior to ground disturbance to ensure activities do not destroy or alter special or rare vegetation, plant communities, sensitive wildlife, or important habitat. If special status or rare plants are discovered, they would be clearly flagged and avoided when possible. If avoidance is impossible, park managers would consult with experts and measures would be considered to avoid or minimize impacts (e.g., transplantation).
- For work within the cave, wildlife surveys would be conducted by qualified biologists prior to ground disturbance to ensure reroutes and new trail routes do not destroy sensitive wildlife or important habitat. If special status or rare animals are located, they would be avoided when possible. If avoidance is impossible, park managers would consult with experts and measures would be considered to avoid or minimize impacts (e.g., relocation).
- Care would be taken to avoid or minimize disturbance of sensitive wildlife species such as bats known to inhabit tour routes. Resource management personnel would be notified or consulted when wildlife must be disturbed or handled.
- Where possible, natural features with obvious high value to wildlife would be preserved (e.g., small pools, cricket guano patches, bat roosting areas).
- Trash and food waste would be removed daily from worksites to avoid attracting wildlife.

- When necessary, park managers would use temporary or seasonal visitor use restrictions or area closures to protect sensitive wildlife habitat, sensitive wildlife behavior, life stages, cultural resources, or cave minerals. That is, park managers would add areas to the "Restricted Overlay" zone as necessary to protect natural and cultural resources,

## Cultural Resources

- Areas without previous cultural resource identification or containing potentially significant archeological or paleontological resources would be monitored by a qualified archeologist or paleontologist during trail construction activities to prevent disturbance of highly significant deposits and to recover samples of scientifically important materials. For off-trail survey and research activities, those same areas would minimally require a briefing by a qualified archeologist regarding the identification and avoidance of significant archeological resources. Significant archeological resource deposits would include dense concentrations of torch remains (beyond the normal background of torch charcoal that is scattered throughout the cave) or archeological materials of rare occurrence in the cave (e.g., cordage, textile fragments, paleofeces, bone deposits, climbing poles, ladders, lanterns, cans, bottles, other artifacts associated with intensive periods of prehistoric or historic activity in the cave).
- Recommendations for areas identified to have high potential for archeological or paleontological resources include a broad range of possible actions, all of which are designed to minimize the effect of proposed trail rehabilitation construction on intact archeological or paleontological deposits. At a minimum, monitoring would be conducted in high-potential areas. Efforts would be made to avoid, minimize, or mitigate effects to cultural and paleontological resources. Among these options are
  - monitoring by a qualified archeologist or paleontologist
  - avoidance, where possible
  - burial of deposits to preserve them from impact
  - bridging over significant areas or otherwise altering the trail construction techniques to minimize disturbances of deposits
  - data recovery through expanded archeological or paleontological excavations
- Should an activity encounter previously undiscovered cultural resources, any activity that might disturb cave floorwork would be stopped in the area of the discovery and park managers would consult with the state historic preservation officer and the Advisory Council on Historic Preservation, as necessary, according to 36 CFR 800.13. In the unlikely event that human remains, funerary objects, sacred objects, or objects of cultural patrimony are discovered during any construction activities, provisions outlined in the Native American Graves Protection and Repatriation Act (25 USC 3001) of 1990 would be followed.
- Infrastructure needed for future cave enhancement, such as curbs, railings, signs, and stairs, would be designed and located to minimize adverse effects on the character and features of the cultural landscape. Every effort would be taken to ensure new construction and components related to infrastructure and visitor safety would be compatible in their materials, color, and texture with historic materials to the extent possible.
- All work that may affect cultural landscapes would be evaluated by a historical landscape architect and other professionals, as appropriate.
- NPS staff would continue to inform visitors and others of the importance of protecting and not disturbing archeological and historic resources. Visitors would be informed (through NPS educational and interpretive programs and/or interpretive media products, and ranger contacts) of the penalties for causing resource damage.

## Visitors

- NPS staff would implement measures to reduce adverse effects of construction on visitor safety and experiences. Measures may include, but are not limited to, noise abatement, visual screening, and directional signs that aid visitors in avoiding construction activities.
- Appropriate barriers and barricades would be used to clearly delineate work areas and provide for safe visitor travel near construction areas.

- Barriers and signs would be used to deter visitor travel on trails being rerouted to allow restoration of these areas.

## PRELIMINARY OPTIONS CONSIDERED BUT DISMISSED FROM DETAILED EVALUATION

While developing each alternative, it became evident that certain actions, alternative concepts, or strategies were not appropriate to fully analyze in the environmental assessment. Certain alternatives can sometimes be considered but eliminated from further study for a variety of reasons. Eliminated alternatives are limited to those that were initially thought to be viable or suggested by the public, but later dismissed. According to the NPS Director's Order 12 Handbook, reasons to eliminate alternatives include the following:

- Technical or economic infeasibility, meaning the alternative could not be implemented if it were selected or would be unreasonably expensive.
- Inability to resolve the purpose and need for taking action, to a large degree.
- Duplication with other, less environmentally damaging or less expensive alternatives.
- The alternative conflicts with an up-to-date and valid park plan, statement of purpose and significance, or other policy, such that a major change in the plan or policy would be needed.
- The alternative would require a major change to a law, regulation, or policy.
- There would be too great of an environmental impact.
- The alternative addresses issues beyond the scope of the NEPA review.
- The alternative would not be allowed by another agency from which a permit is required; therefore, it should be eliminated as "environmentally infeasible."

### Action Alternatives Considered but Dismissed from Detailed Evaluation

**Constructing new cave-trail routes.** Constructing a new trail in previously undisturbed cave passageways has the potential to significantly impact natural and cultural resources located on and adjacent to any new trail routes. Effects of construction and visitor activities in previously undisturbed sections of the cave would require detailed assessment of the potential impacts to both natural and cultural resources as well as the overall environmental impacts. Establishing new tour routes in previously un-toured parts of Mammoth Cave would be undesirable from a resource management perspective and costly. The preferred action alternative considers reopening historic routes that are not currently in use, which would duplicate the desired outcome of creating new routes by allowing for additional visitor experiences and attempting to accommodate current and future use levels, but would be less expensive to implement and has less potential to damage the cave environment. Because of these reasons, the construction of new cave-trail routes was dismissed from further consideration.

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# Chapter 3

## Affected Environment

**CHAPTER 3 DIVIDER (BACK PAGE)**

# CHAPTER 3: AFFECTED ENVIRONMENT

This chapter describes the affected environment (existing setting or baseline conditions) and the resources potentially affected by the alternatives. It is organized by impact topics that were derived from internal National Park Service and external public scoping. This section describes those environmental resources that are relevant to the decision being made and does not describe the entire existing environment. Only those environmental resources that could be affected by the alternatives, if they were implemented, are discussed. This section, in conjunction with the description of the no-action alternative, forms baseline conditions for determining the environmental impacts of the proposed action. Those associated impacts are further analyzed in the Chapter 4: Environmental Consequences.

## BIOLOGICAL RESOURCES

Mammoth Cave is one of the cave biodiversity hotspots in the world, with more than 160 regularly occurring species of troglobites (e.g., cavefish, flatworms), troglophiles (e.g., spiders, salamanders), and trogloxenes (e.g., cave crickets). Of these species, troglobites are fully cave adapted and cannot survive in surface habitats. Troglophiles are species that can complete their life cycle in both cave and surface habitats, and trogloxenes must exit the cave for some portion of their life cycle. Roughly one-third of these fauna are aquatic and two-thirds are terrestrial. Insects and arachnids dominate the terrestrial fauna and crustacea dominate the aquatic fauna.

The cave environment can be separated into a "twilight zone" near the entrance, a middle zone of constant darkness and variable temperature, and a zone of constant darkness and constant temperature in the deep interior. The twilight zone has the largest and most diverse fauna, the middle zone has several common species that may commute to the surface, and the deep cave contains obligate cave fauna. Most terrestrial troglobites cannot tolerate low relative humidities and disappear from twilight zones in winter.

Thirteen species of bats have been documented at the park—eight of these regularly use park caves. The historic section of Mammoth Cave was formerly one of the largest bat hibernacula in the world. This hibernaculum housed Indiana bats (*Myotis sodalis*), little brown bats (*M. lucifugus*), the tricolored bat (*Pipistrellus subflavus*), and to a lesser extent gray bats (*M. grisescens*). Although development of the cave over the past 220 years (from saltpeter mining and tourism) has largely reduced or eliminated this particular bat colony, the park still hosts about seven hibernacula for various species of *Myotis* and numerous hibernacula and maternity roosts for Rafinesque's big eared bat (*Plecotus rafinesquii*). Several species of bats are discussed further in the Rare, Threatened, or Endangered Species and Species of Interest section.

Besides the eight known bat species that use the cave, other fauna, such as the eastern woodrat (*Neotoma floridana*), help support specialized communities of flies, gnats, and beetles. Feces of the woodrat and raccoon, for example, provide an important food source for these insects.

One species in particular, the cave cricket (*Hadenoecus subterranus*), is particularly important as a keystone species in the cave's terrestrial ecosystem and supports at least two food webs. Cave crickets are obligate trogloxenes. This means that although they require the caves for survival, they must exit the cave for some portion of their lives. They exit the cave regularly to feed and then return to the cave and deposit feces. These organic rich feces provide food for a host of invertebrate species. They also breed and lay eggs in the cave. The blind cave beetle (*Neaphaenops tellkampfii*) feeds heavily on the eggs and nymphs of the cave cricket. Cave crickets have the highest density of any species in Mammoth Cave.

Several amphibians occur in the cave. Cave salamanders (*Eurycea lucifuga*) are frequently encountered in moist twilight zones. The northern slimy salamander (*Plethodon glutinosus*) is often found in the twilight zone of the cave. The zigzag salamander (*Plethodon dorsalis*) occurs seasonally in sinkholes and in shallow cave passages. Long-tailed salamanders (*Eurycea longicauda*) have occasionally been seen along the Echo River in Mammoth Cave.

Other terrestrial species in the cave include a large variety of arthropods. Insects and their allies make up a major portion of the arthropods in this cave. In addition to cave crickets, there are at least six species of troglobitic beetles, numerous springtails, a species of dipluran, several species of troglophilic diptera (flies), and species of fleas from bats. Arachnids constitute another important group of species that occur in the park's caves, including several species of spiders, three species of pseudoscorpions, numerous mites, and two species of troglobitic millipedes.

The aquatic fauna of the park's caves is also incredibly diverse. One unusual feature is that the Mammoth Cave area is one of the few places where both the northern cave fish (*Amblyopsis spelaea*) and the southern cave fish (*Typhlichthys subterraneus*) occur together. In addition, there are two troglophilic fish that occur: the banded sculpin (*Cottus carolinae*) and the springfish (*Forbesichtys papilliferus*). A variety of surface fish can also occasionally be found in the streams in the park's caves.

Crustaceans are the most diverse component of the park's cave aquatic fauna. The largest crustaceans are two crayfish and one atyid shrimp. The cave crayfish (*Orconectes pellucidus*) is a common troglobite and occupies habitats ranging from base level to tiny streams and can travel out of water if necessary. The troglophilic cavespring crayfish (*Cambarus tenebrosus*) is also moderately common in larger cave streams in the park. In addition to the crayfish, the park houses several species of troglobitic and troglophilic amphipods and isopods. Sixteen species of copepods (*Maraenobiotus*, *Moraria*, *Nitocra*, and *Parastenocaris*), tiny shrimp-like crustaceans, have been recorded in the streams and pools of the Mammoth Cave system, the majority of which are not restricted to the cave. Troglophiles and accidentals get washed in from the Green River and are found in River Styx, Echo River, Roaring River, and springs.

Perhaps the most interesting crustacean found in the Mammoth Cave area caves (and most important, from a management standpoint) is the Kentucky cave shrimp. This cave shrimp is endemic to the Mammoth Cave area. It is found only in ten groundwater basins. Eight of these basins are completely or partially within Mammoth Cave National Park and the other two are just upstream from the park. The Kentucky cave shrimp is federally listed as endangered. It occurs in a variety of base-level streams and pools in the Mammoth Cave system and other park caves. The Kentucky cave shrimp depends on good water quality for its continued survival.

Other members of the cave aquatic fauna include two troglobitic planarians (flatworms), nematodes, parasitic worms, rotifers, oligochaete worms (*Aeolosoma*), tardigrades (*Macrobiotus*), tubificid worms, and aquatic snails.

The caves of the park have a naturally occurring microbiome (microbial ecosystem). This ecosystem includes a wide variety of bacteria, archae, and fungi. Near the cave entrance there are also areas where light supports algae. In addition to this natural microbial and plant life, the toured sections of the cave can have additional, unwanted plant growth. The caves' fixed lights, placed so visitors can see, also provides light that allows the growth of cyanobacteria, algae, diatoms, and plants where the lights shine on damp or wet surfaces. These organisms are photosynthetic and could not grow without the artificial lighting. Smith and Olson (2007) identified 28 species of lamp flora, including mosses, ferns, cyanobacteria, and algae. Lamp flora, which has flourished for decades since the introduction of lighting systems, has resulted in some damage to cave resources. These pioneer species typically modify the rock surface they inhabit by producing carbonic acid (Smith and Olson 2007). This weak acid is corrosive, especially to limestone cave formations. This dissolution of cave formations can have irreversible damage on speleothems. The recent installation of a new cave lighting system has greatly reduced the growth of lamp flora on cave formations.

## RARE, THREATENED, OR ENDANGERED SPECIES AND SPECIES OF INTEREST

Mammoth Cave National Park is home to 13 federally endangered species and two federally threatened species. In addition, the park is home to unoccupied critical habitat of an additional federally endangered species. All of these species are also state listed. These species are identified in table 1 and described in Chapter 3: Affected Environment. The park also houses an additional 86 species with state listings from the Office of Kentucky Natures Preserves (appendix C). Park staff consulted with the US Fish and Wildlife Service (USFWS) during the development of the plan to identify actions that have the potential to impact federally listed species. The park will continue to consult with the USFWS on this plan and as projects associated with the comprehensive cave and karst management plan are initiated.

**TABLE 1. FEDERAL SPECIAL STATUS SPECIES AT MAMMOTH CAVE NATIONAL PARK**

| Species Type | Common Name | Scientific Name | Status* | Potential to Occur in Cave System? |
|---|---|---|---|---|
| Fish | Diamond darter | *Crystallaria cincotta* | E, KSNPC-SX | No |
| Invertebrate | Spectaclecase | *Margartifera monodonta* | E, KSNPC-E | No |
| Invertebrate | Snuffbox | *Epioblasma triquetra* | E, KSNPC-E | No |
| Invertebrate | Purple cat's paw | *Epioblasma obliquata obliquata* | E, KSNPC-E | No |
| Invertebrate | Pink mucket | *Lampsilis abrupta* | E, KSNPC-E | No |
| Invertebrate | Ring pink | *Obovaria retusa* | E, KSNPC-E | No |
| Invertebrate | Kentucky cave shrimp | *Palaemonias ganteri* | E, KSNPC-E | Yes |
| Invertebrate | Clubshell | *Pleurobema clava* | E, KSNPC-E | No |
| Invertebrate | Fanshell | *Cyprogenia stegaria* | E, KSNPC-E | No |
| Invertebrate | Rough pigtoe | *Pleurobema plenum* | E, KSNPC-E | No |
| Invertebrate | Sheepnose | *Plethobasus cyphyus* | E, KSNPC-E | No |
| Invertebrate | Rabbitsfoot | *Theliderma cylindrica* | T, KSNPC-T | No |
| Mammal | Gray bat | *Myotis grisescens* | E, KSNPC-T | Yes |
| Mammal | Indiana bat | *Myotis sodalis* | E, KSNPC-E | Yes |
| Mammal | Northern long-eared bat | *Myotis septentrionalis* | T, KSNPC-E | Yes |

* E = federally endangered; T = federally threatened; KSNPC = Kentucky State Nature Preserves Commission – E (endangered), T (threatened), SX (extirpated)

NPS guidance for species of management concern states they are "other species the park considers a species of management concern including, but not limited to, keystone species, indicator species, species harvested for sport, commercial, subsistence, or personal use, native species classified as pests, species that are deliberately and actively managed, and species for which there are significant expenditures."

The federally endangered Indiana bat is a temperate, insectivorous, migratory bat that hibernates colonially in caves and mines in the winter. The species was originally listed as in danger of extinction under the Endangered Species Preservation Act of 1966 and is currently listed as federally endangered under the Endangered Species Act of 1973, as amended. Prior to white-nose syndrome (discussed below), Mammoth Cave National Park housed seven known hibernation colonies of Indiana bats. The largest of these, in Dixon Cave, had a population estimated at more than 30,000 bats in the mid-1980s; however, populations have been falling since that peak. By 2013, fewer than 2000 Indiana bats were hibernating there. Since the invasion of white-nose syndrome, that number has continued to decline. Populations in other park Indiana bat hibernacula have likewise fallen, with the exception of the Historic Tour Route entrance area of Mammoth Cave. That roost has remained fairly stable in terms of Indiana bat numbers over the past 6 years.

The federally endangered gray bat occupies a limited geographic limestone karst area of the southeastern United States. Prior to major declines, individual hibernating populations (range-wide) contained from 100,000 to 1.5 million or more bats. With rare exceptions, gray bats live in caves throughout the year and migrate seasonally between hibernacula and maternity caves. During the winter, gray bats hibernate in a variety of large caves. In the summer, they roost in caves that are located along rivers. The gray bat was added to the US List of Endangered and Threatened Wildlife and Plants on April 28, 1976. Gray bats are endangered largely because of their habit of living in very large numbers in only a few caves; as a result, they are extremely vulnerable to disturbance. Mammoth Cave National Park houses one large hibernaculum with more than 250,000 gray bats. In addition, two more hibernacula are located on the land owned by Park Mammoth Resort near the park.

The northern long-eared bat (*Myotis septentrionalis*) is federally listed as threatened because of the impact of white-nose syndrome (discussed below). This species uses caves for hibernation and spring and fall staging. Prior to the impacts of white-nose syndrome, it was the most abundant bat in the park, according to summer capture data. However, because of white-nose syndrome, its populations at the park, again as evidenced by summer capture data, have declined more than 99%. It is now rarely found in the park or in park caves.

Mammoth Cave once housed one of the largest hibernating colonies of bats yet identified, with an estimated 9-13 million bats (primarily the Indiana and gray bats). With the arrival of European settlers in the central portion of the Indiana bat's range in the late 1700s and early 1800s, land conditions and natural resource usage began to change dramatically and undoubtedly affected the species' local and presumably regional abundance (NPS 2009). The abundance of hibernating bat populations almost certainly declined after settlers discovered large deposits of nitrates or saltpeter—essential for making gunpowder—and began year-round mining operations in some of the major hibernacula. By the 1820s, tourism had become lucrative at several major hibernacula and increased rapidly over the next 100 years. Mammoth Cave alone still held "millions" of bats in 1850 after being subjected to disturbance from saltpeter mining, tourism, and impacts associated with cave entrance alterations and restricted airflow.

Although the large colonies that previously occupied the area near the Historic Entrance are gone, bats still use the area for hibernation. Prior to white-nose syndrome, between 100 and 200 bats could be found using this area, including three listed species (the Indiana bat, gray bat, and northern long-eared bat) as well as tricolored bats, big brown bats, eastern small-footed bats (*Myotis leibii*), and Rafinesque big-eared bats. In the most recent count (February 2019), only about 90 bats were found in the area of the Historic Tour Route; however, more than half were Indiana bats.

White-nose syndrome in bats is a devastating disease caused by an invasive, exotic fungus (*Pseudogymnoascus destructans*). Since it was introduced to North America from Eurasia in approximately 2005, it has expanded from one county in upstate New York to the eastern half of the country and two counties in Washington state. The disease affects at least 11 species of bats in North America including seven at the park. The disease has resulted in catastrophic population declines in four species: little brown, northern long-eared, Indiana, and tricolored bats. Northern long-eared bat populations in the park have declined 99% because of the disease. Park little brown bat populations have fallen over 90%. Both Indiana and tricolored bat populations have fallen around 80%. Prior to 2015, Mammoth Cave National Park required stringent decontamination procedures to prevent the disease's arrival and spread at the park. Since its arrival, the park requires decontamination before using gear used in caves outside of the park to help prevent the spread of the fungus from the park.

The entire known population of the federally endangered Kentucky cave shrimp occurs only in streams in base level passages in ten groundwater basins in the Mammoth Cave area. Its lack of eyes and lack of pigmentation indicates that the species has had a long history of subterranean existence. These tiny crustaceans feed on bacteria, protozoa, and other minute organisms that live on organic matter that wash into cave streams. The Kentucky cave shrimp, like other aquatic cave life, is vulnerable to degradation of water quality in its habitat. Contamination of groundwater by siltation and chemicals from agricultural land, inadequate sewage treatment, oil and gas development, toxic spills, and other contaminants could extinguish the species. The Kentucky cave shrimp was listed as endangered and critical habitat was designated on November 14, 1983. The designated critical habitat consists of the base-level stream—Roaring River—in the Mammoth Cave section of the system. Roaring River is an approximately 2-mile-long segment of cave stream within the Echo River basin.

Noted as a species of management concern at the park, the cave cricket (*Hadenoecus subterraneus*) is a keystone species that many other cave species depend upon (NPS 2009). Cave crickets occur in high densities at many cave entrances. They forage outside caves at night and return to caves to roost, digest food, and defecate. Thus, cricket feces accumulate under roosts and are the food base for the cricket guano community. Cave crickets lay eggs in the cave; those eggs and the young crickets that come from them are also an important food source.

In addition to federally listed species, there is potential for the approximately 12 rare, threatened, or endangered species or species of special interest to occur in the park. Cavefish, crayfish, and Kentucky cave shrimp could occur in areas planned for management improvements discussed in this plan. Similarly, cave crickets, woodrats, and cave beetles could be found in areas where maintenance, development, monitoring, or other park operations would occur to implement the proposed action in this plan. Aquatic species could also be affected by changes to local groundwater quality due to ongoing in-park activities and external development near park boundaries.

## CAVE CLIMATE

To classify the climate of the cave, long-term measurement of weather parameters is needed to obtain an average range of conditions over time. Such parameters include temperature, barometric pressure, relative humidity, evaporation, wind speed, and wind direction. The climate of a cave system remains constant through time, with mean cave air temperature being approximately equivalent to the mean annual temperature of the surrounding region. Near the entrances of caves, temperatures can vary greatly during the year, with temperatures stabilizing farther down the passageways. Seasonal fluctuations in caves may be profound, for example, such as when cold, dry, winter airflows into cave entrances, adjusts to the ambient cave temperature, and greatly increases the rate of evaporation in certain areas of the cave in the process (NPS 2009).

As noted, cave areas are usually separated into a twilight zone near the cave entrance, a middle zone of constant darkness and variable weather, and a zone of constant darkness and constant weather in the deep interior. These areas have significantly different climates.

In the zone of constant temperature (away from the influence of entrance), the climate of the cave is relatively non-variable. Temperatures are generally about 54 degrees Fahrenheit. Humidities vary somewhat, but generally range from about 80% in the driest areas to between 95% and 100% in most areas. Evaporation rates are generally very low in these areas throughout the year. The size of a cave and the number of openings also play a role in the stability of a cave's climate. Smaller caves are less likely to have a constant temperature zone. In addition, more and larger entrances tend to reduce the area of the constant temperature zone.

In areas that experience the effects of entrance, the cave climate is much more variable (Olson 2017). This occurs because air is exchanged through the cave entrance and outside air causes the cave conditions to vary. In the case of the main Mammoth Cave system (and several other larger cave systems on the park), airflow is influenced by temperature-density driven airflow (also known as “chimney-effect” airflow). During the winter, humid cave-temperature air rises out of higher entrances and holes in the cave system. This creates a partial vacuum that draws colder, drier outside air into the lower entrance. During the summer, the flow moves in the opposite way, with humid cave-temperature air blowing out of the lower entrance. The Historic Entrance and the Colossal Cave Entrance are two examples of entrances that draw in cold air in the winter and exhale cave temperature air in the summer. In the winter, areas near these entrances vary greatly in temperature and humidity. Temperatures at the Historic Tour Route entrance to the Rotunda, for example, can drop below freezing in the winter as cold surface airflows into the entrance. Relative humidities during the winter can range from 50% to 100%, depending on the cave location and source of cave air. Evaporation rates are usually low in summer but can be significant in the winter.

