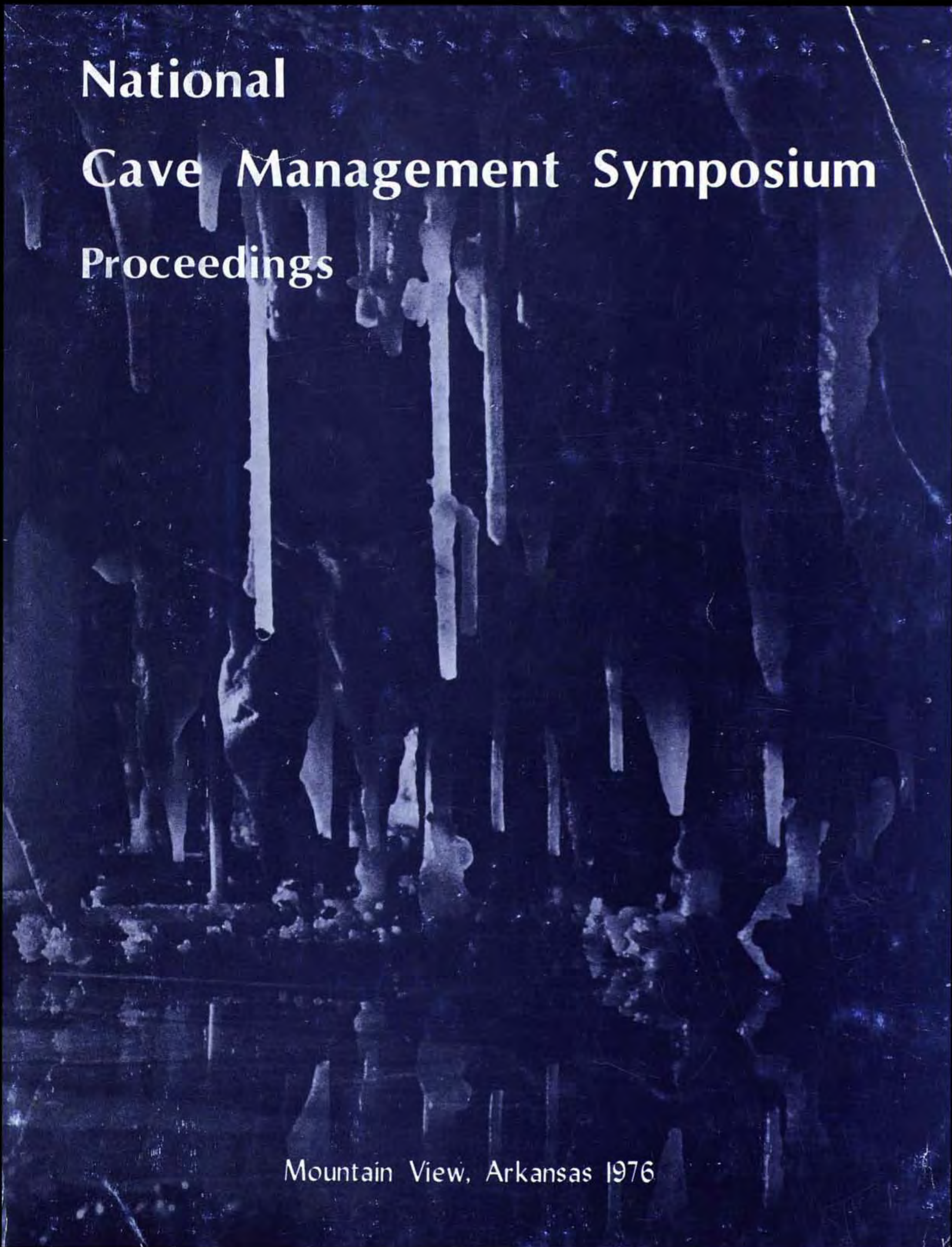
National Cave Management Symposium

Proceedings



Mountain View, Arkansas 1976

National Cave Management Symposium Proceedings

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The Cover photograph of Cottonwood Cave, New Mexico is by Don R. Martin.

The photographs for breaker pages are as follows:

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Cave Inventory, Valuation and Assessment—*Plecotus rafinesquii* (Eastern big-eared bat) in a Tennessee cave by Merlin Tuttle.

Subsurface Management as a Component of General Land Management. A New Mexico Cave by Don R. Martin.

Management of Commercial and High Value Caves—The Christmas Tree, New Cave, Carlsbad Caverns National Park, New Mexico by Don R. Martin.

Other Papers—Caverns of Sonora, Texas, by Charlie and Jo Larson.

Introduction to the Second National Cave Management Symposium

Tom Aley
Technical Session Coordinator, and
Director, Ozark Underground Laboratory

A good way to introduce the Second National Cave Management Symposium is to briefly mention the First Symposium, held in October, 1975, in Albuquerque, New Mexico. That symposium, for which published proceedings are available, served primarily to identify a number of cave management problems. The attendees at the Albuquerque symposium indicated substantial interest in several problem areas; many of the attendees suggested a workshop format as appropriate for the Second Symposium.

In the Second National Cave Management Symposium we focused primarily on cave management approaches and techniques related to problems in four general areas:

(1) Carrying capacity of caves

(2) Cave inventory, valuation, and assessment

(3) Subsurface management as a component of general land management in soluble rock landscapes

(4) Management of commercial and high value caves.

Those of us involved in organizing the Second Symposium believed that the purposes of this meeting would best be served by workshop sessions where there was ample time for discussion and exchange of ideas. It was our hope that the papers presented (and which are published here) would stimulate interest, discussion, and productive controversy.

Although we attempted to deal primarily with cave management approaches and techniques in this symposium, we were not totally successful. In reality, the state of the art is such that we are still heavily engrossed in identifying and trying to understand cave management problems; our approaches to cave management at this time are still exploratory and rather feeble. These Proceedings provide a good picture of just where we are in this dark tangle of slippery problems which we have labelled "cave management."

I believe we are beginning to make some important progress in cave management. The mere recognition by a broad spectrum of interest groups that we have cave management problems is a major accomplishment. A second important accomplishment is the recognition that cave management and surface management must be tied together.

We have a long way to go in this field of cave management. To use a cave analogy, we are still in the twilight zone trying to get our skimpy equipment working so that we may crawl into the black void ahead. These are important times; as any experienced caver knows, crucial mistakes made in the twilight zone may lead to dire consequences in the mazes and pits ahead.

1977
National Cave Management Symposium

The 1977 Cave Management Symposium is tentatively scheduled for the week of October 3—7 at Big Sky, Montana.

Primary emphasis will be placed on the tools and methodology for accomplishing successful cave management.

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