Air currents and even strong winds may occur at great distances from entrances. In some cases, the influence of an entrance can extend more than a mile into the cave. Many of the entrances of the Mammoth Cave system have been modified from their natural conditions (or are wholly artificial). These modified or artificial entrances have caused alterations in the natural airflow of the cave. To alleviate this issue, airlocks have been installed at some man-made entrances to stabilize cave atmospheric conditions. For example, prior to 1990, the gate at the Historic Cave Tour entrance functioned as a restrictive wall that greatly reduced airflow into the cave. The gate was replaced in 1990 with a bat-friendly open gate, which allows for airflow at levels thought to be more consistent with historic airflows.

Increasing park visitation continues to influence cave climate as well. Since 1934, when annual visitation began its dramatic increase, tourist trails have been hardened, cave entrances altered, restrooms built, stairways constructed, an elevator installed, and an underground dining area established—all of which has affected the stability of the cave system climate. For example, although a cave environment is quite stable, the use of lights can lead to minor changes in temperature, humidity, and air movement. A study conducted near the Snowball Room to measure the microclimate of the cave in relation to food preparation and human presence (Trapasso and Kaletsky, 1994) found that visitors alone do not appear to have a substantial effect upon the cave climate. Effects of the indirect presence of visitors, however, via the heat and steam released by food preparation activities, along with the heat generated by the operation of certain equipment, registered notable changes.

## PHYSICAL CAVE FEATURES

At more than 412 miles of surveyed cave passages, Mammoth Cave is the longest cave in the world. The elevational range within Mammoth Cave spans approximately 500 feet, although the cave's depth below the surface varies greatly. Except near the naturally lit Historic Tour Route entrance and electrically lit public tour routes, the cave is in constant darkness. Most parts of the cave are silent, except for the sounds of dripping and running water or wind blowing through constrictions.

The rock at Mammoth Cave formed from sediments laid down in the Mississippian age 350 million years ago when the land presently within the confines of the park lay at the bottom of a shallow sea slightly south of the equator. The shells of decaying organisms, calcium carbonate in the sea water, and pressure from the building and laying down of sedimentary layers resulted in deposition of a thick layer of limestone. Following deposition of the limestone, several hundred feet of sandstone were deposited by river systems in the same area. When the sea receded, the sandstone and limestone beneath it were exposed. The sandstone and shale "cap" resists water and protects the limestone beneath it. Mild tilting and warping of the rock layers created cracks, allowing rainwater to seep into the rock from sinkholes on the surface of the land. The cave system started forming about 10 million years ago when rainwater, acidified by carbon dioxide in the soil, seeped downward through millions of tiny cracks and crevices in the limestone layers. This weak carbonic acid dissolved a network of tiny microcaverns along the cracks. As rainwater continued to enter the system and more limestone was dissolved, the microcaverns enlarged. The sandstone cap on the surface, above the limestone, prevented dissolution of all of the limestone, setting the stage for the development and preservation of these caves.

Cutting down through this insoluble sandstone cap, surface streams encountered more easily weathered limestone formations. As the water worked its way underground, it dissolved and removed calcium carbonate from the limestone formations, beginning the process of forming the Mammoth Cave-Flint Ridge Cave system and other caves in the park. In contrast to depositional processes that create the bedrock matrix of the cave system, the higher passages in the cave system formed first. As base water table levels dropped, sequentially lower passages were formed in the Mammoth Cave system. The lowest—and hence newest—passages are still flooded at the level of the Green River, but the higher and older passages have stabilized and are largely dry, except for small localized areas of seepage. At the present water table, cave passages are still being formed.

Deposits and sediments found throughout Mammoth Cave were formed as either mineral deposits or mechanical deposits. Mineral deposits found in Mammoth Cave as cave formations are commonly referred to as speleothems. Travertine is a calcium carbonate that is dissolved in water and precipitates on various surfaces in caves through evaporation or outgassing of carbon dioxide. Travertine can manifest itself in various physical forms such as flowstone, stalactites, stalagmites, columns, helictites, cave popcorn, drapery, and dripstone.

Gypsum occurs in drier passages and forms as a precipitate coating cave walls and ceilings. The precipitate may take several forms, depending on the concentration of mineral salt dissolved in the water, the amount of airflow, porosity of the rocks, and consistency of humidity. It may form as a thin crust, as crystalline fronds known as "flowers," or as needle-shaped crystals. Gypsum may also occur in cave sediments as selenite crystals. Other important mineral deposits include mirabilite and epsomite. Both are salts that crystallize on cave walls, floors, or ceilings.

Mechanical deposition is responsible for many of the mineral-based sediment deposits found in Mammoth Cave (excluding organic-based deposits, such as guano). These sediments were either carried into the cave by underground streams and re-deposited or are the result of mechanical and chemical breakdown of the limestone cave matrix. Sediments deposited through stream action consist of gravel, sand, silt, clay, and sandstone pebbles and contain a record of surface and subsurface events. Most of these sediments were derived originally from surface contexts resulting from the weathering of insoluble materials such as shale, sandstone, and conglomerates. Most of the mineral sediments deposited in the cave passages were deposited between about 6 million years ago and one million years ago. However, sediment deposition has been an ongoing process in the lower levels of the cave systems and is still continuing. Sand, silt, and clay are deposited in lower levels during flooding events. Breakdown consists of slabs, blocks, or chips of rock that have detached from the cave ceilings or walls due to chemical weathering of joints in the rock matrix and the eventual effects of gravity. Following deposition of these materials, they are subject to further changes through physical, chemical, and biological processes.

Biological factors can also influence the movement of cave sediments. For example, animals that occupy caves can impact cave sediments through burrowing activities or accumulation of fecal matter. The most significant biological alterations of cave sediment derive from accumulation of cricket and bat guano and the ecological community that is supported in this microenvironment. However, other biological alterations of sediments, such as burrowing of insects and worms and the effects of microbes and fungi, take place at a much slower rate within caves than do similar soil-forming processes that occur at the surface. The low biological energy levels in caves make soil formation extremely slow and helps preserve the original sedimentary structure and context of mechanically deposited sediments (NPS 2009).

## WATER RESOURCES

Mammoth Cave is in the heart of southcentral Kentucky karst, which comprise a set of subterranean drainage basins covering more than 400 square miles. The park is bisected east to west by the Green River, which defines the hydrologic base level and divides the region into two distinct physiographic areas. North of the river, an alternating series of limestone and insoluble rocks are exposed with the best cave-forming limestone strata accessible only near the river and in the bottom of a few deeply incised valleys. This has resulted in rugged topography with streams that alternately flow on insoluble rocks, flow over waterfalls, enter caves in limestone, and resurge at springs perched on the next lower stratum of insoluble rock. South of the Green River, the surface and subsurface is comprised of larger underground drainage basins. Six of these drainage basins drain portions of the Mammoth Cave system. The complex nature of the Mammoth Cave karst aquifer is demonstrated by the number of groundwater basins, sub-basins, and intricate groundwater flow routes throughout the region.

Flow through the Mammoth Cave karst aquifer can be very rapid. Water can flow similarly to surface streams, traveling thousands to tens-of-thousands of feet per day. In addition, as in a surface stream, contaminants are not diluted substantially when a spill occurs. However, unlike surface flows, one cannot see where contaminants go or what they impact. Contaminants entering the karst aquifer can thus be rapidly transported unaltered through the conduit system. The karst aquifer is dynamic; that is, it responds nearly instantaneously to rainfall. Aquifer levels can rise tens of feet in a matter of hours. In addition, chemical and bacteriological properties of the groundwater can change dramatically following rainfall events. These rises in water level can activate high-level overflow routes between groundwater basins and thus direct flow in different directions, depending upon aquifer conditions.

Some groundwater basins in the park (including two large basins that feed portions of the Mammoth Cave system) owe the majority of their recharge to areas outside the park boundary. This recharge, in the form of precipitation or the injection of liquid wastes, enters the aquifer through numerous sinking streams and countless sinkholes. Because large portions of the upper Green River watershed and the groundwater basins affecting Mammoth Cave National Park lie outside park boundaries, activities conducted in these areas greatly influence water quality in the park. The primary activities that influence the park's water quality include disposal of domestic, municipal, and industrial sewage; solid waste disposal; agricultural and forestry management practices; oil and gas exploration and production; urban land-use; transportation corridors; and recreational activities. Many smaller groundwater basins lie mostly or entirely within the park. These are influenced mostly by activities within the park that affect water quality.

The Green River flows through the park in a westerly direction, passing just north of the Historic Tour Route entrance to Mammoth Cave. Sinking streams and cave streams are part of the river continuum since they are tributaries of base-level rivers (Green and Nolin Rivers) via springs. These distinct but connected aquatic ecosystems are energetically supported by in-washed organic debris from the forest and former barrens ecosystems. Food transport is usually down gradient, but natural back-flooding from the river ecosystem through springs into the lower cave streams is also very important.

In addition to the larger stream habitats, aquatic cave environments also include smaller running streams and pools fed by dripping water. The pools are characterized by high pH, high concentration of dissolved carbonates, low content of organic matter suitable for food, and sparse fauna (NPS 2009). The running streams, with connections to outside food sources, have a lower pH, are often undersaturated with respect to carbonates, and have a richer fauna.

## PALEONTOLOGICAL RESOURCES

Potential impacts from implementing the plan's proposed action on paleontological resources are subject to analysis and conditions governed by the Paleontological Resources Preservation Act of 2009 (Public Law [PL] 111-11) and the Federal Cave Resource Protection Act (PL 100-691) of 1988 and its implementing regulations (43 CFR 37).

The caves of the park have two very different types of paleontological deposits in them. In many caves, Mississippian age fossils are exposed in the walls of the cave. These include common Mississippian fossils such as crinoids, colonial and solitary corals, brachiopods, and bryozoans. In some areas, teeth, fin spines, and even calcified cartilage of sharks are also exposed. These Mississippian fossils are the same ones you would expect to find in road cuts and other rock exposures in the area. However, the limestone dissolution as the cave forms has left these fossils better exposed than they generally are on the surface.

The more significant paleontological sites and remains in the park are from creatures that came into the cave after it was formed. Some of these are cave deposits found in entrance areas or former entrance areas that are now closed. These entrance areas often have accumulations of sediment in breakdown and debris slopes that contain animal bone. Fish and amphibian remains, and occasional mammal remains, are rarely recovered from sediments that accumulated in caves while they were being formed. These include sediments washed into cave passages through flooding, when the passage was at or near the local base level. Another major type of deposit consists of old bat roosts. These types of deposits contain guano, bats bones, and sometimes mummified bat remains. Other common sources of paleontological remains in Mammoth Cave are raccoon scat, which may contain bat bones, and wood rat feces. Wood rats are common cave dwellers and they may contribute directly to the paleontological resource through their own bones, or indirectly by providing feces. The age of the deposits identified in the cave varies from several million years old to only a few hundred years old.

Some fossil deposits are found far from the toured areas of the cave, such as the Pleistocene mammals found deep in Proctor Cave. However, in some cases, paleontological deposits are near or on tour trails. Tour trails cut through significant paleontological deposits on the Frozen Niagara Tour, for example. In addition, numerous paleontological deposits occur along the Historic and Lantern Tour Routes. Because significant paleontological remains occur in toured areas, it is important to protect those deposits when working on tour infrastructure. Manzano et al. (2009) conducted a combined evaluation of the effects on both archeological and paleontological resources. By conducting the paleontological investigations early in the project, the results of these investigations can provide input into the engineering and logistics of implementing the plan. This would help minimize impacts to irreplaceable paleontological deposits and provides a good example of the type of studies that are needed to sustain these important resources.

## PUBLIC HEALTH AND SAFETY

Cave resources contain such features and conditions as confusing passages, low ceilings, loose rocks, unstable floor material, ledges and pits, tight constrictions, conditions conducive to hypothermia, and areas with water. These are part of the natural environment the park preserves. The park mitigates these hazards to the greatest extent possible for visitors, researchers, and staff. For visitors on walking tours, there is a high degree of mitigation while Wild Cave Tours, off-trail educational trips, and researchers are more exposed to these conditions. The park strives to ensure these activities occur in the safest way possible. The park's "Working in Caves Job Hazard Analysis" provides guidance on safely working off-trail in the cave (see appendix D).

Existing cave facilities have sometimes presented concerns for visitors since their construction in the late 1930s. High visitation and the challenges of maintaining less vulnerable conditions have resulted in several trail closures and trail improvement projects in the past. Current hazards on the tour routes include potholes, slick or slippery trail surfaces, stairs, low lighting, and low ceilings. Pothole formation on cave tour trails has been accelerating despite a variety of options that have been implemented to prevent them, including placing carpeting and cord mats over potholes.

There is no radio communication or cellular phone communication inside the cave system; this can delay the initiation of search and rescue operations. The park does have regular wired phone service in most tour sections of the cave. Certain areas of the public tours are extremely remote, however, and it can take highly skilled cavers several hours to reach an injured visitor to hand-carry them from the cave. Skilled cavers would not be required to assist injured visitors on other tours, although carry-out still requires numerous people and can take several hours to accomplish.

Long-term exposure to radon gas in the cave is a potential safety hazard for people who spend many hours per day in the cave. This could be a concern for park staff and contractors, but would not impact visitors on cave tours. Through regular monitoring and management of time people spend in the cave, the park ensures that radon exposure levels remain below Occupational Safety and Health Administration standards.

## CULTURAL RESOURCES

Within the boundaries of Mammoth Cave National Park, 284 archeological sites have been recorded with the Kentucky Office of State Archaeology, representing past human activity dating from at least 9,500 B.C. to the establishment of the Park in 1941. Numerous other sites have been recorded in the Archeological Sites Management Information System (ASMIS) database maintained by the National Park Service. Prehistoric material found in Mammoth Cave includes torch debris from river cane, weed stalks, or other plant material, including both unburned torch remnants and occasionally the plant fiber ties that held the torch bundles together. Torch charcoal scattered on the floor and torch marks on cave walls, as well as human paleofeces, are also documented. Tools, such as digging sticks, mussel shell scrapers, and hammerstones for removing mineral deposits from walls and ceilings, are documented, as are gourd and wooden bowls. Bits of cordage and textile fragments (from textile bags used to carry minerals, sandals, or parts of clothing), climbing poles, and human burials (consisting of mummified remains covered with rock) are also recorded in ASMIS. Other surface materials recovered from sites include lithic tools (e.g., projectile points, blades, gravers, drills/reamers, scrapers), ceramics, and fire-cracked rock. Petroglyphs and pictographs have also been recorded in multiple caves in the park, with geometric designs and anthropomorphic figures included in the range of motifs identified.

This material evidence indicates that human activity in the caves was episodic and limited in duration. Prehistoric caving activities likely included the recovery and removal of gypsum and mirabilite crystals, ritualistic activities involving small groups or individual males, and the desire to explore and fulfill curiosity.

Historic material found in Mammoth Cave include remains from saltpeter mining operations that occurred in the early 1800s. Remains can be seen in archeological contexts from various states of disrepair throughout the historic section of the cave, and include ox carts, wooden bored pipelines, saltpeter leaching vats, an oxen cart trail, and pump tower ruins. Historic stone structures are also located in the historic section of the cave, including medical test tuberculosis huts, 19th century tour trail walls, monuments and cairns, and rock work constructed by the Civilian Conservation Corps (CCC).

Sections of Mammoth Cave were designated a historic district on the National Register of Historic Places in 1991. An area with approximately 12 miles of underground passages—including those portions of the cave used for early mining, medical, exploratory, and commercial purposes—are included in the historic district. The district includes five contributing sites (the Historic Entrance, the Carmichael Entrance, the Violet City Entrance, the Frozen Niagara Entrance, and Gothic Avenue where historic signatures, monuments, and rock walls are found); eleven contributing structures (the Mushroom Beds, Rock Stairs and Walls near Olive's Bower, Saltpeter mining works, Rock Wall at the Bridal Altar, Rock Wall at Jenny Lind's Armchair, Rock Wall at the end of Gothic Avenue, two stone Tuberculin Huts, Albert's Stairway, and the Landing at Crystal Lake); and one contributing object (the cable at Aerobridge Canyon).

The preservation of cultural materials in the cave differs substantially from most conditions found in surface archeological sites. The stable environment of the cave has provided a unique level of preservation for many of these cultural materials for an extended period of time. Perishable cultural materials are unlikely to be preserved in active or wet cave environments but abandoned or "arrested" cave passages are more likely to preserve perishable cultural material. In these locations, temperature and humidity are more constant, and humidity is lower than levels found in active or wet passages. The term "lower humidity" is used loosely, as abandoned passages commonly have relative humidity levels of "only" 80% compared to 95% to 100% in active or wet passages. In Mammoth Cave, the older, higher passages have been largely abandoned and are relatively dry. Consequently, perishable human artifacts and paleontological materials (e.g., mummified bat remains, guano) may be common in segments of these trails and passages.

Changes to airflow in Mammoth Cave in the 1990s resulted in increased humidity and condensation in the cave. This resulted in water accumulation on the level surfaces of the saltpeter works. These increased moisture conditions on the wood structures and other archeological organic materials in the historic section of the cave and nearby passages resulted in an increased rate of decomposition of these materials. A conservation study was completed by a group of specialists, organized by the Webb Museum of Anthropology at the University of Kentucky. Numerous recommendations came from this study, including implementation of the immediate priorities that were completed in the last 5 years.

Cultural landscapes in Mammoth Cave are currently under formal evaluation. The Mammoth Cave Historic District Cultural Landscape Report (CLR) is anticipated to be completed in 2020. The forthcoming Cultural Landscape Report may recommend expanding the period of significance from 1816-1941 to 1798-1969 to include Mission 66 resources and additional areas of significance. The Cultural Landscape Report will likely suggest expanding the historic district boundaries to include all passages that have been the focus of tourism between the Historic Entrance and Frozen Niagara, which include evidence of historic industry, medical experimentation, science, and exploration. This suggests a total area of approximately 35 miles of passages. The CLR treatment recommendations will provide preservation strategies and specific recommendations for the long-term management of the cultural landscape including trail management and supporting infrastructure based on the district's significance, existing conditions, and use. The Cultural Landscape Report would define a new Mammoth Cave historic district, subject to national register update.

## VISITOR USE AND EXPERIENCE

The visitor experience at Mammoth Cave National Park is offered on two levels. The park provides opportunities for exploration and recreation above the surface, and below the surface within the complex cave systems. Surface visitor activities also impact cave resources but impacts related to those activities would be analyzed in a forthcoming trails management plan. This section discusses visitor use related to those experiences that occur in the cave systems. Ranger-led cave tours are among the most popular activities offered by the park. The importance of the visitor experience related to interpretive themes, environmental concerns, and cave trails was identified in the park's 2014 foundation document (NPS 2014).

Since the establishment of Mammoth Cave National Park, visitation has fluctuated. In 1941, the year the park was established, there were 165,996 recorded recreation visitors. Over the last decade, average visitation to Mammoth Cave National Park has steadily increased (see figure 6 in appendix A). In 2008, there were 446,174 recreation visitors; in 2018, the visitation had risen to 533,206. On average, the park sees an increase of approximately 16,000 visitors each year. Over the last 10 years, the park receives an average of 65% of its annual visitation between May and September. Like many national park units, Mammoth Cave visitation patterns follow a standard bell curve in which visitation increases in the summer with peak visitation occurring in July (see figure 7 in appendix A). Visitation greatly declines in the winter.

## Counting Method

The park tracks visitor data by using ticket sales for each cave tour. Each tour requires a ticket and is the most reliable form of visitor data collection the park has. School reports include the number of students that attend educational programs and tours in the cave.

## Diversity of Visitor Opportunities and Experiences

Mammoth Cave offers a wide variety of cave tours catered to a range of physical abilities, tour lengths, costs, and visitor experiences. Each tour offers the visitor the chance to discover the cave systems. Depending on staffing levels, tours are offered throughout the year and multiple times per day in order to meet visitor demand for tours. As of 2018, tours vary in cost ranging from $7 to $55 for adults and $3.50 to $19 for youth. Most tours meet at the visitor center; some take participants on a bus to the cave entrance while others walk down to the Historic Entrance. There is an accessible tour that allows wheelchairs and mobile assistant devices in the cave.

Visitor use of the caves often results in many challenges. Reservations for cave tours are encouraged because the tours fill quickly, however reservations are not required. In a 2006 visitor study, 57% of visitors were aware of the cave tour reservations system at Mammoth Cave (Swayne et al. 2006). Visitors who arrive without a reservation have trouble achieving their desired experience related to specific tours. The self-guided Discovery Tour was added to act as an overflow tour for visitors who cannot get on a guided tour, and under current management of the cave has unlimited capacity. During high peak times, there can be up to 500 visitors participating in the Discovery Tour each hour, which is about the maximum number of visitors park staff can interact with while also overseeing needed resource protection.

Currently, information is provided to park visitors about cave tours and availability. However, an increase of information surrounding high-peak visitation times, intensity levels for each tour, and other cave tour options outside of the park, is needed to prepare visitors for a cave experience that is safe and also achieves desired conditions for visitor experience. Crowding of the most popular tours diminishes the visitor experience, increases emergency response times to incidents, and increases vandalism to the natural and cultural resources in the caves. A 2006 visitor study conducted for Mammoth Cave showed that 76% of visitors encountered the amount of crowding they expected on tours, while 10% of visitors thought the tour was more crowded than they expected. In this same study, 66% of visitors preferred for the tour lengths to be maintained with fewer people on tours if cave resources experienced deterioration and needed to be protected and cave tour capacities were reached (Swayne, et al. 2006).

The cave tours offered at Mammoth Cave National Park are listed below.

- Frozen Niagara: 0.25 mile, 1.25 hours, 30 tickets per tour
- Mammoth Passage: 0.75 mile, 1.25 hours, 70 tickets per tour, offered throughout the year
- Historic: 2 miles, 2 hours, 110 tickets per tour, offered throughout the year
- Domes and Dripstones: 0.75 mile, 2 hours, 110 tickets per tour, offered throughout the year
- Mammoth Cave Accessible: 0.5 mile, 2 hours, 14 tickets per tour, elevator entrance and accessible bathroom in the Snowball Room, offered throughout the year
- Gothic Avenue: 1 mile, 2 hours, 40 tickets per tour, offered throughout the year
- Cleaveland Avenue: 1 mile, 2 hours, 38 tickets per tour
- Grand Avenue: 4 miles, 4 hours, 78 tickets per tour

- Wild Cave: 5 miles, 6.5 hours, 14 tickets per tour, adults only
- Focus: 0.25 mile, 1.75 hours, 30 tickets per tour, currently not offered
- Great Onyx: 1 mile, 2.25 hours, 36 tickets per tour
- Introduction to Caving: 1 mile, 3.5 hours, 20 tickets per tour
- River Styx: 2.5 miles, 2.5 hours, 40 tickets per tour
- Snowball: 2 miles, 3 hours, 38 tickets per tour, currently not offered
- Star Chamber: 1.5 miles, 2.5 hours, 40 tickets per tour
- Violet City Lantern: 3 miles, 3 hours, 38 tickets per tour
- Trog: 1 mile, 2.75 hours, 12 tickets per tour, youth only
- Discovery: 0.75 mile, 30 minutes, no ticket limit

The number of tours per month varies among the tours offered. Of the year-round tours, the Domes and Dripstones Tour and the Historic Tour are the most popular, followed by the Frozen Niagara Tour. Monthly numbers for year-round tours are presented in figure 8 (appendix A). Of the tours offered seasonally, the Grand Avenue, Lantern, and Cleaveland Avenue Tours are popular. Monthly numbers for seasonal cave tours are presented in figure 9 (appendix A).

# Chapter 4

## Environmental Consequences

**CHAPTER 4 DIVIDER (BACK PAGE)**

# CHAPTER 4: ENVIRONMENTAL CONSEQUENCES

This section describes the environmental consequences associated with the alternatives. It is organized by impact topic for analysis. These topics focus on the presentation of the affected environment and environmental consequences and allow a standardized comparison between the two alternatives.

## RESOURCE IMPACTS OF THE CAVE AND KARST MANAGEMENT ALTERNATIVES

### Methodology

The National Park Service based the following impact analyses and conclusions on the review of existing literature and Mammoth Cave National Park studies; information provided by experts within the National Park Service and other agencies; professional judgments and park staff insight; and public input.

### Cumulative Impact Scenario

CEQ regulations (40 CFR 1508.7) require the assessment of cumulative impacts in the decision-making process for federal projects. A cumulative impact is an impact on the environment that results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (federal or non-federal), organization, or person undertakes such other actions. Cumulative impacts can result from individually minor, but collectively significant, actions taking place over a period of time.

Cumulative impacts are considered for all alternatives and are presented at the end of each impact topic discussion analysis. Potential projects identified as cumulative actions included any planning or development activity that was currently being implemented or that would be implemented in the reasonably foreseeable future.

These cumulative actions are evaluated in the cumulative impact analysis in conjunction with the impacts of each alternative to determine if they would have any additive effects on natural resources, cultural resources, or visitor use. Because some of these cumulative actions are in the early planning stages, the evaluation of cumulative effects was based on a general description of the project. Known past, current, and reasonably foreseeable future projects and actions in the vicinity of Mammoth Cave are described below.

**Considerations in the cumulative impact analysis.**

- Use occurs throughout the year with peak visitation in summer, spring break, and over holiday weekends.
- Demand for tours and visitor use levels are typically highest during afternoons and on weekends (especially summer weekends).
- Park staffing and budgets do not substantially change. The existing level of maintenance work continues to occur in the future.
- In the action alternative, visitor capacity indicators would be regularly monitored and action taken if thresholds were being approached.
- Portions of the cave were used for prehistoric mining and collection of minerals, early historic saltpeter mining, collection of minerals, medical studies (tuberculosis experiment), exploration, and early commercial cave tours.
- Construction and maintenance of cave trails has been ongoing since the early 19th century, with informal trail building occurring through the 20th century for commercial purposes. More formalized trail design occurred during CCC-era construction projects and NPS tour developments (including the current trail system). Damage to irreplaceable cave features occurred during the early periods of cave use, including graffiti, removal of cave formations, smoke deposits from torches and fires, and burning of archeological materials.
- Damage to irreplaceable cave features—including graffiti, vandalism, and removal of cave formations—continues in modern cave uses.

- Prior to 2009, underground cave electric and telephone systems were constructed along 6.7 miles of cave trails in Mammoth Cave. A 2009 Cave Electric Project replaced the cave electric supply, control systems, and lights with a modern system. The use of electric lighting for cave tours has allowed the growth of mosses, fungi, and algae in the cave, which eventually spoils the natural beauty of some of the unique formations. The lighting system was designed to reduce (to the extent possible) the lamp flora problem that the previous system created. A 2017 project replaced the light fixtures and bulbs from the 2009 project to attempt to standardize fixtures to a smaller number and aid in the ease of replacing bulbs. This project expanded the ability to use bulbs that are less prone to algae growth; however, lamp flora still occurs in many damp areas of the cave that are electrically lit.
- The Prototype Cave Trail project (1997) replaced a small section of cave-sediment trail surfaces with a hardened surface and installed lint curbs and railing, thus eliminating the use of cave sediments for trail construction, substantially controlling the migration of potentially harmful lint introduced by visitors, eliminating dust created by cave-sediment-based trails, and reducing the opportunity for graffiti and vandalism with the channelized flow gained through the lint curbs and railings.
- From 2015 to 2017, the Historic Tour trail was reconstructed. This project replaced the entire Historic Tour trail with hardened trail surfaces, added stairs and handrails in areas where they were needed, and extended lint curbs into all areas of the upper section of the Historic Tour.
- During the 1970s, the sewage lagoon at the old Job Corps site on Flint Ridge would overflow into the Flint Ridge section of Mammoth Cave.
- Mammoth Cave operated an independent sewage treatment system that was constructed in the 1930s. Over time, that system developed leaks and could not meet the demands of increasing park visitation. In the early 1980s, federal, state, and local authorities cooperated to begin to develop a regional sewer system in the area to minimize the pollutants reaching groundwater. The park connected to this system in 1996, which continues to expand its regional service.
- Oil and gas wells were installed at the park when it was established; wells inside the park have since been formally closed. In adjacent areas, oil and gas exploration has increased recently, which poses the risk of spillage into the park's groundwater system.
- There is an extensive sinkhole plain to the south and east of the park. Runoff from this area flows through the park via underground streams into the Green River. This sinkhole plain includes several towns—Park City, Cave City, and portions of Smiths Grove and Glasgow. Illegal dumping of wastes into sinkholes outside of the park continues to be a concern. Any changes in the quality or quantity of water may adversely affect the unique aquatic life in the underground streams and alter natural cave development.
- The park would continue using parking lot filters to help keep parking lot contaminants from entering the cave with draining water and would expand them as new areas are developed.
- Extensive dye tracing has traced many of the paths that water follows between where it sinks in the ground and where it emerges at springs. However, many flow paths are still uncharacterized.
- Research and monitoring activities continue.
- Prior to 1999 there was little or no airflow control at artificial entrances to the Mammoth Cave system. This resulted in changes in the temperature, humidity, and wildlife near these entrances and potentially influenced airflow far into the cave. In 1999, a project added airlocks to many of the entrances with the most serious issues (such as the Frozen Niagara and Austin entrances). Later, the airlock at the bottom of the elevator was added to reduce unnatural airflow there. These airlocks would continue to be maintained.
- During the cold weather seasons, airflow through the historic section of the cave causes warmer cave air to come in contact with cold surface air, resulting in condensation buildup in Mammoth Cave. The condensation has been observed coming down on the historic saltpeter works in the Rotunda and Booth’s Amphitheatre.

**Actions considered in the cumulative impact analysis – future projects and actions.**

- Renovate Great Onyx, Crystal Cave, and Wondering Woods areas to improve visitor access (PEPC)
- Reconstruct cave trail along Grand Avenue Tour between the Snowball Room and Grand Central Station (PEPC)
- Upgrade cave communication system (PEPC)
- Upgrade and modify sewer systems (PEPC)
- Upgrade outlying cave security system (PEPC)
- Repair and rehabilitate backcountry trails (PEPC)
- Redesign parking and traffic flow at the hotel
- Replace seasonal housing
- Renovate campground
- Renovate Domes and Dripstones Tour Route
- Rehabilitate Maple Springs Campground
- Upgrade River Hall
- Upgrade Audubon Avenue
- Implement cave gating projects
- Build new family cottages
- Bury utilities

## BIOLOGICAL RESOURCES

### No-Action Alternative

**Analysis.** As certain existing cave infrastructure continues to impede natural airflow, cave trails continue to deteriorate, impacts from stormwater runoff continue to negatively impact water quality, and a number of cave entry access points remain vulnerable to illegal entry and vandalism, current cave management practices could lead to a range of adverse impacts on biological resources. Similarly, maintaining existing visitor capacities on certain tour routes could increasingly stress and potentially damage vulnerable biological resources.

**Cumulative effects.** Biota in Mammoth Cave—including bats, woodrats, amphibians, cave crickets, spiders, beetles, and springtails—are subject to disturbance and displacement from past, present, and future visitor use; trail maintenance; cave exploration; and research activities.

Surface activities affect water infiltrating into the cave. Chemicals and other toxins occurring in cave water adversely affect underground aquatic life and fauna that drink the water. Dye traces have shown a direct hydrologic link between parking lot runoff and certain cave passages, which may have led to contamination of cave drip water in the past. Parking lot filters currently reduce or prevent parking lot contaminants from entering the cave with draining water. The regional sewer system developed in the area also helps keep pollutants from reaching the groundwater; however, upgrades in the sewer system would further improve protection and extend the life of the system. Nearby oil and gas exploration poses the risk of spillage into the park's groundwater system. Illegal dumping of wastes into sinkholes outside of the park also contaminates groundwater.

Installation of new cave light fixtures and bulbs in 2017 has somewhat reduced the growth of lamp flora on cave formations. The new lighting system was designed to reduce the lamp flora problem that the previous lighting system created to the greatest extent possible.

Cumulatively, these past, present, and future actions would have potentially wide-ranging, adverse impacts on biological resources due in large part to water quality reduction from surface trail uses. The no-action alternative would contribute moderate to potentially more severe adverse cumulative impacts on biological resources, depending on the magnitude of potential spills, leaks, or similar contamination threats. In combination, these actions would result in moderate to potentially severe cumulative impacts on biological resources.

**Conclusion.** The no-action alternative would likely result in moderate, long-term, local, and worsening adverse impacts on biological resources from surface trail uses, increased trail maintenance, and continued human presence in the sensitive cave environment. However, because there would be no major adverse impacts to a resource or value whose conservation is (1) necessary to fulfill specific purposes identified in the establishing legislation or proclamation of the park, (2) key to the natural or cultural integrity of the park or to opportunities for enjoyment of the park, or (3) identified as a goal in the park's general management plan or other relevant NPS planning documents, there would be no impairment of the park's resources or values with respect to biological resources.

## Action Alternative

**Analysis.** Proposed actions to sustain natural airflow by modifying artificial entrances, improve stormwater management by installing catchment basins in strategic locations, implement improved cave-access protocols, and reduce harmful off-trail impacts by continuing to improve trail boundaries would have small to moderate, wide-ranging benefits for biological resources. Compared to the no-action alternative, implementing the proposed action would reduce potential damage to biological resources through the various physical improvements and management, monitoring, and mitigation strategies proposed in the action alternative. Noise and human presence during construction activities for cave-enhancement activities would cause temporary displacement and disturbance of cave wildlife such as bats, raccoons, amphibians, springtails, spiders, and beetles; however, these activities would be temporary and localized, and would mainly occur in areas where noise and disturbance associated with cave tours is already a daily occurrence. Species are expected to return to sites after any proposed development activities are completed. Impacts on macrofauna would be localized and limited to the immediate area of cave-enhancement activities.

Although the growth of lamp flora has been reduced with the current cave lighting system that updated certain electrified sections of the tour trails, lamp flora would remain undisturbed and would continue to grow under existing cave lighting. If additional lighting is added to tour routes, it would consist of a system that would not promote growth of lamp flora.

**Cumulative effects.** Biota in Mammoth Cave—including bats, woodrats, amphibians, cave crickets, spiders, beetles, and springtails—are subject to disturbance and displacement from past, present, and future visitor use; trail maintenance; cave exploration; and research activities.

Surface activities affect water infiltrating into the cave. Chemicals and other toxins occurring in cave water adversely affect underground aquatic life and fauna that drink the water. Dye traces have shown a direct hydrologic link between parking lot runoff and certain cave passages, which may have led to contamination of cave drip water in the past. Parking lot filters currently reduce or prevent parking lot contaminants from entering the cave with draining water. The regional sewer system developed in the area also helps keep pollutants from reaching the groundwater. Nearby oil and gas exploration poses the risk of spillage into the park's groundwater system. Illegal dumping of wastes into sinkholes outside of the park also contaminates groundwater.

Lamp flora would remain undisturbed and continue to grow under existing cave lighting, although this growth has been greatly reduced with lighting system improvements. The new lighting system was designed to reduce the lamp flora problem that the previous lighting system created to the greatest extent possible.

Cumulatively, these past, present, and future actions would have minor adverse impacts on biological resources. The action alternative would have small to moderate, wide-ranging benefits for biological resources. In combination, these actions would result in small, mainly beneficial cumulative impacts on biological resources.

**Conclusion.** Proposed actions to sustain natural airflow by modifying artificial entrances, improve stormwater management by installing catchment basins, implement improved cave-access protocols, and reduce harmful off-trail impacts by continuing to improve trail boundaries would have small to moderate, wide-ranging benefits for biological resources. Temporary, local, and direct adverse impacts on biological resources from proposed management activities would be expected under the action alternative; however, these impacts would be largely mitigated by the long-term beneficial effects of implementing the proposed actions. Because there would be no major adverse impacts to a resource or value whose conservation is (1) necessary to fulfill specific purposes identified in the establishing legislation or proclamation of the park, (2) key to the natural or cultural integrity of the park or to opportunities for enjoyment of the park, or (3) identified as a goal in the park's general management plan or other relevant NPS planning documents, there would be no impairment of the park's resources or values with respect to biological resources.

## RARE, THREATENED, OR ENDANGERED SPECIES AND SPECIES OF INTEREST

### No-Action Alternative

**Analysis.** As there would not be any new actions under the no-action alternative, there would not be any new impacts to the rare, threatened, or endangered species or species of special interest that have the potential to occur in the cave system. There would not be additional human activity in the cave for construction or other enhancement activities, so rare and listed species would not be affected beyond current disturbance from visitor tours passing through the cave and from maintenance activities. As trails continue to deteriorate, however, cave-trail maintenance could increase, thus somewhat increasing the frequency of disturbance of special status species.

**Cumulative effects.** Rare, threatened, or endangered species and species of special interest are subject to disturbance and displacement from past, present, and future visitor use, trail maintenance, cave exploration, and research activities.

Surface activities affect water infiltrating into the cave. Chemicals and other toxins occurring in cave water adversely affect the three species of cave fish, the Kentucky cave shrimp, the Mammoth Cave crayfish, and species that may drink the water (e.g., the three special status bats). Dye traces have shown a direct hydrologic link between parking lot runoff and certain cave passages, which may have led to contamination of cave drip water in the past. Parking lot filters currently reduce or prevent parking lot contaminants from entering the cave with draining water. The regional sewer system developed in the area also helps keep pollutants from reaching the groundwater. Nearby oil and gas exploration poses the risk of spillage into the park's groundwater system. Illegal dumping of wastes into sinkholes outside of the park also contaminates groundwater.

Past modifications that affected the thermal regime of the cave—and therefore the cave's suitability to support hibernating Indiana bats—include alterations to accommodate tourists, erection of physical barriers (e.g., doors, gates) to control cave access, and saltpeter mining. Entrance gates caused significant modification of the airflow and climate in the cave; this, in turn, profoundly affected the quality of bat roosting habitat and physically restricted the access of bats to the cave. Restrictive entrance gates were in place until 1990 when an open-grid gate was installed at the Historic Entrance. The negative effects of cave modifications were compounded by physical disturbance of hibernating bats resulting from commercial, recreational, scientific, or educational cave use. Because the Indiana bat and gray bat congregate in large numbers, these species have been inherently vulnerable to loss or degradation of hibernation habitat.

Cumulatively, these past, present, and future actions would have medium adverse impacts on rare, threatened, or endangered species, and species of special interest. The no-action alternative would contribute very small to negligible adverse cumulative impacts on these special status species. In combination, these actions would result in medium adverse cumulative impacts on rare, threatened, or endangered species or species of special interest.

**Conclusion.** There would be long-term, small to negligible, local, direct adverse impacts to rare and listed species as a result of the no-action alternative due to continued human presence and increased trail maintenance. Because there would be no major adverse impacts to a resource or value whose conservation is (1) necessary to fulfill specific purposes identified in the establishing legislation or proclamation of the park, (2) key to the natural or cultural integrity of the park or to opportunities for enjoyment of the park, or (3) identified as a goal in the park's general management plan or other relevant NPS planning documents, there would be no impairment of the park's resources or values with respect to rare, threatened, or endangered species or species of special interest.

### Action Alternative

**Analysis.** There is potential for rare, threatened, or endangered species and species of interest to occur in areas where proposed cave-enhancement activities would occur. For example, cavefish and the Mammoth Cave crayfish are frequently found in River Styx and the Lake Lethe area where previous trail-rehabilitation activities occurred. The Kentucky cave shrimp has not been observed in the Lake Lethe area, but is known to occur in downstream areas of River Styx. These aquatic species could also be affected by changes to local groundwater quality due to changes at other trail locations. The surprising cave beetle, a highly specialized troglobitic species, would most likely be encountered on the Great Onyx Tour Route but could also occur in other parts of the cave system. Cave crickets, woodrats, and cave beetles could be found in various areas where trail work would occur.

Gray bats and Indiana bats are known to have used the Historic Entrance and historic section of Mammoth Cave in the past and may still occasionally occur in the area. At this time, however, no Indiana or gray bats are known to hibernate in the historic section of Mammoth Cave or other cave locations in the park. The Rafinesque's big-eared bat does not generally use toured sections of the cave or entrances and there is no evidence that they did so in the past. Cave personnel and equipment may be subject to stringent decontamination protocols to prevent the introduction and spread of white-nose syndrome in bats. If introduced prior to the start of this project, bats weakened by the disease might be more sensitive to otherwise minor disturbance from cave-trail activities. Seasonal restrictions to proposed rehabilitation, maintenance, and possible development associated with this plan may be necessary to protect bats. However, there is a very low possibility that these bats could be present during proposed management activities, thus this alternative is not likely to adversely affect Indiana, gray, or Rafinesque's big-eared bats.

Noise and human presence during this plan's proposed cave-enhancement activities would cause temporary displacement and disturbance of special status species, including bats (if present), woodrats, cave crickets, and cave beetles. Although individual cave-enhancement activities would occur over relatively short periods of time, work activities and disturbance of rare and listed species in any one section of the cave would be substantially shorter. Any construction would take place in passages where disturbance associated with cave tours is already a daily occurrence. Species are expected to return to project sites after construction is completed. Impacts would be localized and limited to the immediate area of the particular cave-enhancement activity.

Only a short section of the project trails occurs in the lowest section of the cave where cavefish, crayfish, and the Kentucky cave shrimp may occur. Although some trail portions flood regularly, trail work would not be conducted during those periods; it would be conducted only when trails are mostly dry. There are also very limited potential effects related to runoff from other cave-enhancement activities; however, as most passages are dry, the few wet areas do not change significantly during wet periods. No adverse effects are expected for the aquatic special status species.

Propane may be needed to operate some of the equipment used for cave-enhancement activities involving trail construction; therefore, there is some risk of an accidental fuel or chemical spill, which could adversely affect groundwater quality. To prevent accidental spills, no fuels or chemicals would be stored at the project site. An emergency spill kit containing absorption pads, absorbent material, a shovel or rake, and other cleanup items would be readily available on site in the event of an accidental spill. Thus, there is a very low likelihood for contaminants that could harm special status aquatic cave species to enter groundwater from the actions in this alternative.

**Cumulative effects.** Rare, threatened, or endangered species and species of special interest are subject to disturbance and displacement from past, present, and future visitor use; trail maintenance; cave exploration; and research activities.

Surface activities affect water infiltrating into the cave. Chemicals and other toxins occurring in cave water adversely affect the three species of cave fish, the Kentucky cave shrimp, the Mammoth Cave crayfish, and species that may drink the water (e.g., the three special status bats). Dye traces have shown a direct hydrologic link between parking lot runoff and certain cave passages, which may have led to contamination of cave drip water in the past. Parking lot filters currently reduce or prevent parking lot contaminants from entering the cave with draining water. The regional sewer system developed in the area also helps keep pollutants from reaching the groundwater. Nearby oil and gas exploration poses the risk of spillage into the park's groundwater system. Illegal dumping of wastes into sinkholes outside of the park also contaminates groundwater.

Past modifications that affected the thermal regime of the cave—and therefore the cave's suitability to support hibernating Indiana bats—include alterations to accommodate tourists, erection of physical barriers (e.g., doors, gates) to control cave access, and saltpeter mining. Entrance gates caused significant modification of the airflow and climate in the cave; this, in turn, profoundly affected the quality bat roosting habitat and physically restricted the access of bats to the cave. Restrictive entrance gates were in place until 1990 when an open-grid gate was installed at the Historic Entrance. The negative effects of cave modifications were compounded by physical disturbance of hibernating bats resulting from commercial, recreational, scientific, or educational cave use. Because the Indiana bat and the gray bat congregate in large numbers, these species have been inherently vulnerable to loss or degradation of hibernation habitat.

Cumulatively, these past, present, and future actions would have medium adverse impacts on rare, threatened, or endangered species, and species of special interest. The action alternative would contribute negligible adverse cumulative impacts on these special status species. In combination, these actions would result in moderate adverse cumulative impacts on rare, threatened, or endangered species or species of special interest.

**Conclusion.** The action alternative would likely result in temporary, small to negligible, localized, direct adverse impacts on special status species from proposed cave-enhancement activities. Because there would be no major adverse impacts to a resource or value whose conservation is (1) necessary to fulfill specific purposes identified in the establishing legislation or proclamation of the park, (2) key to the natural or cultural integrity of the park or to opportunities for enjoyment of the park, or (3) identified as a goal in the park's general management plan or other relevant NPS planning documents, there would be no impairment of the park's resources or values with respect to rare, threatened, or endangered species or species of special interest.

## CAVE CLIMATE

### No-Action Alternative

**Analysis.** As no construction activities would occur under the no-action alternative, there would not be any new impacts on the climate of the cave system. Effects on cave climate from cave tours, trail lighting, and trail maintenance would continue at current levels.

**Cumulative effects.** Past and ongoing cave tours, trail maintenance, cave exploration, and research activities have and continue to alter the climate in Mammoth Cave. For example, existing restroom facilities block natural airflow, which has also affected cave climate. However, rehabilitation of the lighting system and airlock at the Snowball Room and elevator have helped restore the original airflow patterns in the passage and minimized heat emanating from old lighting fixtures.

Five artificial entrances were constructed to provide access to various areas of the cave: the Carmichael Entrance, Violet City Entrance, New Entrance, Frozen Niagara Entrance (prior to park establishment), and Elevator Entrance. Additionally, the Historic Entrance pathway has been enlarged and gated. Entrance gates caused significant modification of the airflow and climate in the cave before they were refitted with airlocks to prevent climatic changes (especially drying) in the cave, which can harm speleothems and cave organisms. Placement of an open bat gate on the Historic Tour entrance in 1990 likely caused significant changes in airflow during winter, allowing dense, cold, dry air to move virtually unimpeded into the cave system. This altered airflow was mitigated using panels of plexiglass to reduce influx of cold air to approximate pre-disturbance rates. Similarly, gates on several other cave entrances were designed to allow natural airflow and movement of cave organisms. Although these entrances are carefully controlled, they continue to alter airflow and change the cave climate.

Cumulatively, these past, present, and future actions would have medium adverse impacts on the cave climate. As no new actions would occur under the no-action alternative, there would not be any contribution to cumulative impacts on cave climate. In combination, these actions would result in medium adverse cumulative impacts on cave climate.

**Conclusion.** The no-action alternative would not result in any additional impacts on cave climate. Because there would be no major adverse impacts to a resource or value whose conservation is (1) necessary to fulfill specific purposes identified in the establishing legislation or proclamation of the park, (2) key to the natural or cultural integrity of the park or to opportunities for enjoyment of the park, or (3) identified as a goal in the park's general management plan or other relevant NPS planning documents, there would be no impairment of the park's resources or values with respect to cave climate.

### Action Alternative

**Analysis.** Under the action alternative, public tour trails in Mammoth Cave would continue to be improved through additional safety and infrastructure improvements and would include updated mitigation measures and best management practices that would have largely beneficial impacts on cave climate. Activities that would likely be conducted to support these overall improvements include sustaining natural airflow to caves by targeting locations for future airlock installations and reopening cave areas that provided historic airflow at specific cave entrances.

**Cumulative effects.** Past and ongoing cave tours, trail maintenance, cave exploration, and research activities have and continue to alter the climate in Mammoth Cave. Existing restroom facilities block natural airflow, which has also affected cave climate. However, rehabilitation of the lighting system and airlock at the Snowball Room and elevator have helped restore the original airflow patterns in the passage and minimizing heat emanating from old lighting fixtures.

Five artificial entrances were constructed to provide access to various areas of the cave: the Carmichael Entrance, Violet City Entrance, New Entrance, Frozen Niagara Entrance (prior to park establishment), and Elevator Entrance. Additionally, the Historic Entrance pathway has been enlarged and gated. Entrance gates caused substantial modification of the airflow and climate in the cave before they were refitted with airlocks to prevent climatic changes (especially drying) in the cave, which can harm speleothems and cave organisms. Placement of an open bat gate on the Historic Entrance likely caused substantial changes in airflow during winter, allowing dense, cold, dry air to move virtually unimpeded into the cave system. This altered airflow was mitigated using panels of plexiglass to reduce influx of cold air to approximate pre-disturbance rates. Similarly, gates on several other cave entrances were designed to allow natural airflow and movement of cave organisms. Although these entrances are carefully controlled, they continue to alter airflow and change the cave climate.

Cumulatively, these past, present, and future actions would have moderate adverse impacts on the cave climate. The action alternative would contribute modest beneficial cumulative impacts on cave climate. In combination, these actions would result in moderate adverse cumulative impacts on cave climate.

**Conclusion.** There would be long-term beneficial impacts to the cave climate in the action alternative due to consideration of future airlock installations at strategic, human-made cave entrances that are currently altering natural airflow. Similarly, the action alternative would modestly improve the climate by reopening certain cave areas that provided historic airflow. The action alternative would also provide small, long-term, beneficial impacts to cave climate from reduced vandalism and accumulation of lint and dust. Because there would be no major adverse impacts to a resource or value whose conservation is (1) necessary to fulfill specific purposes identified in the establishing legislation or proclamation of the park, (2) key to the natural or cultural integrity of the park or to opportunities for enjoyment of the park, or (3) identified as a goal in the park's general management plan or other relevant NPS planning documents, there would be no impairment of the park's resources or values with respect to cave climate.

## PHYSICAL CAVE FEATURES

### No-Action Alternative

**Analysis.** As there would not be any new actions under the no-action alternative, there would not be any new impacts on physical cave features. However, without implementing infrastructure improvements and other cave-enhancement activities proposed in this plan, cave walls and features in certain cave areas would remain within relatively easy reach of visitors, and damage to cave walls and speleothems would continue. Lint from visitors on cave tours would continue to accumulate, forming a layer of material and providing an energy source for microscopic organisms that can cause substantial damage to natural physical features in the cave. Clouds of dust on certain cave tours would continue to form from visitors walking on cave-sediment trail surfaces. This dust would continue to have adverse impacts by forming a coating on sensitive speleothems in the cave.

**Cumulative effects.** Mammoth Cave is a nonrenewable resource that lacks natural regenerative processes; therefore, impacts are cumulative, and some may be permanent. Damage to irreplaceable cave features occurred during the early periods of cave use, including graffiti and smoke deposits from torches and fires. Later impacts include the physical degradation of cave formations, such as speleothems, and cave surfaces from construction of cave trails and other CCC-era structures. Visitation throughout the cave has caused both inadvertent and deliberate damage to speleothems and other cave features. Some speleothems are extremely fragile. In one example of protecting a cave feature, the park installed a grate around fragile speleothems located immediately adjacent to the trail on the Frozen Niagara Route to prevent damage. Human presence in the cave results in the deposition of a small amount of detritus consisting of hair, skin cells, and lint from clothing. Human travel then stirs up fine sediments that settle onto adjacent cave surfaces. This redistributed dust can build up over time and affect cave aesthetics and damage delicate speleothems.

A prototype walkway on the Historic Route was constructed in 1997 as part of a demonstration project that would be more compatible with the cave environment. The primary goals were to eliminate the use of cave sediments for trail construction, control the migration of potentially harmful lint introduced by visitors, eliminate dust created by cave-sediment-based trails, and reduce the opportunity for graffiti and vandalism. Hardened trail surfaces were constructed without exploiting the cave's resources. Without cave sediment for a tread, dust was no longer a problem, although dirt is tracked onto the new surfaces from the remaining sediment-based segments. Within weeks of their completion, lint and other materials had visibly accumulated at the base of the lint curbs preventing dispersal throughout the passage. With the channelized flow of tour groups gained through the lint curbs and railings, potential damage to cave walls and other resources is reduced.

In addition to various mitigation activities, the park's completion of a large-scale renovation of cave trails on the Historic Tour Route in 2017 represented the culmination of 20 years of project development to improve visitor experience and safety, protect cave resources, and improve long-term maintenance protocols. Efforts to improve accessibility along portions of the Cleaveland Avenue and Grand Avenue Tours, for example, have also contributed beneficial physical upgrades that protect physical cave features.

Impacts from food preparation and distribution services as well as water seepage into the cave via the elevator shaft may have impacted cave formations in the Snowball Room. Dust mitigation and mold-removal activities were later conducted in 1995.

Electric lighting along trails has encouraged the unnatural growth of algae and other lamp flora. The green algae are unsightly and unnatural and do not give cave visitors a true impression of the natural cave environment. The algae also produce organic acids that can cause degradation of bedrock and speleothems. Lamp flora would continue to grow under existing cave lighting, however, large-scale updates to the fixtures and bulbs in 2017 have reduced (to the extent possible) the lamp flora problem that the previous system created.

Cumulatively, these past, present, and future actions would have medium adverse impacts on the physical cave features. The no-action alternative would contribute medium adverse cumulative impacts on physical cave features. In combination, these actions would result in medium adverse cumulative impacts on physical cave features.

**Conclusion.** There would be long-term, medium, local, direct adverse impacts to physical trail features under the no-action alternative because of continuing damage to cave formations by visitors and from accumulation of lint and dust. Because there would be no major adverse impacts to a resource or value whose conservation is (1) necessary to fulfill specific purposes identified in the establishing legislation or proclamation of the park, (2) key to the natural or cultural integrity of the park or to opportunities for enjoyment of the park, or (3) identified as a goal in the park's general management plan or other relevant NPS planning documents, there would be no impairment of the park's resources or values with respect to physical cave features.

## Action Alternative

**Analysis.** Cave-enhancement construction activities have the potential to damage physical cave features from the use of material-moving equipment, an increased number of workers in the cave, and surface disturbance on or adjacent to cave tour trails. Best management practices would be employed to ensure that speleothems are avoided and protected from damage and that cave walls and floors are not impacted inadvertently. However, some areas of cave walls and floors would be adversely impacted because of cave enhancements, such as drilling into rock to install new lint curbs, handrails, stairs, and other similar infrastructure. Employing mitigation measures recommended by Manzano et al. (2009) for areas that have medium and high potential to produce scientifically significant paleontological materials would avoid or greatly reduce adverse impacts to physical cave features.

Under the action alternative, cave-enhancement activities and other maintenance improvements outlined in this plan would reduce lint and dust and would decrease the opportunity for graffiti on or vandalism of cave resources. For example, in areas where the edges of cave trails remain poorly defined, measures would be taken to better define trails (e.g., installing lint curbs or hand rails). In other areas, hardening the trail surface may be sufficient to delineate certain sections of trail. Well-defined trails should reduce the number of visitors who wander off the trails and cause damage to physical cave features. Lint curbs would accumulate lint along the curbs in sections of the cave where they are installed, preventing lint from covering cave formations in those areas. Dust would be abated on trail segments where the surface would be replaced with paving stones or other hardened surfaces; however, some trails may still maintain cave-sediment surfaces in areas where dust is not a major problem. Thus, most dust clouds caused by visitors walking on trails would be controlled in the cave and greatly reduced in some areas. Cave-enhancement activities would have beneficial impacts on physical cave features by greatly reducing the detrimental effects of lint, dust, and vandalism.

**Cumulative effects.** Mammoth Cave is a nonrenewable resource that lacks natural regenerative processes; therefore, impacts are cumulative, and some may be permanent. Damage to irreplaceable cave features occurred during the early periods of cave use, including graffiti and smoke deposits from torches and fires. Later impacts include the physical degradation of cave formations, such as speleothems, and cave surfaces from construction of cave trails and other CCC-era structures. Visitation throughout the cave has caused both inadvertent and deliberate damage to speleothems and other cave features. Human presence in the cave results in the deposition of a small amount of detritus consisting of hair, skin cells, and lint from clothing. Human travel then stirs up fine sediments that settle onto adjacent cave surfaces. This redistributed dust can build up over time, negatively impacting cave aesthetics and damaging delicate cave features.

Electric lighting along trails has encouraged the unnatural growth of algae and other lamp flora. The green algae are unsightly and unnatural and do not give cave visitors a true impression of the natural cave environment. The algae also produce organic acids that can cause degradation of bedrock and speleothems. Lamp flora would continue to grow under existing cave lighting, however, the existing lighting system was designed to reduce (to the extent possible) the lamp flora problem that the previous system created.

Cumulatively, these past, present, and future actions would have long-term, moderate adverse impacts on physical cave features. The action alternative would contribute modest beneficial cumulative impacts on physical cave features due to maintenance improvements and more-effective implementation of best management practices. In combination, these actions would result in ongoing, adverse and beneficial cumulative impacts on physical cave features.

**Conclusion.** There would be long-term, moderate and wide-ranging beneficial impacts to physical cave features under the action alternative due to cave-enhancement construction activities and reduced vandalism and accumulation of lint and dust. Because there would be no major adverse impacts to a resource or value whose conservation is (1) necessary to fulfill specific purposes identified in the establishing legislation or proclamation of the park, (2) key to the natural or cultural integrity of the park or to opportunities for enjoyment of the park, or (3) identified as a goal in the park's general management plan or other relevant NPS planning documents, there would be no impairment of the park's resources or values with respect to physical cave features.

## WATER RESOURCES

### No-Action Alternative

**Analysis.** Under the no-action alternative, ongoing surface activities in the park and general vicinity would continue to pose wide-ranging threats to karst water resources in the park. Continued or increasing visitation levels, ongoing park maintenance and operational activities, and expected decrease in effectiveness of existing sewer lines over time are expected to have long-term, adverse impacts to park water resources. Effects on cave water resources from surface contaminants that may infiltrate into the cave would also continue, but overall water quality is not expected to change significantly from current conditions.

**Cumulative effects.** Past, present, and future chemicals and contaminants from surface activities have the potential to infiltrate groundwater and reach Mammoth Cave in drip water and cause adverse impacts. Dye traces have shown a direct hydrologic link between parking lot runoff and certain cave passages, which may have led to contamination of cave drip water. Nearby oil and gas exploration poses the risk of spillage into the park's groundwater system. Illegal dumping of wastes into sinkholes outside of the park also contaminates groundwater. The previous visitor center renovation project (2010), future concessions operations, campground rehabilitation (2010), and various road maintenance projects have the potential to contribute inputs to groundwater reaching the cave; however, implementing best management practices would minimize the negative impacts of adjacent groundwater infiltration.

Several measures have been taken to reduce or eliminate groundwater contamination. Parking lot filters have been installed to reduce or prevent contaminants from parking lots from entering the cave. The improved regional sewer system developed in the area also reduces potential pollutants from reaching groundwater. The park replaced the old water supply system with a modern system to meet the needs of the park for potable water, for fire protection, and to eliminate leaks.

Cumulatively, these past, present, and future actions have a wide range of potential impacts on karst water resources in the park. Potential oil spills or transportation-related accidents, for example, could have notable impacts, while surface water runoff from a roadway maintenance project, combined with best management practices to mitigate the input of contaminants into groundwater, would have comparatively small impacts. The no-action alternative would contribute a potentially wide range of adverse cumulative impacts on water resources.

**Conclusion.** The no-action alternative would likely result in long-term, localized impacts of potentially wide-ranging severity that could directly affect water resources from continued water seeping into the cave via several external contaminant sources. However, because there would be no major adverse impacts to a resource or value whose conservation is (1) necessary to fulfill specific purposes identified in the establishing legislation or proclamation of the park, (2) key to the natural or cultural integrity of the park or to opportunities for enjoyment of the park, or (3) identified as a goal in the park's general management plan or other relevant NPS planning documents, there would be no impairment of the park's resources or values with respect to water resources.

### Action Alternative

**Analysis.** Cave-enhancement activities under the action alternative would largely avoid wet areas, such as running streams and pools fed by dripping water, during construction activities. Underground rivers rise periodically and flood certain trail sections. Work on such trails would be conducted during dry periods. Any necessary contact with cave-water resources would implement best management practices to control erosion, sediment release, and runoff during all construction activities. As most passages are dry and work would not be conducted during wet periods, runoff would not likely occur. There is very little probability for direct impacts on water resources in most of the cave system.

Propane may be needed to operate some of the equipment used for cave enhancements that involve trail construction; therefore, there is some risk of an accidental fuel or chemical spill, which could adversely affect groundwater quality. To prevent accidental spills, no fuels or chemicals would be stored at the project site. An emergency spill kit (such as the park currently uses) containing absorption pads, absorbent material, a shovel or rake, and other cleanup items would be readily available on site in the event of an accidental spill. Thus, there is a very low likelihood that contaminants would enter groundwater from the actions in this alternative.

**Cumulative effects.** Past, present, and future chemicals and contaminants from surface activities have the potential to infiltrate groundwater and reach Mammoth Cave in drip water and cause adverse impacts. Prior to construction of the regional sewer system, which has greatly reduced groundwater contamination within park boundaries and in the general vicinity, the park had endured considerable long-term, adverse impacts on groundwater quality. Dye traces have shown a direct hydrologic link between parking lot runoff and certain cave passages, which may have led to contamination of cave drip water. Nearby oil and gas exploration poses the risk of spillage into the park's groundwater system. Illegal dumping of wastes into sinkholes outside of the park also contaminates groundwater. Future concessions operations and road maintenance activities have the potential to contribute inputs to groundwater reaching the cave.

While adverse impacts from outside park boundaries continue to impact groundwater in the park, several measures have been taken to reduce or eliminate contamination of groundwater feeding karst aquifers in the park. For example, parking lot filters have been installed to reduce or prevent parking lot contaminants from entering the cave and the improved regional sewer system has minimized levels of pollutants reaching the groundwater. In addition, the park replaced an old water supply system with a modern system in 2011 to meet potable water and fire protection needs.

Cumulatively, these past, present, and future actions would have small adverse impacts on water resources in the cave. The action alternative would contribute small to negligible adverse cumulative impacts on water resources. In combination, these actions would result in small adverse cumulative impacts on water resources.

**Conclusion.** The action alternative would likely result in temporary, localized, and relatively small adverse impacts on water resources from potential contamination attributed to opening new cave tours and ongoing visitor use and operational activities in the park. Because there would be no major adverse impacts to a resource or value whose conservation is (1) necessary to fulfill specific purposes identified in the establishing legislation or proclamation of the park, (2) key to the natural or cultural integrity of the park or to opportunities for enjoyment of the park, or (3) identified as a goal in the park's general management plan or other relevant NPS planning documents, there would be no impairment of the park's resources or values with respect to water resources.

## PALEONTOLOGICAL RESOURCES

### No-Action Alternative

**Analysis.** As there would not be any new actions under the no-action alternative, there would not be any new impacts on paleontological resources. However, since the edges of some cave trails still need to be properly defined, park visitors on cave tours would continue to stray off trail, which may disturb paleontological resources in the cave. Additionally, without containment of lint and better abatement of dust in some areas of the cave, lint and dust would continue to accumulate on paleontological resources. Layers and mats of lint harbor microscopic organisms that could cause damage to exposed paleontological features in the cave; artifacts under trails would not be affected.

**Cumulative effects.** Past, present, and future impacts to paleontological resources include lint and dust accumulation, accidental or intentional damage, and natural degradation in the cave environment. Lint—as well as factors such as changes to airflow, pH, and temperature—disrupts the delicate balance that exists in a cave environment. There is also potential for damage to paleontological resources from microbial action that is made possible by energy provided in the form of lint and other materials. Additionally, paleontological resources in the cave may have been affected by past and current projects, such as operation of the Snowball Room dining facilities, restroom installation, the cave electric upgrade, and construction of prototype cave trails. For example, past actions have had notable, localized, adverse impacts on paleontological deposits near the Frozen Niagara area.

Cumulatively, these past, present, and future actions would have long-term, localized, direct adverse impacts on paleontological resources in the cave.

**Conclusion.** The no-action alternative would likely result in long-term, localized, direct adverse impacts on paleontological resources from disturbance of artifacts by visitors continuing to stray off trails in certain areas and from continued accumulation of lint and dust. Because there would be no major adverse impacts to a resource or value whose conservation is (1) necessary to fulfill specific purposes identified in the establishing legislation or proclamation of the park, (2) key to the natural or cultural integrity of the park or to opportunities for enjoyment of the park, or (3) identified as a goal in the park's general management plan or other relevant NPS planning documents, there would be no impairment of the park's resources or values with respect to paleontological resources.

### Action Alternative

**Analysis.** Under the action alternative, a host of cave-enhancement activities resulting in surface disturbance has the potential to adversely impact numerous paleontological resources. However, employing mitigation measures recommended by Manzano et al. (2009) for areas that have medium and high potential to produce scientifically significant paleontological materials would avoid or greatly reduce adverse impacts to paleontological resources. Additionally, locations containing significant sensitive resources would be excluded from cave-enhancement activities to ensure that no impacts would occur.

Under the action alternative, some of the cave-enhancement activities would reduce lint and dust and would decrease the opportunity for vandalism of cave resources. For example, in some areas where the edges of the cave trails are still poorly defined, measures would be taken to better define trails (e.g., installing lint curbs or hand rails). In other areas, hardening the trail surface may be sufficient to define the trail. Well-defined trails should reduce the number of visitors who wander off the trails and cause damage to paleontological resources. Lint curbs would accumulate lint along the curbs in sections of the cave where they are installed, preventing lint from covering paleontological resources in those areas. Dust would be abated on trail segments where the surface would be replaced with paving stones or other hardened surfaces; however, some trails may still maintain cave-sediment surfaces in areas where dust is not a major problem. Thus, most dust clouds caused by visitors walking on trails would be controlled in the cave and greatly reduced in some areas. Since dust would track onto the hardened surfaces from the remaining sediment-based segments, however, dust would not likely be eliminated completely. Proposed cave-enhancement activities would have beneficial impacts on paleontological resources by greatly reducing the detrimental effects of lint, dust, and vandalism.

**Cumulative effects.** Past, present, and future impacts to paleontological resources include lint and dust accumulation, accidental or intentional damage, and natural degradation in the cave environment. Lint—as well as factors such as changes to airflow, pH, and temperature—disrupts the delicate balance that exists in a cave environment. There is also potential for damage to paleontological resources from microbial action that is made possible by energy provided in the form of lint and other materials. Additionally, paleontological resources in the cave may have been affected by past and current projects, such as operation of the Snowball Room dining facilities, restroom installation, the cave electric upgrade, and construction of prototype cave trails. As the example noted in the no-action alternative analysis, past actions have had notable, localized, adverse impacts on paleontological deposits near the Frozen Niagara area.

Cumulatively, these past, present, and future actions would have long-term, localized, direct adverse impacts on paleontological resources in the cave system.

**Conclusion.** The action alternative would have long-term, localized, direct adverse effects on the paleontological resources from potential damage that could occur during cave enhancements. However, efforts to continue upgrading cave tour trails would reduce or mitigate ongoing impacts to paleontological resources along tours such as the Lantern Route, resulting in long-term, beneficial impacts from the reduction of dust, lint, and vandalism. Because there would be no major adverse impacts to a resource or value whose conservation is (1) necessary to fulfill specific purposes identified in the establishing legislation or proclamation of the park, (2) key to the natural or cultural integrity of the park or to opportunities for enjoyment of the park, or (3) identified as a goal in the park's general management plan or other relevant NPS planning documents, there would be no impairment of the park's resources or values with respect to paleontological resources.

## CULTURAL RESOURCES

### No-Action Alternative

**Analysis.** Under the no-action alternative, there would be no new conditions or treatments to cultural resources in Mammoth Cave. Current cultural resource management activities in the park and cave tour operations would continue. Tours would be scheduled for routes that are used at current tour-capacity levels. All existing tour infrastructure (walkways, fencing, stairs, lighting) would stay in place in the cave. Cultural resources located near established tour routes with walkway edges that are not well defined would continue to be vulnerable to damage due to inadvertent visitor behaviors or vandalism. Any impacts to archeological resources or historic structures would be localized, potentially adverse, and permanent. Lint introduced by visitors and dust created by tour groups and park operations would accumulate at the current levels on archeological resources and historic structures and could contribute to the deterioration of historic materials.

**Cumulative effects.** Past, present, and reasonably foreseeable future projects in the park and surrounding areas have the potential to affect cultural resources. Any past trail and infrastructure projects using heavy machinery, removing or relocating cave materials, or creating ground disturbance had the potential to damage nearby archeological resources. Recent NPS trail-improvement projects would have been completed in accordance with NPS management policies and would have considered how to best minimize effects to archeological resources, extant historic structures, and the overall national register-listed historic district.

Present and reasonably foreseeable future actions, when combined with the continuation of cave tours and park operations described in the no-action alternative, would likely result in minimal, localized adverse effects on archeological resources and historic structures due to inadvertent visitor impacts and lint and dust accumulation that would continue until improvements are enacted.

**Conclusion.** Both intentional and unintentional visitor-caused damage and lint/dust accumulation affect important archeological resources located near currently used trail routes in the park. These effects—when considered with other past, present, and reasonably foreseeable future projects—would have permanent, localized, adverse impacts on individual archeological resources and historic structures that would continue until improvements are enacted.

### Action Alternative

**Analysis.** The action alternative includes potential trail improvements, installation of new tour infrastructure on currently used and historic trail routes, and implementation of revised visitor capacities for routes and areas included on cave tour routes. The potential construction of additional tour infrastructure in the action alternative may include stairs, walkways, fencing, or lighting along currently used trail routes. Any construction activities could involve heavy machinery/equipment, ground disturbance, and the creation of dust and debris that could damage nearby cultural resources. All additional trail infrastructure or improvements related to actions proposed in the action alternative would comply with the Secretary of the Interior's Standards and Guidelines for Archeology and Historic Preservation, and Director's Order 28: *Cultural Resource Management*. Any trail improvements or additional infrastructure resulting from this plan would be sited to minimize effects on known cultural resources and areas with high potential for archeological resources or other sensitive cultural resources would be avoided. Individual projects to develop new infrastructure or improve existing structure along trail routes connected with this plan would be subject to future section 106 consultation with the Kentucky State Historic Preservation Office. Mitigation measures outlined in this plan or included in future NEPA or section 106 documentation would be implemented to minimize potential effects to historic material in the cave, archeological sites, and the national register-listed historic district.

Changes to or the addition of infrastructure along historic trail routes could affect cultural landscapes associated with earlier tourism efforts, CCC development, and Mission 66 development. Any updates to historic infrastructure or trail-improvement projects associated with this plan should consider important cultural landscape characteristics and contributing cultural landscape features during the design phase and implementation. Landscape characteristics—including historic vistas and views of the natural cave, spatial organization and the historic trails' interplay with cave topography, and small-scale and circulation features—contribute to the district's integrity and support the understanding of the relationship between significant cultural activities and the natural environment. Individual trail and construction projects identified during implementation of this plan that have the potential to impact the overall integrity of the historic district, individual contributing landscape features, and other national register-eligible resources would be subject to section 106 consultation with the Kentucky State Historic Preservation Office.

Trail refinements and improvements also have the potential for beneficial impacts to cultural resources. Well-defined trail boundaries and walking surfaces could reduce off-trail activities and the inadvertent damage of archeological sites and historic resources. Improved walkways could also include lint curbs that gather lint and direct lint accumulation away from cultural resources. Hardened walking surfaces would drastically reduce the amount of dust created by tours. While these improvements could result in permanent adverse effects on the integrity of historic infrastructure and historic trails due to their replacement or alteration, they would provide localized beneficial impacts by reducing lint and dust accumulation and reducing the potential for visitors to wander off trail and inadvertently damage cultural resources in the vicinity.

Some historic trail routes not currently in use could be reopened to guided tours under the action alternative. Increased visitor access through park-guided tours or permits to portions of the cave system not currently included in tours could lead to inadvertent damage or vandalism to archeological resources and/or historic structures found along the proposed routes. However, controlling visitor access to park-guided cave tours and park-approved permits would limit the potential for visitor-caused damaged or destruction of cultural resources along trail routes. Furthermore, implementing visitor capacities for individual tours and tour routes and managing to visitor use thresholds would offer additional monitoring protocols and help to limit visitor-use impacts.

**Cumulative effects.** Cumulative effects of the action alternative would be similar to those described for the no-action alternative.

Trails and tour infrastructure built in the early years of tourist development in the cave could have destroyed archeological sites or inadvertently damaged archeological resources. The action alternative has the potential to contribute to these past adverse impacts related to archeological resources. However, the cumulative impacts of past actions, ongoing activities, and the action alternative would not affect the integrity of identified archeological sites due to the mitigation measures included in this plan, thoughtful project siting, and monitoring by cultural resource professionals associated with NPS actions. Over time, replacement of early tourism-era and CCC-era tour infrastructure and lighting has adversely affected the integrity of the associated cultural landscape but has improved visitor safety. Recent NPS trail-improvement projects would have been completed in accordance with NPS management policies and would have considered how to best minimize effects on archeological resources, extant historic structures, and the overall national register-listed historic district.

**Conclusion.** The action alternative has potential for beneficial and adverse effects on cultural resources. Trail and tour infrastructure improvements proposed under the action alternative would have beneficial impacts on archeological resources and historic structures by greatly reducing the detrimental effects of lint and dust and decreasing the likelihood of inadvertent damage by visitors and vandalism. Revising tour capacities and ensuring visitor access through guided tours or permits can also limit the potential for visitor-related resource damage. The replacement of historic infrastructure or the addition of modern infrastructure on historic trail routes could adversely affect the integrity of the Mammoth Cave Historic District and other national register-eligible resources through the removal or replacement of contributing features. New additions and the removal of historic features could result in the diminished integrity of materials, design, setting, and workmanship. Any adverse effects related to actions proposed under the action alternative, which would be localized and permanent, would be limited by the mitigation measures outlined in this plan or included in future NEPA or section 106 documentation prepared during the design and construction of individual trail or improvement projects.

# VISITOR USE AND EXPERIENCE

## No-Action Alternative

**Analysis.** Under the no-action alternative, current impacts to visitor use and experience would continue. Current park management of cave tour operations would continue. Existing cave tours would maintain current tour capacity levels and no additional routes would be added. Adverse impacts to visitor experience occur during high peak visitation periods when tours are filled and visitors are turned away to wait for an available tour or go on the Discovery Tour. The Discovery Tour would continue to see large numbers of visitors without an identified capacity, creating crowding and congestion during high peak visitation. With the trend of increasing visitation and no identified cave daily capacity, the risk for crowding increases, along with the additional impacts related to crowding (e.g., compromised visitor safety, resource damage). Crowding impacts visitor safety by creating longer response times for emergency situations. It also increases the risk of vandalism to the cave and prevents visitors from experiencing the fundamental resources and values of the cave environment. Existing information available to visitors about cave tours in the park and surrounding area would continue, resulting in some visitors not being able to go on their preferred cave tour or meet their desired visitor experience. This would result in unrealized visitor expectations and adverse impacts to the visitor experience.

**Cumulative effects.** Past, present, and reasonably foreseeable future projects in the park have the potential to affect visitor use and experience. The addition of more cave tours, including an accessibility tour, has allowed for more visitors to experience the cave. This past action has also increased the number of visitors in the cave and, at times, resulted in congestion that adversely impacts the visitor experience. Ongoing and future maintenance of cave trails and infrastructure would temporarily (during construction only) adversely impact visitor experience but would result in long-term beneficial effects. Projected increase in visitation would result in more congestion in the cave and more visitors having to take overflow tours.

Cumulatively, these past, present, and future actions would have moderate adverse impacts on visitor use and experience in the cave. The no-action alternative would contribute moderate to negligible adverse cumulative impacts on visitor use and experience. In combination, these actions would result in small adverse cumulative impacts on visitor use and experience.

**Conclusion.** The no-action alternative would contribute more adverse than beneficial effects to visitor experience and safety. Visitors would still have access to a diverse range of experiences. A need for more park information provided to visitors, such as peak visitation times of day and year, would continue to adversely impact the visitor experience. Visitors would not have adequate information to make informed decisions about the best time to visit the caves to enjoy their desired visitor experience. Maintenance of the cave trail systems would adversely impact the visitor experience, at first, and then improve their experience when trails reopen. With visitation to the park increasing every year, crowding in the cave would become a concern if no overall daily capacity is set. Crowding causes adverse impacts to visitor safety and delayed emergency response times. Desired conditions for resources and visitor experiences are less likely to be achieved in the no-action alternative than under the action alternative.

## Action Alternative

**Analysis.** The action alternative includes potential trail and tour improvements, enhanced ticketing and information surrounding cave tours, and revised visitor capacities for cave tour routes. In addition to the actions in the alternatives, the impact analysis includes strategies and actions associated with the indicators, thresholds, and visitor capacity. Not all strategies—specifically the trail and cave tour improvements and temporary and/or permanent closures—would necessarily be implemented concurrently with the action alternative. These strategies and actions would be implemented based on feasibility, staff resources, park funding, or as needed when thresholds are approached or as part of managing visitor capacity.

Beneficial impacts to visitor use and experience occur from the reopening of previously used and temporarily closed tour routes. This would provide a more diverse range of cave experiences for visitors and spread out visitation in different areas of the park resulting in less crowding of the overflow Discovery Tour and an enhanced visitor experience. Increasing the number of tours offered throughout the year and day provides more opportunity to shift visitation to off-peak times. This reduces congestion in the cave and results in a beneficial impact to visitor use and experience.

Trail and tour-route improvements also provide enhanced safety for visitors and decreases the chance for vandalism. Increasing the number of guides on large tours can help with answering visitor questions, provide safety instructions, and help monitor for potential impactful behavior to the resources. In the action alternative, the proposal for improved trail infrastructure, such as the installation of handrails and permanent anchoring systems to aid in patient evacuations, provides safety-related beneficial impacts to visitor use and experience.

Providing more information to visitors about cave tour difficulty levels and high-peak visitation times would allow visitors to select the experiences and tours that align with their motivation and preferences on desired opportunities and create expectations for when high use in the caves is to be expected. These are all beneficial effects for visitor use and experience.

Implementing age and footwear requirements for certain tours creates both adverse and beneficial impacts to the visitors use and experience. Some visitors may be turned away from tours if they have small children or do not have the proper footwear. For those visitors who acquired the information in advance, their experience on the tour would be heightened and safer since they would be equipped with proper footwear and with other visitors who can handle the cave terrain for that tour.

Under the action alternative, the current capacity levels for most existing cave tours would stay the same or increase slightly (see appendix B for a more detailed and thorough analysis). An overall Main Cave capacity was identified as 6,500 visitors per day, which would impact the frequency of cave tours per day. Implementation of the visitor capacity would result in beneficial impacts to the visitor experience by managing crowding and congestion on tours in the caves. Implementing visitor capacity disperses visitation over time and space, leading to less overlap of numerous tours in the same cave area at one time. This would help to achieve or maintain the desired conditions for visitor experience of being immersed in the sights and sounds of the cave. Other beneficial impacts include a reduction in visitor conflicts as a result of reduced crowding and congestion on the Discovery Tour. Implementing the visitor capacity has the potential to create adverse impacts to visitor use and experience as visitors might be required to wait for the next available tour. These adverse impacts are slight and would only occur during peak visitation times. The park would print times on Discovery Tour tickets to manage how many visitors enter the cave at specified time intervals; this would be a beneficial impact by managing crowding and congestion.

Other adaptive strategies associated with implementing visitor capacity include temporary or permanent closures. Visitors are likely to experience adverse impacts when temporary or permanent closure of tour routes are implemented for natural resource protection. In the short term, temporary closures are likely to result in moderate adverse impacts to visitor experience as they could go on a different tour or wait for the experience to become available. However, permanent closures of certain cave tours are likely to result in a decreased range of visitor opportunities and higher demand for other tours. In the long run, a permanent closure could result in visitor displacement from the cave experience.

**Cumulative effects.** The reopening of additional cave tours and increasing the frequency of existing cave tours called for in the action alternative would likely help spread visitation use throughout the cave and reduce congestion as visitation increases. Increased information provided to visitors about cave tour opportunities and peak visitation times would also help mitigate those issues. The projected increase in visitation and implementing visitor capacity for the Discovery Tour, which acts as an overflow tour, would likely result in adverse visitor impacts. During high peak times of day, if the Discovery Tour capacity is reached, visitors would be asked to wait until the next tour time becomes available.

The effects of other past, current, and reasonably foreseeable future actions by others, in combination with the effects of the NPS action alternatives, would result in minor, beneficial cumulative effects. Combining the effects of implementing the NPS action alternatives with the effects of other past, current, and reasonably foreseeable future actions described above, the cumulative long-term visitor use and experience impacts would be minor and mostly beneficial.

**Conclusion.** Desired conditions for resources and visitor experiences are more likely to be achieved under the action alternative than under the no-action alternative. Beneficial impacts would result from providing an increased range of visitor opportunities by offering an expanded range of cave tours, safer trail routes for visitors, and information to visitors about the range of available opportunities. Adverse impacts to visitor use and experience would result from temporary or permanent tour closures for resource protection. These effects, when considered with other past, present, and reasonably foreseeable future projects, would have long-term, beneficial cumulative impacts to visitor experience and safety.

# Chapter 5

## Consultation and Coordination

CHAPTER 5 DIVIDER (BACK PAGE)

# CHAPTER 5: CONSULTATION AND COORDINATION

## US FISH AND WILDLIFE SERVICE, SECTION 7 CONSULTATION

Special status species occurring at Mammoth Cave National Park includes federally endangered and federally threatened species. In addition, there is potential for several species of special interest to occur at the park. These species are identified in table 1 and described in Chapter 3: Affected Environment. Mammoth Cave compliance and resource management staff consulted with members of the US Fish and Wildlife Service throughout the development of the plan to identify and proactively avoid actions that have the potential to impact federally listed or threatened species found within the cave. The park will continue to informally consult with USFWS representatives as projects associated with the comprehensive cave and karst management plan are initiated to ensure the identified species are not affected during implementation of individual actions outlined in this planning effort.

## KENTUCKY HERITAGE COUNCIL AND AFFILIATED TRIBES, SECTION 106 CONSULTATION

Agencies that have direct or indirect jurisdiction over historic properties are required by section 106 of the National Historic Preservation Act of 1966, as amended (54 USC 306108) to take into account the effect of any undertaking on properties eligible for listing in the National Register of Historic Places. Under the terms of the 2008 Programmatic Agreement among the National Park Service, the Advisory Council on Historic Preservation, and the National Conference of State Historic Preservation Officers for Compliance, "all undertakings that do not qualify for streamlined review will be reviewed in accordance with 36 CFR Part 800."

Due to the comprehensive nature of the cave and karst management plan and the extended potential timeline for implementation, details related to the exact location, design, and necessary construction activities for all associated actions that may affect historic properties have not been determined. This level of detail is necessary to properly assess the potential effects on historic properties through section 106 compliance and to identify additional mitigation measures to best preserve the historic character of the cultural resources found in the cave. Since the National Park Service cannot yet assess the specific effects of some individual projects on historic properties carried out as the selected alternative is implemented, Mammoth Cave National Park commits to continuing to consult with the Kentucky Heritage Council, traditionally associated tribes, and other consulting parties as necessary and completing section 106 compliance for individual actions as they are pursued. This requires that the park continue to perform identification and evaluation of potential historic properties within designed areas of potential effect, in accordance with section 106 regulations (36 CFR 800). Undertakings will be evaluated for their affects findings and every effort will be made to avoid, minimize, or mitigate any activity that is found to have an adverse effect on a historic property.

Indicators and thresholds that have been identified by this current assessment will support the park's efforts to avoid and minimize effects to the park's cultural resources within the cave setting. Monitoring of cave cultural resources by cave guides, cultural resource staff, and volunteer supporters will help preservation specialists provide treatments to historic properties and the surrounding cave setting. This monitoring and treatment process is ongoing and continuous, with this plan supporting future section 106 compliance actions that will complete independent review of a project area, as well as provide information for future section 110 identification and evaluation of cultural resources within the park's caves.

Future undertakings that will result in other activities that may have an effect on historic properties will be reviewed under the section 106 process. For section 106 reviews, Mammoth Cave National Park's consulting parties include the Kentucky Heritage Council, the seven traditionally associated tribal organizations, the Friends of Mammoth Cave National Park, and other local and regional partners interested in providing comment.

Based on the described plan, the park has taken into consideration those routine actions and resource management activities that will have an effect on historic properties in the cave and karst environment within Mammoth Cave National Park. The National Park Service recommends the proposed plan to result in No Adverse Effects on historic properties (36 CFR 800.5[d][1]).

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# Chapter 6

## References

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# CHAPTER 6: REFERENCES

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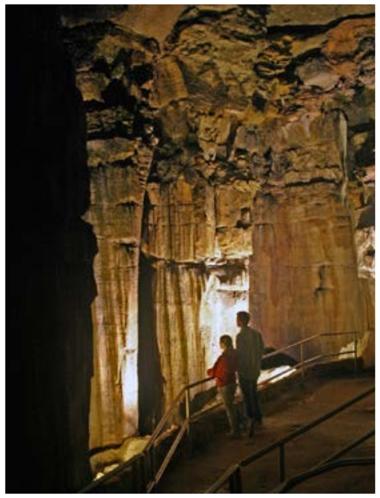
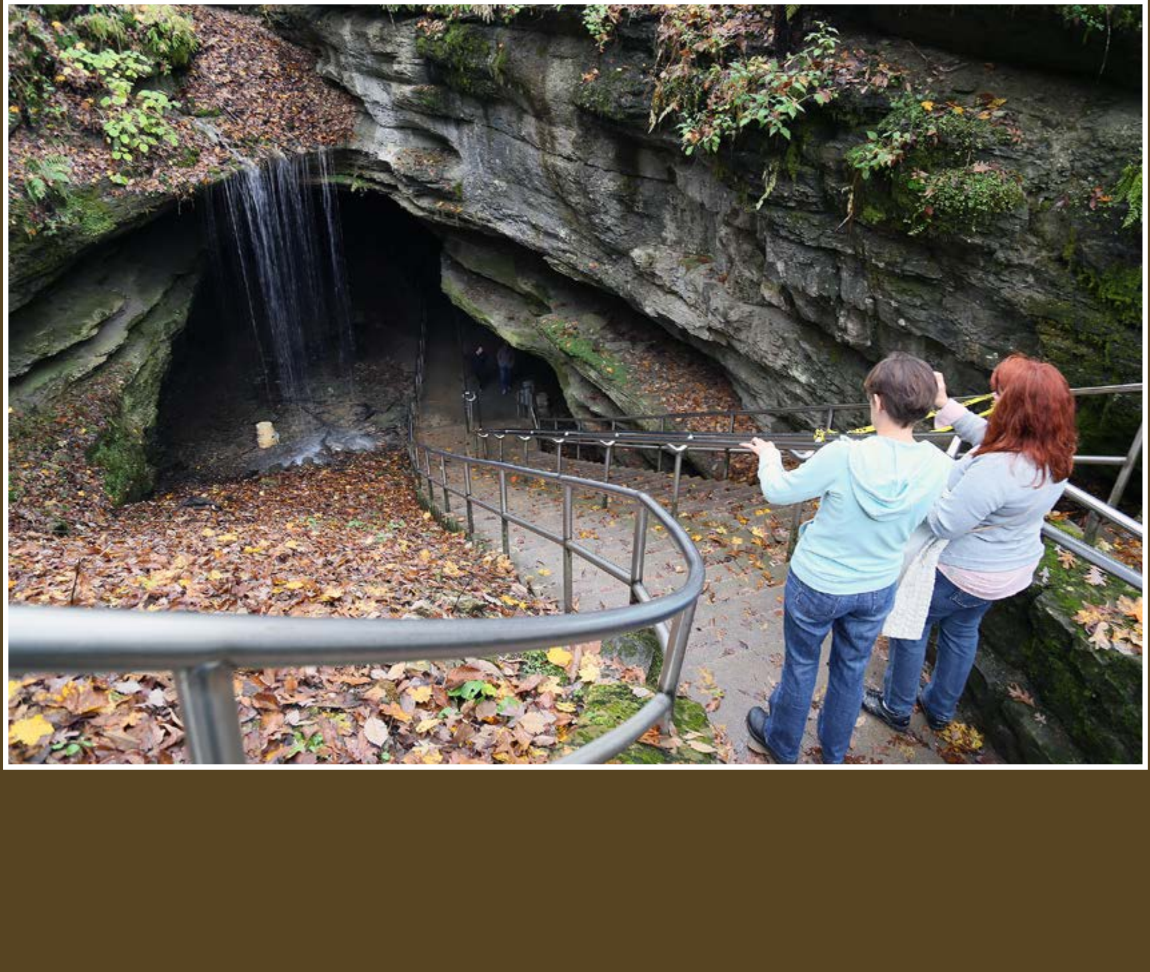
# Appendixes





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# APPENDIX A: FIGURES

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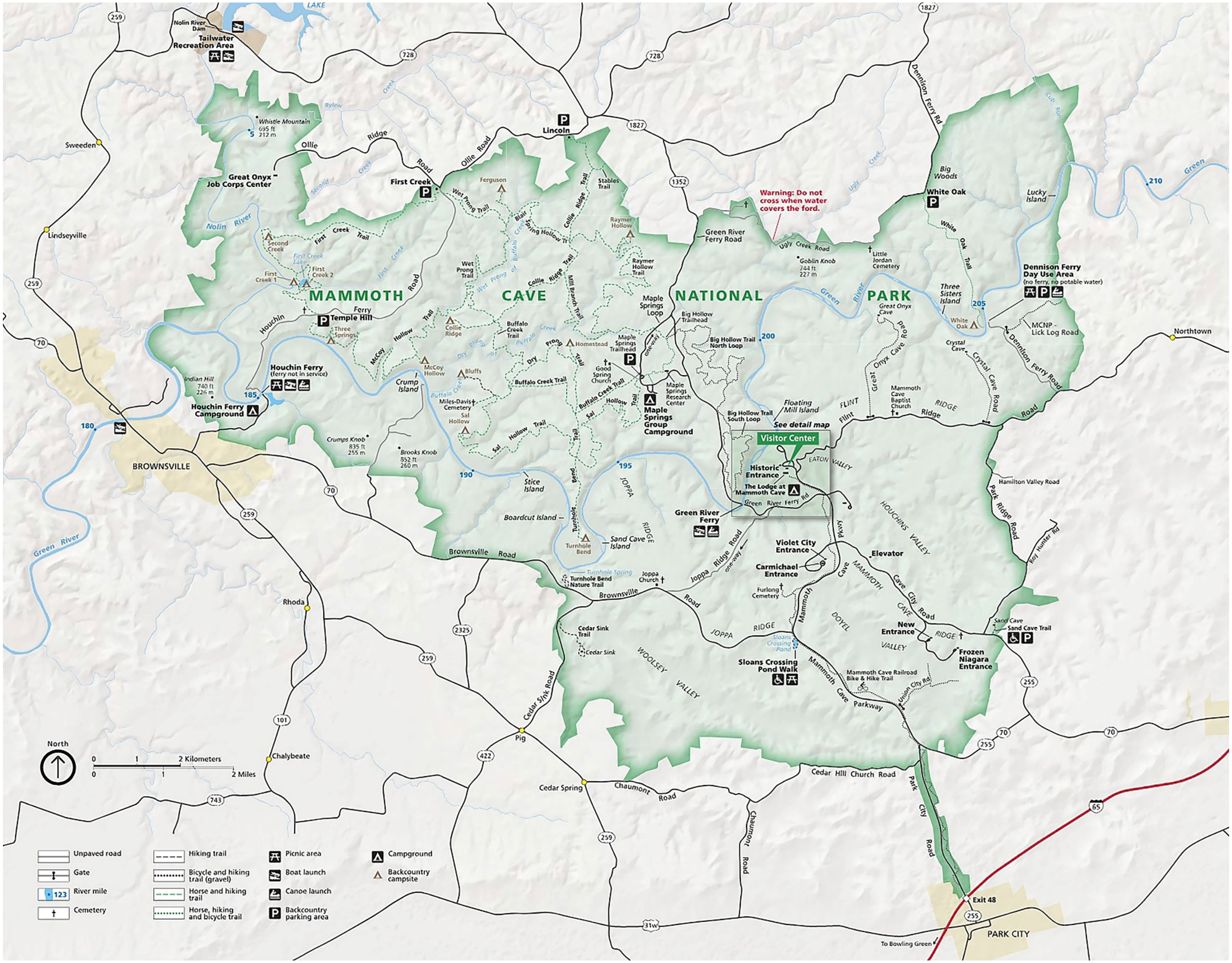
Figure 1. Map of Mammoth Cave National Park



Karst on Mammoth Cave National Park

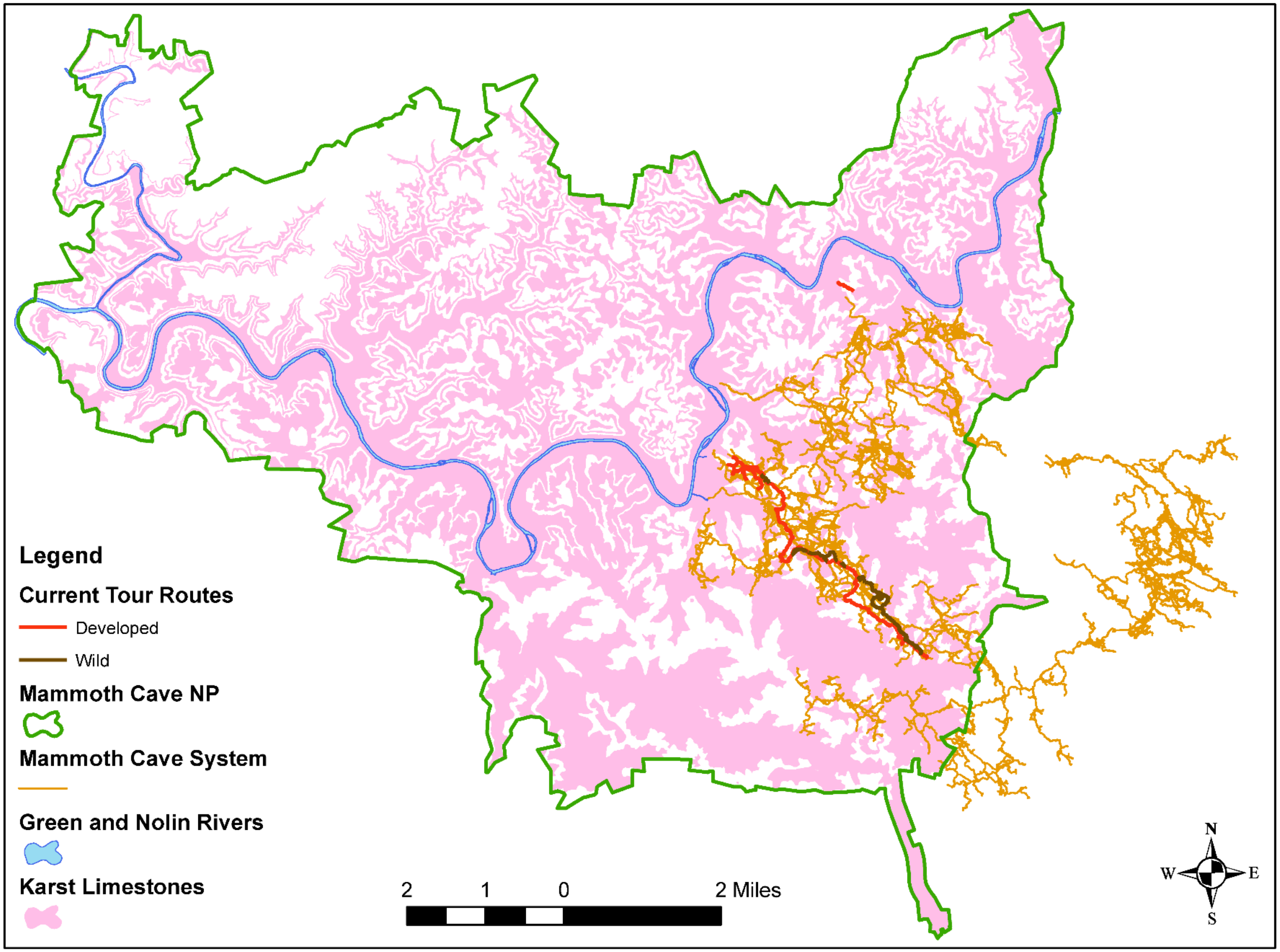



FIGURE 2. MAP OF MAMMOTH CAVE SYSTEM

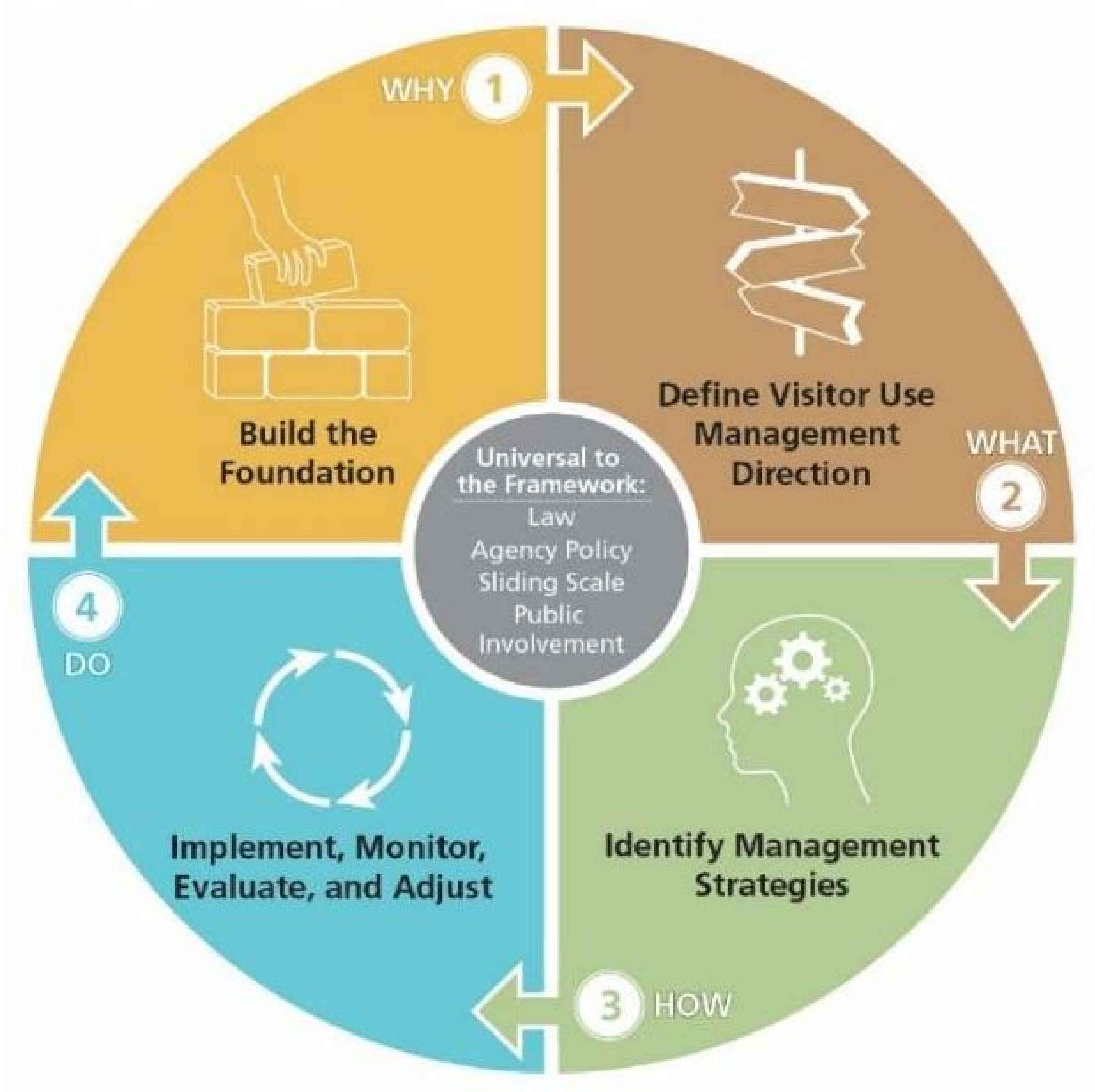



**FIGURE 3. OVERVIEW OF VISITOR USE MANAGEMENT PLANNING PROCESS**

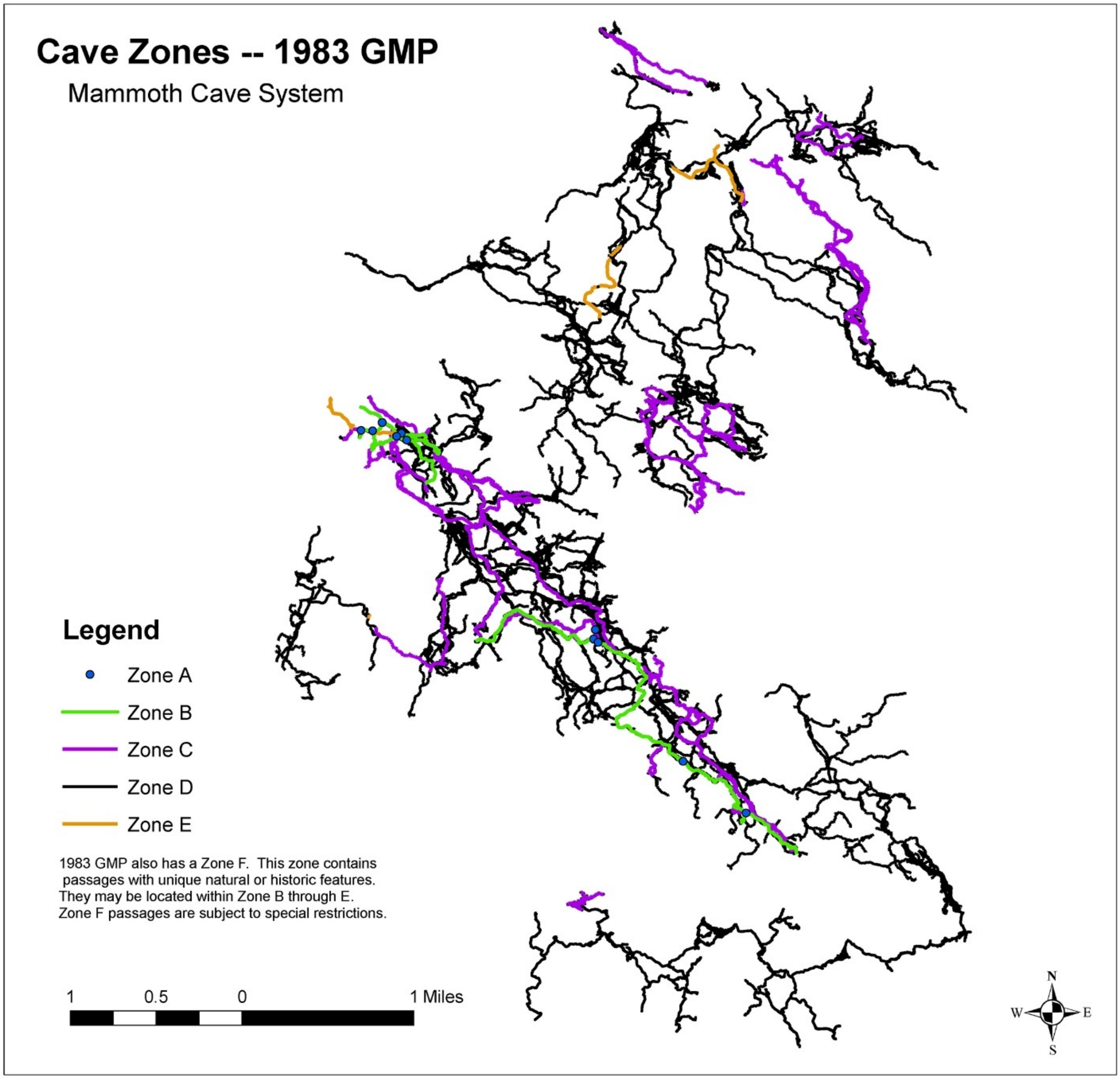



**FIGURE 4. CURRENT CAVE ZONES**

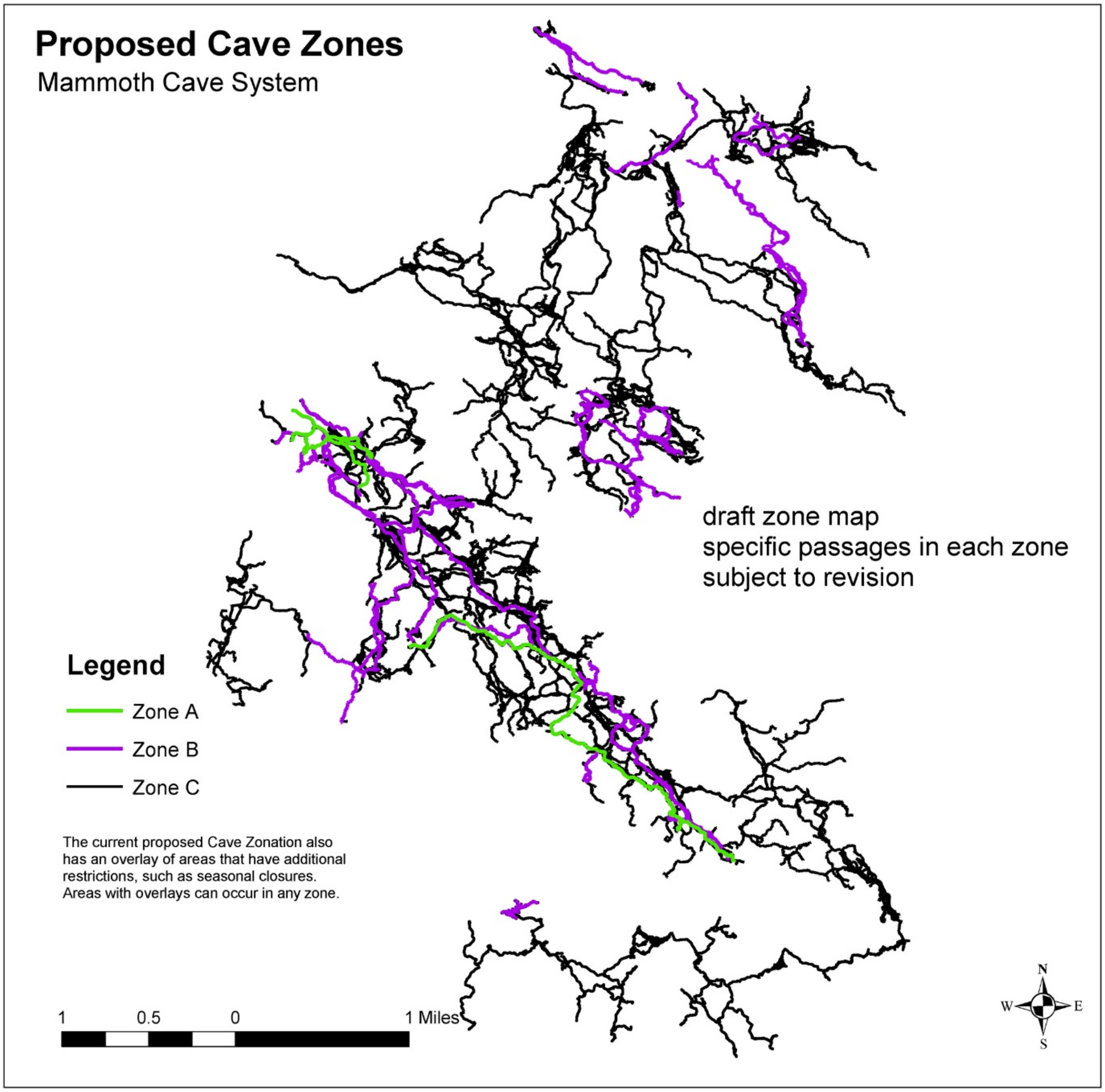



**FIGURE 5. PROPOSED CAVE ZONES**

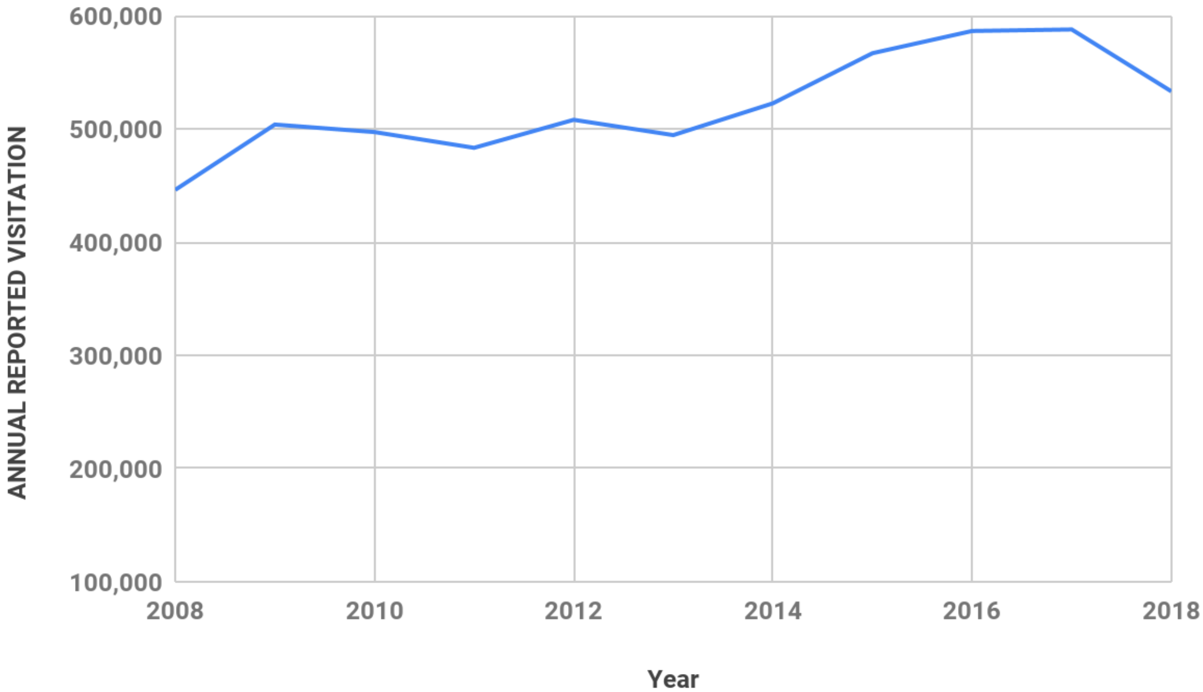



**Figure 6. Annual visitation to Mammoth Cave National Park (2008-2018)**

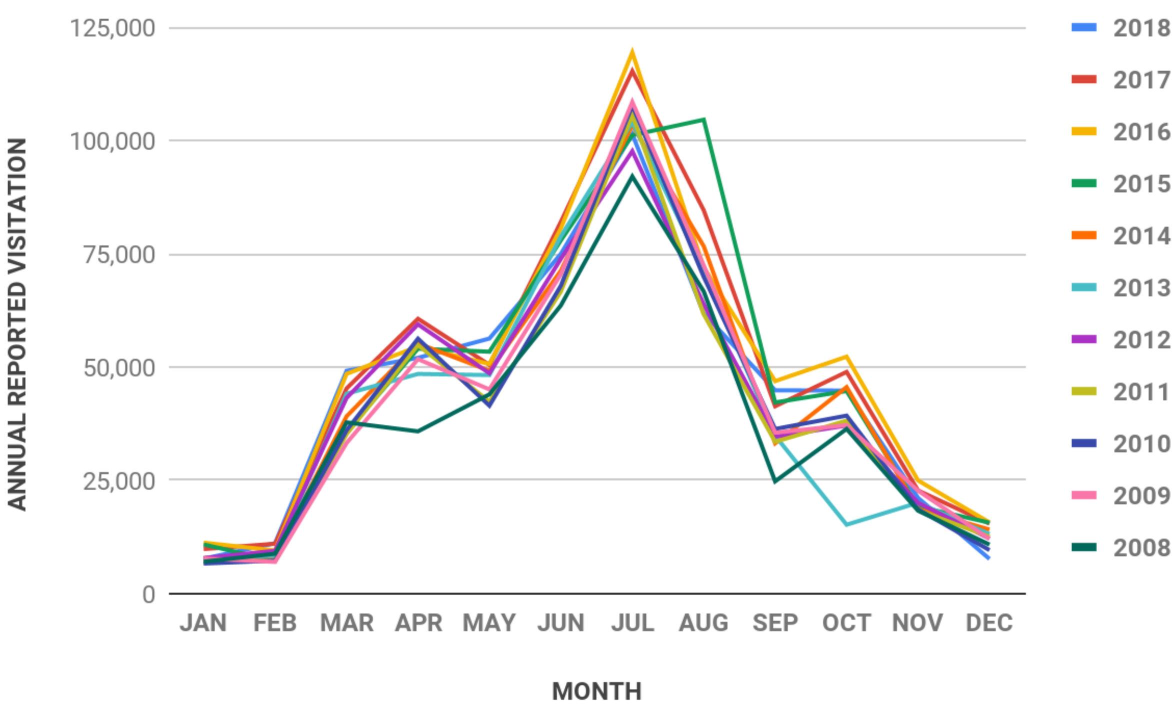



**Figure 7. Monthly visitation to Mammoth Cave National Park (2008-2018)**

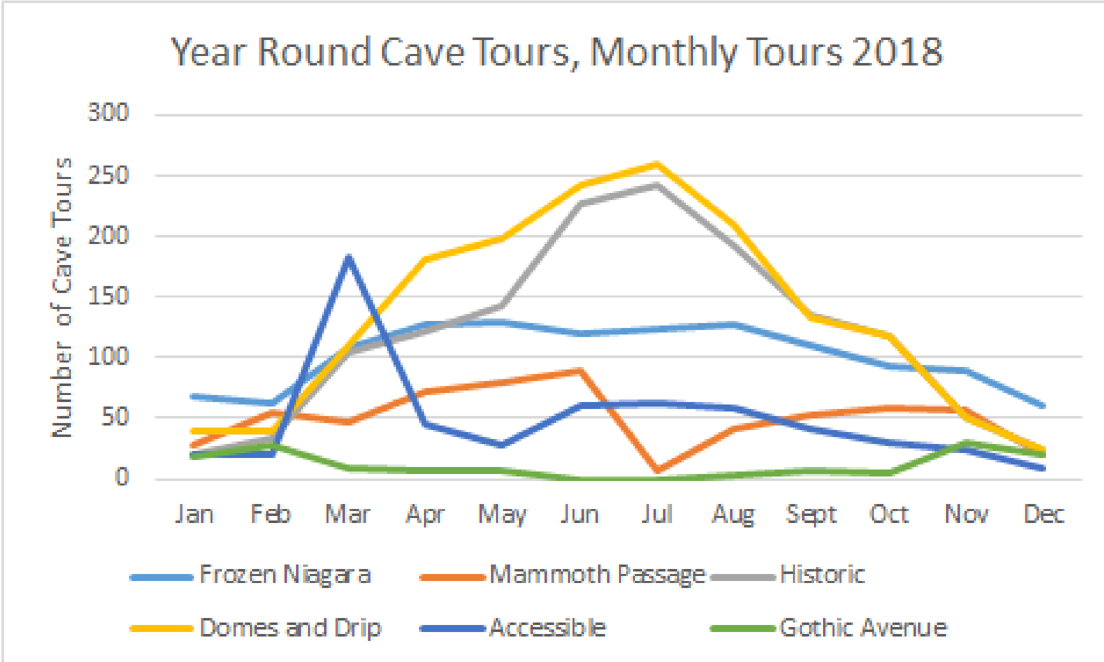



**FIGURE 8. MONTHLY TOURS GIVEN IN 2018 FOR CAVE TOURS OFFERED THROUGHOUT THE YEAR**

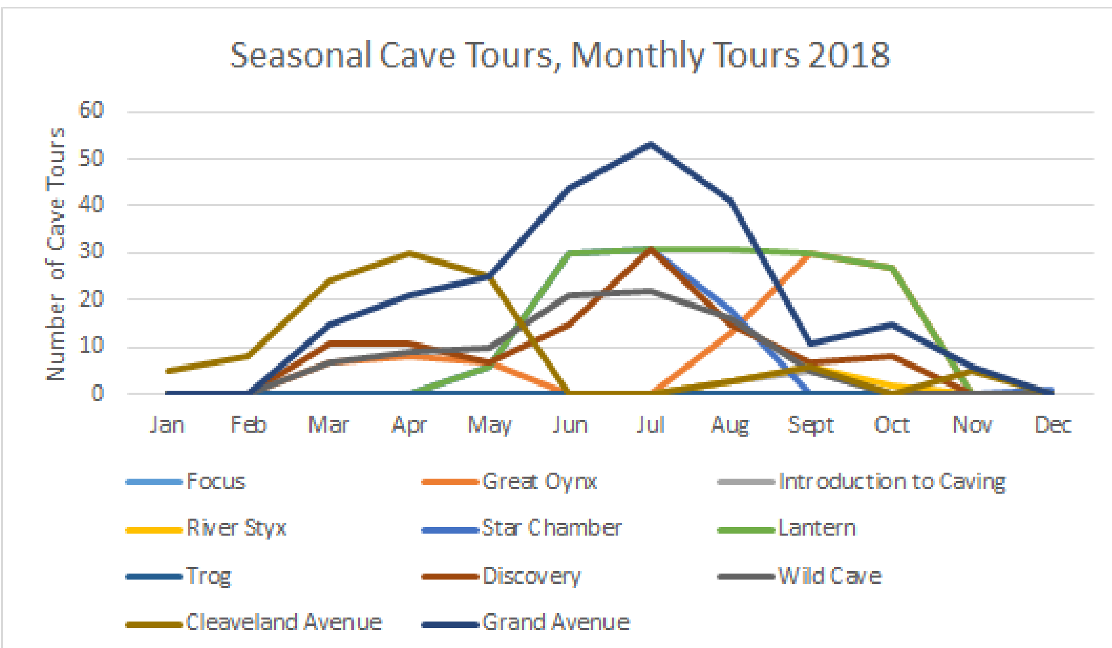



**FIGURE 9. MONTHLY TOURS GIVEN IN 2018 FOR SEASONAL CAVE TOURS**

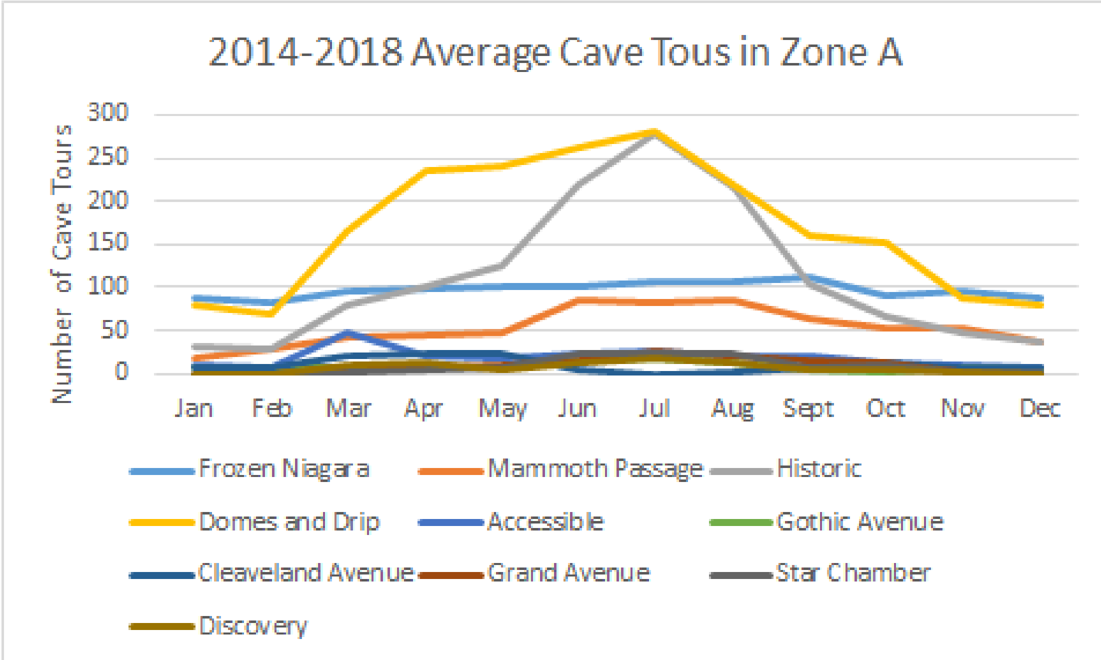



**FIGURE 10. 2014-2018 AVERAGE CAVE TOURS IN ZONE A**

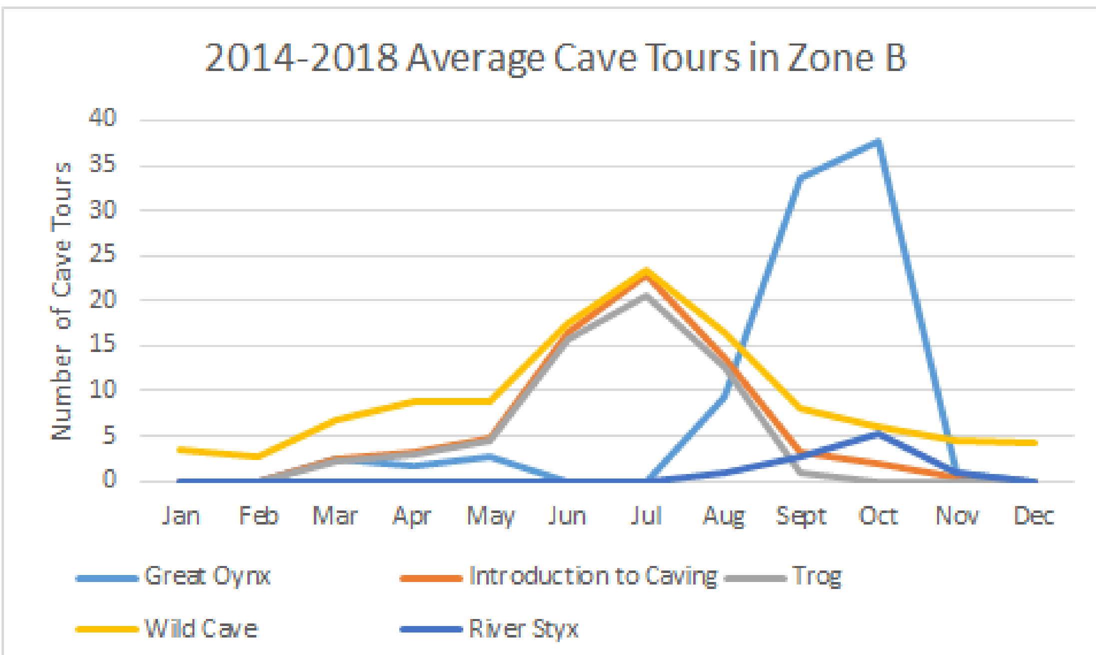



**FIGURE 11. 2014-2018 AVERAGE CAVE TOURS IN ZONE B**

# APPENDIX B: VISITOR USE MANAGEMENT MONITORING STRATEGY FOR INDICATORS, THRESHOLDS, AND VISITOR CAPACITY

## INDICATORS, THRESHOLDS, MONITORING, AND MANAGEMENT STRATEGIES

The park has current monitoring programs—the Cumberland Piedmont Network Inventory and Monitoring Program—that monitor the cave-and-karst biome, and a forthcoming partnership with the University of Tennessee to monitor algae growth and water quality in the caves. This section adds to ongoing monitoring in the park, with a focus on visitor-caused impacts.

The interdisciplinary planning team considered potential issues and developed related indicators that would help identify when a level of visitor-related impacts become a cause for concern and when management action may be needed. The following are indicators park staff identified to be most important in maintaining desired conditions for visitor experience and natural and cultural resources:

- number of incidents of vandalism on tour routes per year
- number of illegal cave entries per year resulting from break-ins
- visitor concerns related to tour size and crowding on park cave tours
- algae growth
- water quality

### Indicator 1

Number of incidents of vandalism on tour routes per year.

**Thresholds.**

- No more than five incidents of rock theft or resource damage from visitors walking off trail in any one section of cave.
- No more than two incidents of new graffiti in any one section of cave (a cave section is typically defined by the primary tour routes even though it is recognized that multiple tours traverse the same cave sections).
- No more than one incident of formation damage or theft of cultural resource in any one section of cave.

**Rationale for Indicator and Thresholds.**

Damage to resources can occur through both intentional and unintentional means; both can cause impacts that influence the integrity of these resources. This indicator focuses on intentional damage to resources. Examples of incidents of vandalism include (but are not limited to) graffiti, theft of materials or objects, off-trail activities in sensitive resource areas, breaking of formations, and killing or harassing cave wildlife. Vandalism can cause resource damage that is difficult or impossible for resources to recover from or to repair. Many of the resources, both cultural and natural, are highly sensitive; they are not resilient to damage from vandalism.

**Monitoring Guidelines.**

Monitoring would occur through physical monitoring on tour routes by staff. Physical monitoring would be conducted in the everyday operations of cave tours and other cave activities. Staff would continue completing condition assessments in sensitive areas of the cave or for specific resources, as needed. Staff would evaluate areas most vulnerable to vandalism (e.g., narrow passages, historic routes, areas with formations). If potential vandalism is observed, park staff would notify supervisory and management staff to initiate further investigation and documentation of cave damage. Resource subject matter experts would conduct a damage analysis to determine if vandalism was a cause or contributing factor.

**Management Strategies.**

- Educate visitors, researchers, park staff, and others on the sensitivity of resources and the need to protect them, including messaging through signage.

- Increase staff/volunteer presence to monitor visitor use in the cave.
- Investigate reports and take appropriate action.
- Create physical barriers (e.g., low fences, ropes, lint traps) to separate visitors from sensitive resources.
- Consider discontinuing tours (short term or long term) along specific routes until mitigation measures are in place.

### Indicator 2

Number of illegal cave entries per year resulting from break-ins (evidence of broken or removed locks and gates, unauthorized entries into the cave by the public) or visitor trespass (unattended access points left open and crossed, intentionally or unintentionally, and caves without gates). Sometimes, damage to cave resources may be the only evidence of illegal entry.

**Thresholds.**

- No more than one incident annually of an illegal cave entry.
- No more than one incident of significant damage from illegal entry of a cave without a gate.
- No more than five "casual" illegal entries (gated or not) with minimal damage/impact.

**Rationale for Indicator and Thresholds.**

Cave entrances include those created by people in the past, naturally occurring entrances, and naturally occurring entrances that have been modified. Entrances are closed to the public, at times with gates being put in place because of the cave's sensitive natural and cultural resources such as plants, animals, artifacts, or features that may be disturbed or damaged by the presence of humans. When cave entrances are illegally entered, whether gated or not, the consequences include resource and visitor safety concerns. Conditions in these caves may pose serious safety risks because of cave formations, lack of infrastructure, and those accessing potentially being unprepared for the conditions they could face. These concerns are all exacerbated by the fact that those accessing these entrances are not accompanied by authorized NPS staff or affiliates.

**Monitoring Guidelines.**

Monitoring would occur through both physical monitoring at sites by looking for evidence of human presence at sites (e.g., broken locks, trash, footprints, resource damage) as well as through remote monitoring (e.g., surveying social media posts of illegal entries, cameras, information provided by stakeholders and community members). Physical monitoring should be conducted both in the everyday operations of cave tours and resource management activities, but also as dedicated actions that would be scheduled for locations that are determined to be most vulnerable to illegal entry.

**Management Strategies.**

- Investigate suspected illegal cave entries to determine timing and, if possible, individuals.
- Conduct resource condition and damage assessments to determine the extent of any damage caused by illegal cave entries.
- Educate stakeholders, members of the public, and others about the importance of staying out of closed cave entrances because of the consequences that include resource damage and visitor safety concerns.
- Establish a stewardship or volunteer program that would focus on education and the protection of cave resources.
- Install cameras or other monitoring devices to track or identify illegal cave entries.
- Increase monitoring of cave entrances.
- Consider opening cave entrances on a select basis for special events or guided expeditions.
- Install gates or other infrastructure or devices that would deter access to closed entrances. Additional gates may be required as visitor use management needs dictate.

### Indicator 3

Number of visitor concerns related to tour size and crowding on park cave tours.

**Threshold.**

- No more than 5% of reasonable complaints related to concerns regarding tour size and crowding are received each year.

**Rationale for Indicator and Threshold.**

Desired conditions related to visitor use and experience in Mammoth Cave focus on providing high-quality visitor experiences where visitors can learn about the significance of the resources found within and the history related to the cave system. Perceptions of crowding can vary from person to person, however, the park strives to provide opportunities that—while at times may be highly social—are not impacting a visitor's ability to experience the cave. Tracking the number of complaints related to tour size and crowding would help park managers better understand visitor experiences in the cave and make management adjustments to improve those experiences as much as possible.

**Monitoring Guidelines.**

The park would continue to review/monitor visitor comments on an annual basis and would determine if they meet the threshold. Visitor comments are submitted by email, mail, and filling out visitor comment forms on site. The park would also explore new ways to seek input from visitors. This monitoring provides feedback that is important for managers to ensure desired conditions are maintained.

**Management Strategies.**

- Develop a public information effort about the desired conditions for the cave, and provide information about the actions the park is taking to achieve those conditions. Information could include the fragile cave resources and the effects that visitors can have on them. This information could be distributed through direct visitor contact, park publications (online and printed), and wayside exhibits.
- Make greater public education efforts to encourage voluntary redistribution of visitor use to off-peak times or to other tours.

**Adaptive Management Strategy.**

- Consider changing the tour schedule to space visitors throughout the cave.

## Indicator Topic 4

Algae growth

## Indicator 4(a)

Number of lights that show visible algae growth.

**Thresholds.**

- No more than 1% of non-algae control lights show algae growth at any one time.
- No more than 5% of algae control lights show visible algae growth at any one time

## Indicator 4(b)

Total area (coverage) of algae

**Thresholds.**

Differing thresholds have been established for the six areas of the cave that currently have significant algae growth. The thresholds differ because of the distinct nature and size of these different cave sections.

- Houchins Narrows: 0.5 square meter ($m^2$) of visible algae coverage
- Lower Historic: 1 $m^2$ of visible algae coverage
- Snowball Room: 0.25 $m^2$ of visible algae coverage

- Boone Avenue: 2 $m^2$ of visible algae coverage
- New Entrance through NY Subway: 3 $m^2$ of visible algae coverage
- Fairy Ceiling through Frozen Niagara: 10 $m^2$ of visible algae coverage

**Rationale for Indicator and Thresholds.**

Algae growth around artificial lights in caves is a significant management issue for tour caves, including along routes in Mammoth Cave. In addition to an aesthetic issue, it (1) perturbs the cave's biological environment, (2) can disrupt speleothem growth, (3) leads to etching of cave walls, (4) obscures or damages signatures and other cultural features, (5) supports invasive species, and (6) produces cyanotoxins, which could impact people or cave animals.

Some areas of the cave are more susceptible to algae growth than others. In addition to the amount of incidental light, the amount of moisture in an area greatly impacts algae growth. Wet areas are much more likely to grow algae if illuminated with the same amount of light than an equivalent section that is dry. At Mammoth Cave, the park has instituted use of lights that should help reduce algae growth (because of their color) in areas where growth is more likely. However, these measures only reduce potential, they would not prevent algae growth. Because of these different susceptibilities, two thresholds are needed: one for susceptible areas with algae control lights and one for areas with normal lighting.

The lower threshold for non-algae control lights is because algae are much less likely to grow in those areas. The threshold for algae control lights recognizes that although algae would grow in these areas, we should attempt to maintain low algae prevalence. This indicator and its threshold are being evaluated in a steady-state situation (i.e., number of lights with algae at any given time). We anticipate that algae would grow in various areas continuously and that the park would be controlling algae as they grow. As such, the park wants to maintain conditions so at any time the number of lights showing algae growth is less than the threshold.

Indicator 4(b) and accompanying threshold is appropriate for areas of the cave that are susceptible to algae growth. Areas that are not susceptible can be adequately managed using only the number of lights with visible algae indicator. This areal coverage indicator and its threshold are being evaluated in a steady-state situation (i.e., number of lights with algae at any given time). We anticipate that algae would grow in various areas continuously and that the park would be controlling algae as they grow. As such, the park wants to maintain conditions so at any time the area for algae growth is less than the threshold level.

**Monitoring Guidelines.**

Indicator 4(a) was chosen because it is a relatively easy indicator to monitor. The area around each light can be checked to determine if algae are present. If so, it is scored as positive; if not, it is scored as negative. The type of light (algae control or not) is also recorded. The results can then be calculated to see if the thresholds have been exceeded. This monitoring could be done by volunteers, and it is recommended that it be conducted twice a year.

Indicator 4(b), while powerful, is one that is more difficult to monitor. Monitoring would require sending a team to all lights in the algae-susceptible sections of the cave. They would then measure and record the extent of algae at each light. They may use photography (including hyperspectral photography) to document and better allow measurement of the algae coverage.

As of 2019, the park is continuing to work with a team from Tennessee State University to develop a monitoring plan for algae coverage and develop specific protocols.

**Management Strategies.**

Several strategies can be taken to reduce the number of lights that have algae growing near them, and to reduce algae growth below the identified thresholds. They include the following:

- Where threshold exceedances are in areas without algae control lights, algae control lights can be installed in place of normal lights.
- Lights can be moved or repositioned to reduce illumination of areas growing algae.
- Light bulbs can be changed to reduce illumination on areas growing algae.

- Shrouds and other physical structures can be used to reduce illumination on areas with algae.
- Physical algae removal can be undertaken using water, spray bottles, and brushes (where appropriate).
- Chemical removal of algae using dilute bleach or hydrogen peroxide solutions may be accomplished (where appropriate).
- UV-C sterilization may be used to interfere with algae growth and reproduction on site.
- Heat may be used to kill algae on cave walls (where appropriate).

## Other Related Monitoring

## Indicator Topic 5.

*E. coli* in select springs and cave discharges.

**Threshold.**

- No exceedance of the US Environmental Protection Agency recommendation for "Single Sample Infrequently Used Full Contact Recreation" of 579 Most Probable Number/100 milliliters.

**Rationale for Indicator and Threshold.**

Good water quality is important to achieve desired conditions for cave resources as well as for the safety of the park's visitors. Although *E. coli* is not necessarily pathogenic to humans or cave biota, they do come from the digestive tract of warm-blooded animals and can be considered an indicator of other potential pathogens and nutrient enrichment. Water quality may be impacted from parking lot runoff, sewer leaks, trail uses, agricultural runoff from outside the park, and recreational vehicle leaks in campground and parking lots.

Degraded water quality has the potential to impact natural resources and the visitor experience. It can impact cave biota, including Kentucky cave shrimp, cave fish, and cave crayfish. Degraded water quality also has the potential to impact visitor experience due to sewage smells in the cave and has potential visitor health implications through direct visitor contact with pathogens.

**Monitoring Guidelines.**

Implement synoptic monthly sampling at 10 locations chosen to represent areas that are potentially impacted by visitor surface and subsurface activity and that may expose visitors to karst water. Colilert techniques for measuring *E. coli* concentrations will be used in the park's water laboratory. Additional details will be provided in an appendix to this plan.

**Management Strategies.**

- Maintain and upgrade park sewer system.
- Maintain and upgrade park stormwater runoff filters.
- Maintain and upgrade pump-out station(s) for recreational vehicles.
- Potentially modify trail use to reduce water-quality impacts.
- Expand monitoring to more streams and cave discharges as the threshold is approached to better determine source of *E. coli* and to understand variability in water quality.
- Educate visitors, researchers, park staff, and others on the sensitivity of resources and the need to protect them, including messaging through signage.
- Investigate reports of sewage smells or surface leaks and take appropriate action.
- Create physical barriers (e.g., low fences, ropes, railings, awnings) to separate visitors from water resources that exceed safety thresholds.
- Consider discontinuing tours (short term or long term) along specific routes until mitigation measures are in place.

## VISITOR CAPACITY

### Overview

This appendix provides additional information about the visitor capacity identification as it relates to the visitor use management (VUM) monitoring strategy for the Mammoth Cave National Park Cave and Karst Plan. For additional resources in the VUM framework please visit the following web address: http://visitorusemanagement.nps.gov/ for a full description of the Interagency Visitor Use Management Council and Framework Guidance (IVUMC). The Interagency Visitor Use Management Council and Framework Guidance defines visitor capacity as the maximum amounts and types of visitor use that an area can accommodate while achieving and maintaining the desired resource conditions and visitor experiences that are consistent with the purposes for which the area was established. Visitor capacities were identified using best practices and examples from other plans and projects across the National Park Service. Based on these best practices, the planning team describes the process for identifying capacity using the following guidelines: (1) determine the analysis area, (2) review existing direction and knowledge, (3) identify the limiting attribute, and (4) identify visitor capacity.

Through this planning effort, the park has identified a number of strategies associated with the plan alternatives to directly address the key issues; these strategies then inform the associated visitor capacity for the cave. For most of the cave, current use levels do not appear to be impacting experiences or resources; therefore, the visitor capacity has been identified to be at, near, or above current use and is based on the limiting attributes described at the site. Associated monitoring and additional strategies and actions needed to manage to these visitor capacities can be located with the indicators and thresholds (this appendix) and below with the identified capacities. Those strategies identified for use as needed are adaptive strategies. Not all of the strategies related to the indicators, thresholds, and visitor capacity would be implemented immediately, rather as thresholds and/or capacities are approached. This appendix documents the considerations and processes used to identify and implement visitor capacity for key destinations.

### The Analysis Area

Key areas were selected as destinations where high levels of use are currently or are projected to cause impacts to natural resources, cultural resources, and visitor experiences and are related directly to desired conditions. These key areas are based off the cave management zones that are updated as a part of this planning project. The park opens tours for visitors only in Zones A and B and manages those in accordance with desired conditions listed above. Zones C and Proposed Restriction Overlay Zone D are not included in the analysis area, as they are not open to visitors. Zone C is for NPS staff and researchers; Overlay Zone D is closed for entry and in some instances open for staff and limited permit holders. For these key areas, a detailed analysis has been conducted to identify the visitor capacities. The visitor capacities would be used to implement management strategies for these sites as part of the plan. Two key areas were identified

1. Cave Zone A
2. Cave Zone B

To fulfill the requirements of the 1978 National Parks and Recreation Act (54 United States Code 100502), visitor capacity identifications are legally required for all destinations and areas that this planning effort addresses (IVUMC 2016). Together, the above areas comprise all of the visitor use areas within the project planning area. Future monitoring of use levels and indicators would inform the National Park Service if use levels are at or near visitor capacities. If so, management strategies as outlined in this plan would be taken.

### Review of Existing Direction and Knowledge

**Mammoth Cave National Park Area Context.** During this step, the planning team developed desired conditions, indicators, and thresholds, with particular attention to conditions and values that must be protected and are most related to visitor use levels. Desired conditions for these areas can be found in chapter 1 of this plan. For each key area, relevant indicators are listed. The associated thresholds can also be found in the previous section of this appendix.

The amount and timing of visitor use in the cave systems of Mammoth Cave National Park influence both resource conditions and visitor experiences. Peak visitation during the summer concentrates heavy visitor use in the caves and on tours. Under the no-action alternative, a lack of an identified visitor capacity on popular tours would lead to crowding as visitation increases, causing a diminished visitor experience, increased emergency response times to incidents, and vandalism to the natural and cultural resources in the caves. These impacts influence the ability of the National Park Service to maintain desired conditions for resources and visitor experiences consistent with the purposes for which the park was established.

The analysis areas of visitor capacity are identified, first by overall Main Cave capacity and then by tour routes in the cave. Setting a Main Cave capacity of visitors per day would ensure that the park maintains and achieves overall desired conditions for visitor experience and natural and cultural resources throughout the cave system. Each tour route is also managed for specific desired conditions and would have different visitor capacities. By setting the capacity by tour, the park can also ensure that they are achieving or maintaining the specific desired condition for that area.

Cave Zone A is limited to those areas where people assemble, such as the Snowball Room, Grand Central Station, Mt. McKinley comfort station, and elevator portals. Such places, essential to the comfort and convenience of the visitor, are situated in sections or cave passages that have high visitation. Cave Zone B includes those cave passages aesthetically arranged and developed with trails, bridges, steps, stairways, and handrails. Guides accompany all parties, and a fee is charged in most cases (Wondering Woods and Discovery are exceptions). The 1983 general management plan documented the park decision at the time that parties not exceeding 120 persons with two guides may be conducted over the trails in passages so developed. This party size of 120 persons is the maximum; visitors would generally have a higher-quality experience when numbers are smaller. Although some facilities and lighting have changed in the cave, the visitor experience in Zones A and B, as described in the 1983 general management plan, would be largely maintained in this plan.

**Identify the Limiting Attributes.** This step requires identification of the limiting attributes that most constrain the analysis area's ability to accommodate visitor use. The limiting or constraining attributes may vary across the analysis area and are described under each key analysis area. This is an important step given that an analysis area could experience a variety of challenges regarding visitor use issues, natural resources, and cultural resources.

**Identify Visitor Capacity.** To identify the appropriate amount of use at key analysis areas, summaries from previous steps were reviewed to understand current conditions compared to desired conditions for the area. Visitation data collected annually by NPS staff to track levels of visitor use parkwide and by area was used as a data source. The National Park Service also collects annual data including counts of fees, parking availability, trail counts, and other data.

## Analysis of Key Areas

### Zone A.

*Review of existing direction and knowledge:* Under the proposed action, Cave Zone A includes public tour areas of the cave that have major development for walking (or accessible) tours, electric lights, and could include a telephone communication system. It supports concentrated use designed for visitor comfort and convenience. This zone contains infrastructure that can accommodate events and interpretive opportunities for a large number of visitors. It would accommodate a variety of users with varying experience and physical abilities, including large groups and areas for large gatherings. Visitors in this zone would be immersed in the sights and sounds of the cave; however, at times the sounds of other people may dominate, and visitor-caused impacts may be visible to cave resources. Desired conditions would be achieved by managing congestion and conflict to provide visitors with a high-quality experience.

The geographical areas of the cave included in Zone A are Main Cave, Cleaveland Avenue, Snowball Room, Kentucky Avenue, Grand Central Station, Frozen Niagara, Boone Avenue, Rafinesque Hall, Houchin's Narrows, Broadway, Main Cave, Blacksnake Avenue, Fat Man Misery, Great Relief, Sparks Avenue, Mammoth Dome, Little Bat Avenue, and Audubon Avenue. Most of the tours in

Zone A pass through the Main Cave. The following cave tours that are currently available in Zone A and their tour size are presented in table 2.

**TABLE 2. CAVE TOURS AVAILABLE IN ZONE A**

| Tour Name | Existing Tour Size |
|---|---|
| Accessible | 14 |
| Star Chamber | 40 |
| Frozen Niagara | 30 |
| Cleaveland Ave | 38 |
| Gothic | 40 |
| Broadway | 60 |
| Mammoth Passage | 70 |
| Grand Ave | 78 |
| Domes and Dripstones | 110 |
| Historic | 110 |
| Extended Historic | 60 |
| Discovery | Unlimited under no-action alternative |

Zone A receives heavy visitor use between April and October. Typically, July is the highest peak visitation month for Zone A, with a 4-year average of 870 tours. These trends can be seen in figure 10 (appendix A). No data were found for the Broadway and Extended Historic Tours. The tour numbers for the Historic Tour are skewed because of construction closures from September 2015 to May 2016 and September 2016 to May 2017. Looking at current tour capacities and visitor trends for each tour during the highest peak visitation month, current use levels contribute 99,000 monthly visitors (a daily average of 3,200 visitors) to Zone A in July.

*Limiting attribute:* The most limiting attributes constraining visitor use levels in Zone A are the desired visitor experience and natural and cultural resource impacts from visitor use. The desired visitor experience in Zone A is to "provide visitors with varying experience levels and physical abilities with an opportunity to be immersed in the sights and sounds of the cave." These desired conditions allow Zone A to be the most accessible for the majority of cave visitors, which can lead to crowding and congestion. Crowding and congestion in areas of the cave creates conflicts with other tours and diminishes the desired visitor experience. It is difficult for park staff to communicate with and keep track of larger tour sizes; this results in a higher risk of graffiti on cave resources and increased safety concerns for visitors. The ability to move visitors safely and effectively through narrow sections of tour routes in Zone A constrains the amount and types of visitor use that can be accommodated on the tours. Algae growth from the cave lighting systems, installed on all tour routes in Zone A, negatively impacts the desired natural resource conditions of Mammoth Cave. The proximity of cultural resources to cave tours is also a constraint impacting visitor use. The most relevant indicators to monitor are the number of visitor concerns related to tour size and crowding on park cave tours, number of incidents of vandalism on tour routes per year, number of lights that show visible algae growth, and total area (coverage) of algae.

*Visitor capacity:* Activities associated with the proposed action provide the opportunity to increase the current tour capacities because the new trails provide opportunities to expand the range of visitor experiences. Therefore, park staff identified the potential to increase current use levels in Zone A and still achieve and maintain the desired conditions. The Main Cave is where the majority of tours pass through and is a part of Zone A. The identified visitor capacity per day for the Main Cave is 6,500 people. The capacity for the Main Cave was based on park review of previous peak activity for visitor use levels occurring during special events such as the 2017 solar eclipse and summer holidays. Park staff identified the possibility to increase visitor use by 15% on several of the most popular tour routes, plus an additional 10% in overall future increases in visitation while still maintaining the desired level of visitor experience.

Each of the tour capacities in table 3 were identified by the park to maintain or accommodate a slight increase in visitation. If the tour goes through the Main Cave, the frequency of occurrence for the tour on any given day will be managed within the Main Cave capacity.

**TABLE 3. IDENTIFIED TOUR CAPACITY IN ZONE A**

| Tour Name | Existing Tour Size | Identified Tour Capacity | Maximum Capacity Per Day |
|---|---|---|---|
| Accessible | 14 | 14 | Managed within Main Cave daily capacity 6,500 |
| Star Chamber | 40 | 40 | Managed within Main Cave daily capacity 6,500 |
| Frozen Niagara | 30 | 38 | Managed within Main Cave daily capacity 6,500 |
| Cleaveland Ave. | 38 | 38 | Managed within Main Cave daily capacity 6,500 |
| Gothic | 40 | 40 | Managed within Main Cave daily capacity 6,500 |
| Broadway | 60 | 70 | Managed within Main Cave daily capacity 6,500 |
| Mammoth Passage | 70 | 80 | Managed within Main Cave daily capacity 6,500 |
| Grand Ave | 78 | 100 | Managed within Main Cave daily capacity 6,500 |
| Domes and Dripstones | 110 | 118 | Managed within Main Cave daily capacity 6,500 |
| Historic | 110 | 150 | Managed within Main Cave daily capacity 6,500 |
| Extended Historic | 60 | 70 | Managed within Main Cave daily capacity 6,500 |
| Discovery | Unlimited under no-action alternative | 500 (per hour) | Managed within Main Cave daily capacity 6,500 |

**Zone B.**

*Review of existing direction and knowledge:* Zone B tours are offered at different times of the year and times throughout the week. Scheduling is confined by park staffing levels. Zone B receives the most visitation from May through October. Typically, July is the highest peak visitation month for Zone B, with a 4-year average of 80 tours. However, the Great Onyx Tour is normally only offered in the spring and fall, so that tour sees peak visitation in October. These trends can be seen in figure 11 (appendix A). No data were found for the Violet City Lantern Tour and the following have no data because they were not previously offered: the Colossal, Bedquilt to Colossal, Cathedral, Crystal, Marion Ave, Wondering Woods, All Day Tour River Styx to Grand Ave, and All Day Violet City to Grand Ave. Looking at current tour capacities and visitor trends for each tour during the highest peak visitation month, current use levels contribute 1,000 monthly visitors (a daily average of 32 visitors) to Zone B in July.

Under the proposed action, Cave Zone B would provide for a more primitive cave experience and would require handheld lanterns or flashlights, and/or headlamps. Moderate development including formalized trails may also occur in this zone to improve resource conditions; however, visitors may need to prepare for potentially challenging conditions. Approved educational groups and activities may occur in this zone. This zone could provide visitors with an opportunity to learn basic caving skills and necessitate the use of appropriate caving gear. Use would be managed to protect and enhance the natural function, diversity, complexity, and resiliency of the cave. Desired conditions would be achieved by providing visitors with a cave experience where the sights and sounds of the cave, along with personal interpretive opportunities, dominate this experience and providing research permits in appropriate areas. This zone could provide for a more intensively primitive cave experience; however, at times some visitor-caused impacts or developments may be experienced.

The geographical areas of the cave included in Zone B are Main Cave from Star Chamber to Violet City, Great Onyx Cave, Clark Avenue, Cathedral Domes, Becky's Alley, Nickerson Avenue, Big Break, Ganter and Jessup near Wooden Bowl, El Ghor-Silliman Avenue, Woodbury Pass, Colossal Entrance to Bedquilt Route, Historic Crystal Cave Trails, Historic Proctor, Long Cave, Upper Salts Cave, Olive's Bower, Briggs Avenue, Black Chambers, Blue Spring Branch, Echo River (end of Styx Catwalk to Minnehaha), Pensacola Avenue, Sylvan Avenue, Emily's Avenue, Wondering Woods Cave, Dixon Cave, Pohl Avenue, Turner Avenue, New Discovery (main passage to end of trail development with potential extension to Big Paradise), Owl Cave, Fort's Way, Roaring River, etc. Table 4 presents the cave tours that are currently available in Zone B and their current tour size.

**TABLE 4. CAVE TOURS AVAILABLE IN ZONE B**

| Tour Name | Existing Tour Size |
|---|---|
| Trog | 12 |
| Colossal to Colossal Dome | 0 (not offered currently) |
| Intro to Caving | 14 |
| Bedquilt to Colossal | 0 (not offered currently) |
| Wild Cave | 14 |
| Cathedral | 0 (not offered currently) |
| Crystal | 0 (not offered currently) |
| Marion Ave | 0 (not offered currently) |
| Wondering Woods | 0 (not offered currently) |
| Great Onyx | 38 |
| All Day Tour River Styx to Grand Ave | 0 (not offered currently) |
| Violet City Lantern | 38 |
| All Day Violet City to Grand Ave | 0 (not offered currently) |
| River Styx | 40 |

*Limiting attribute:* The most limiting attributes constraining visitor use levels in Zone B are the desired visitor experience and resource impacts from visitor use. The desired visitor experience in Zone B is to create a more immersive and natural cave experience "where the sights and sounds of the cave would dominate." To help achieve this desired condition, there is no electricity on tour routes. All tours are conducted with handheld flashlights or lanterns, or head lamps. This low lighting environment increases tripping hazards and visitor safety concerns. The cave tours in Zone B are more physically demanding on visitors than in Zone A, and at times involves crawling. Low lighting and physical demands on tours constrains the amount and types of visitor use that can be accommodated on the tours in Zone B, including smaller tour sizes. The proximity of natural and cultural resources to cave tours is also a constraint influencing visitor use. Resources found right next to cave tour routes and the desired visitor experience in Zone B limits the park's ability to improve or add infrastructure to keep visitors away from sensitive resources. The most relevant indicators to monitor are the number of visitor concerns related to tour size and crowding on park cave tours and number of incidents of vandalism on tour routes per year.

*Visitor capacity:* Activities associated with the proposed action create the opportunity to increase the current tour capacities because the new trails provide opportunities to expand the range of visitor experiences. Therefore, park staff identified the opportunity to increase current use levels in Zone B and still achieve and maintain the desired conditions.

Each of the tour capacities in table 5 were identified by the park to maintain or accommodate a slight increase in visitors to achieve visitor experience and resource desired conditions for that particular tour. If the tour goes through the Main Cave, the frequency of occurrence for the tour in any given day would be managed within the Main Cave capacity.

**TABLE 5. IDENTIFIED TOUR CAPACITY IN ZONE B**

| Tour Name | Existing Tour Size | Identified Tour Capacity | Maximum Capacity Per Day |
|---|---|---|---|
| Trog | 12 | 12 | Managed within Main Cave daily capacity 6,500 |
| Colossal to Colossal Dome | 0 (not offered currently) | 20 | 50 |
| Intro to Caving | 14 | 20 | Managed within Main Cave daily capacity 6,500 |
| Bedquilt to Colossal | 0 (not offered currently) | 14 | Managed within Main Cave daily capacity 6,500 |
| Wild Cave | 14 | 14 | Managed within Main Cave daily capacity 6,500 |
| Cathedral Domes | 0 (not offered currently) | 38 | Managed within Main Cave daily capacity 6,500 |
| Crystal | 0 (not offered currently) | 38 | 150 |
| Marion Ave | 0 (not offered currently) | 38 | Managed within Main Cave daily capacity 6,500 |
| Wondering Woods | 0 (not offered currently) | 38 | 500 |
| Great Onyx | 38 | 38 | 150 |
| All Day Tour River Styx to Grand Ave | 0 (not offered currently) | 38 | Managed within Main Cave daily capacity 6,500 |
| Violet City Lantern | 38 | 38 | Managed within Main Cave daily capacity 6,500 |
| All Day Violet City to Grand Ave | 0 (not offered currently) | 38 | Managed within Main Cave daily capacity 6,500 |
| River Styx | 40 | 70 | Managed within Main Cave daily capacity 6,500 |

*Visitor capacity implementation strategies.* Park staff will employ a variety of management options to implement visitor capacity for cave tours in both Zones A and B. Not all strategies, specifically the temporary and/or permanent closures of cave areas and/or cave tour cancellations, would necessarily be implemented concurrently. These strategies and actions would be implemented based on feasibility, staff resources, park funding, or as needed when thresholds are approached or as part of managing visitor capacity. These strategies include the following:

- Update the cave tour time monitors in the ticket area with a more positive message such as a "join us on Discovery Tour" message.
- Age requirements for certain tours.
- Provide a designated tour time on the ticket and stage start times at specified intervals.
- Station additional guide/volunteer in the middle of larger tour groups.

- Install lint curbs and trail hardening in certain sections to mitigate off-trail visitor impacts and improve resource conditions.
- Improve trail conditions through the addition of pavers on the back part of the route to lengthen tour.
- Install additional 0.25 mile of flat, concrete, accessible trail toward Mary's Vineyard.
- Stabilize the entrance and redesign entrance gates for better functionality.
- Implement temporary or permanent closure of cave areas to alleviate congestion and/or protect sensitive resources.
- Implement temporary or permanent cave tour cancellation to alleviate congestion and/or protect sensitive resources.

# APPENDIX C: STATE AND FEDERAL SPECIAL STATUS SPECIES AT MAMMOTH CAVE NATIONAL PARK

| Species Type | Common Name | Scientific Name | Status* | Potential to Occur in Cave System? |
|---|---|---|---|---|
| Amphibian | Hellbender | *Cryptobranchus alleganiensis* | KSNPC-SC | No |
| Bird | Bald eagle | *Haliaeetus leucocephalus* | D, KSNPC-T | No |
| Bird | Sharp-shinned hawk | *Accipiter striatus* | KSNPC-SC | No |
| Bird | Northern harrier | *Circus cyaneus* | KSNPC-T | No |
| Bird | Osprey | *Pandion haliaetus* | KSNPC-T | No |
| Bird | Hooded merganser | *Lophodytes cucullatus* | KSNPC-T | No |
| Bird | American coot | *Fulica americana* | KSNPC-E | No |
| Bird | Red-breasted grosbeak | *Pheucticus ludovicianus* | KSNPC-SC | No |
| Bird | Brown creeper | *Certhia americana* | KSNPC-E | No |
| Bird | Dark-eyed junco | *Junco hyemalis* | KSNPC-SC | No |
| Bird | Savannah sparrow | *Passerculus sandwichensis* | KSNPC-SC | No |
| Bird | Blackburnian warbler | *Dendroica fusca* | KSNPC-T | No |
| Bird | Golden-winged warbler | *Vermivora chrysoptera* | KSNPC-T | No |
| Bird | Canada warbler | *Wilsonia canadensis* | KSNPC-SC | No |
| Bird | Red-breasted nuthatch | *Sitta canadensis* | KSNPC-E | No |
| Bird | Pied-billed grebe | *Podilymbus podiceps* | KSNPC-E | No |
| Bird | Least flycatcher | *Empidonax minimus* | KSNPC-E | No |
| Bird | Red-breasted nuthatch | *Sitta canadensis* | KSNPC-E | No |
| Fish | Northern cavefish | *Amblyopsis spelaea* | KSNPC-SC | Yes |
| Fish | Southern cavefish | *Typhlichthys subterraneus* | KSNPC-SC | Yes |
| Fish | Diamond darter | *Crystallaria cincotta* | E, KSNPC-SX | No |
| Fish | Spotted darter | *Etheostoma maculatum* | KSNPC-T | |
| Invertebrate | Shaggy cavesnail | *Antroselates spiralis* | KSNPC-SC | Yes |
| Invertebrate | Cave obligate beetle | *Batrisodes henroti* | KSNPC-T | Yes |
| Invertebrate | Cave obligate mite | *Belba bulbipedata* | KSNPC-T | Yes |
| Invertebrate | Cave obligate mite | *Galumna alata* | KSNPC-T | Yes |
| Invertebrate | Cave obligate pseudoscorpion | *Kleptochthonius cerberus* | KSNPC-SC | Yes |

| Species Type | Common Name | Scientific Name | Status* | Potential to Occur in Cave System? |
|---|---|---|---|---|
| Invertebrate | Cave obligate pseudoscorpion | Kleptochthonius hageni | KSNPC-SC | Yes |
| Invertebrate | Cave obligate pseudoscorpion | Tyrannochthonius hypogeus | KSNPC-SC | Yes |
| Invertebrate | Cave obligate mite | *Macrocheles troglodytes* | KSNPC-T | Yes |
| Invertebrate | Cave obligate planarian | *Sphalloplana buchanani* | KSNPC-T | Yes |
| Invertebrate | Punctate coil | *Helicodiscus punctatellus* | KSNPC-SC | Yes |
| Invertebrate | Ectocommensal ostracod | *Sagittocythere stygia* | KSNPC-T | Yes |
| Invertebrate | Amphipod | *Stygobromus vitreus* | KSNPC-SC | Yes |
| Invertebrate | Cave obligate springtail | *Pygmarrhopalites altus* | KSNPC-T | Yes |
| Invertebrate | Cave obligate springtail | *Pseudosinella espanita* | KSNPC-SC | Yes |
| Invertebrate | Elktoe | *Alasmidonta marginata* | KSNPC-T | No |
| Invertebrate | Spectaclecase | *Margartifera monodonta* | E, KSNPC-E | No |
| Invertebrate | Snuffbox | *Epioblasma triquetra* | E, KSNPC-E | No |
| Invertebrate | Purple cat's paw | *Epioblasma obliquata obliquata* | E, KSNPC-E | No |
| Invertebrate | Longsolid | *Fusconaia subrotunda* | KSNPC-SC | No |
| Invertebrate | Pink mucket | *Lampsilis abrupta* | E, KSNPC-E | No |
| Invertebrate | Pocketbook | *Lampsilis ovata* | KSNPC-E | No |
| Invertebrate | Ring pink | *Obovaria retusa* | E, KSNPC-E | No |
| Invertebrate | Mammoth cave crayfish | *Orconectes pellucidus* | KSNPC-SC | Yes |
| Invertebrate | Kentucky cave shrimp | *Palaemonias ganteri* | E, KSNPC-E | Yes |
| Invertebrate | Clubshell | *Pleurobema clava* | E, KSNPC-E | No |
| Invertebrate | Fanshell | *Cyprogenia stegaria* | E, KSNPC-E | No |
| Invertebrate | Rough pigtoe | *Pleurobema plenum* | E, KSNPC-E | No |
| Invertebrate | Pyramid pigtoe | *Pleurobema rubrum* | KSNPC-E | No |
| Invertebrate | Sheepnose | *Plethobasus cyphyus* | E, KSNPC-E | No |
| Invertebrate | Bold cave beetle | *Pseudanophthal audax* | KSNPC-T | Yes |
| Invertebrate | Surprising cave beetle | *Pseudanophthal inexpectatus* | KSNPC-T | Yes |
| Invertebrate | Rabbitsfoot | *Theliderma cylindrica* | T, KSNPC-T | No |
| Invertebrate | Kentucky creekshell | *Villosa ortmanni* | KSNPC-T | No |
| Invertebrate | Little spectaclecase | *Villosa lienosa* | KSNPC-SC | No |
| Mammal | Gray bat | *Myotis grisescens* | E, KSNPC-T | Yes |

| Species Type | Common Name | Scientific Name | Status* | Potential to Occur in Cave System? |
|---|---|---|---|---|
| Mammal | Indiana bat | *Myotis sodalis* | E, KSNPC-E | Yes |
| Mammal | Northern long-eared bat | *Myotis septentrionalis* | T, KSNPC-E | Yes |
| Mammal | Eastern small-footed bat | *Myotis leibii* | KSNPC-T | Yes |
| Mammal | Evening bat | *Nycticeius humeralis* | KSNPC-SC | No |
| Mammal | Rafinesque's big-eared bat | *Plecotus rafinesquii* | KSNPC-SC | Yes |
| Reptile | Corn snake | *Elaphe guttata* | KSNPC-SC | No |
| Reptile | Coal skink | *Eumeces anthracinus* | KSNPC-T | No |
| Vascular plant | Delta arrowhead | *Sagittaria platyphylla* | KSNPC-E | No |
| Vascular plant | Sessilefruit arrowhead | *Sagittaria rigida* | KSNPC-E | No |
| Vascular plant | Heartleaf pondweed | *Potamogeton pulcher* | KSNPC-T | No |
| Vascular plant | Cutleaf meadowparsnip | *Thaspium pinnatifidum* | KSNPC-T | No |
| Vascular plant | Star-flower Solomon's-seal | *Maianthemum stellatum* | KSNPC-E | No |
| Vascular plant | Western dwarfdandelion | *Krigia occidentalis* | KSNPC-E | No |
| Vascular plant | Tansy rosinweed | *Silphium pinnatifidum* | KSNPC-SC | No |
| Vascular plant | French's shootingstar | *Dodecatheon frenchii* | KSNPC-SC | No |
| Vascular plant | Yellow screwstem | *Bartonia virginica* | KSNPC-T | No |
| Vascular plant | Steuve's lespedeza | *Lespedeza steuvei* | KSNPC-SC | No |
| Vascular plant | Twining snoutbean | *Rhynchosia tomentosa* | KSNPC-E | No |
| Vascular plant | Buffalo clover | *Trifolium reflexum* | KSNPC-E | No |
| Vascular plant | Water oak | *Quercus nigra* | KSNPC-T | No |
| Vascular plant | Maroon Carolina milkvine | *Matelea carolinensis* | KSNPC-E | No |
| Vascular plant | Downy gentian | *Gentiana puberulenta* | KSNPC-E | No |
| Vascular plant | Narrowleaf bluecurls | *Trichostema setaceum* | KSNPC-E | No |
| Vascular plant | Spreading yellow false foxglove | *Aureolaria patula* | KSNPC-SC | No |
| Vascular plant | Eastern sweetshrub | *Calycanthus floridus var. glaucus* | KSNPC-T | No |
| Vascular plant | Wood lily | *Lilium philadelphicum* | KSNPC-T | No |
| Vascular plant | Prostrate blue violet | *Viola walteri* | KSNPC-T | No |
| Vascular plant | Little evening primrose | *Oenothera perennis* | KSNPC-E | No |
| Vascular plant | Cypressknee sedge | *Carex decomposita* | KSNPC-T | No |
| Vascular plant | Creeping mannagrass | *Glyceria acutiflora* | KSNPC-E | No |

| Species Type | Common Name | Scientific Name | Status* | Potential to Occur in Cave System? |
|---|---|---|---|---|
| Vascular plant | Rough dropseed | *Sporobolus clandestinus* | KSNPC-T | No |
| Vascular plant | Creeping mannagrass | *Glyceria acutiflora* | KSNPC-E | No |
| Vascular plant | Spinulose woodfern | *Dryopteris carthusiana* | KSNPC-SC | No |
| Vascular plant | Agrimony | *Agrimonia gryposepala* | KSNPC-T | No |
| Vascular plant | Creeping mannagrass | *Glyceria acutiflora* | KSNPC-E | No |
| Vascular plant | Allegheny brookfoam | *Boykinia aconitifolia* | KSNPC-T | No |
| Vascular plant | Fox grape | *Vitis labrusca* | KSNPC-SC | No |
| Vascular plant | American chestnut | *Castanea dentata* | KSNPC-E | No |
| Vascular plant | Yellow lady’s-slipper | *Cypripedium parviflorum* | KSNPC-T | No |
| Vascular plant | Bearded skeletongrass | *Gymnopogon ambiguus* | KSNPC-SC | No |
| Vascular plant | Eggert’s sunflower | *Helianthus eggertii* | D, KSNPC-T | No |
| Vascular plant | Butternut | *Juglans cinerea* | KSNPC-SC | No |
| Vascular plant | Roundhead lespedeza | *Lespedeza capitata* | KSNPC-SC | No |
| Vascular plant | September elm | *Ulmus serotina* | KSNPC-SC | No |

* E = federally endangered; T = federally threatened; D = delisted from federal listing; KSNPC = Kentucky State Nature Preserves Commission – E (endangered), T (threatened), SX (extirpated)

# APPENDIX D: LIST OF CAVE AND KARST PLANNING AND MONITORING GUIDELINES ASSOCIATED WITH THIS PLAN

In addition to actions proposed in this plan/environmental assessment, the following planning and monitoring guidelines represent additional, current (2019) guidance the park follows for various aspects of cave and karst management. Some of these guidelines are in development and may not be complete by the time a potential decision document has been signed for the proposed action in this plan/environmental assessment. Planning and monitoring guidelines that require additional analysis may be subject to future NEPA review.

- Access restrictions and standard operating procedures for off-trail areas
- Cave safety (includes job hazard analysis)
- White-nose syndrome management plan
- Cave algae monitoring and control plan
- Guidance on microbial research and living collections
- Visitor impacts photo-monitoring plan
- NPS Inventory and Monitoring vital signs monitoring protocols
- Supplemental groundwater quality monitoring plan
- Construction restrictions in cave
- Cave survey and mapping standards
- Policy for distribution of cave data
- Lesser cave policies and procedures
- Restricted areas and gated cave
- Cave gating decision matrix and standards
- After hours educational cave tour procedures
- Management of research in caves
- Cave restoration and cleaning guidelines
- Radon plan
- Non-toured-cave entry monitoring plan
- History of cave and karst resource management at Mammoth Cave National Park
- Future development guidelines and decision matrix
- Saltpeter works stabilization and restoration

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As the nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

NPS/MACA/135/154657 JULY 2019

NATIONAL PARK SERVICE • U.S. DEPARTMENT OF THE INTERIOR

# Cave and Karst Management Plan / Environmental Assessment

## Mammoth Cave National Park
## Kentucky

July 2019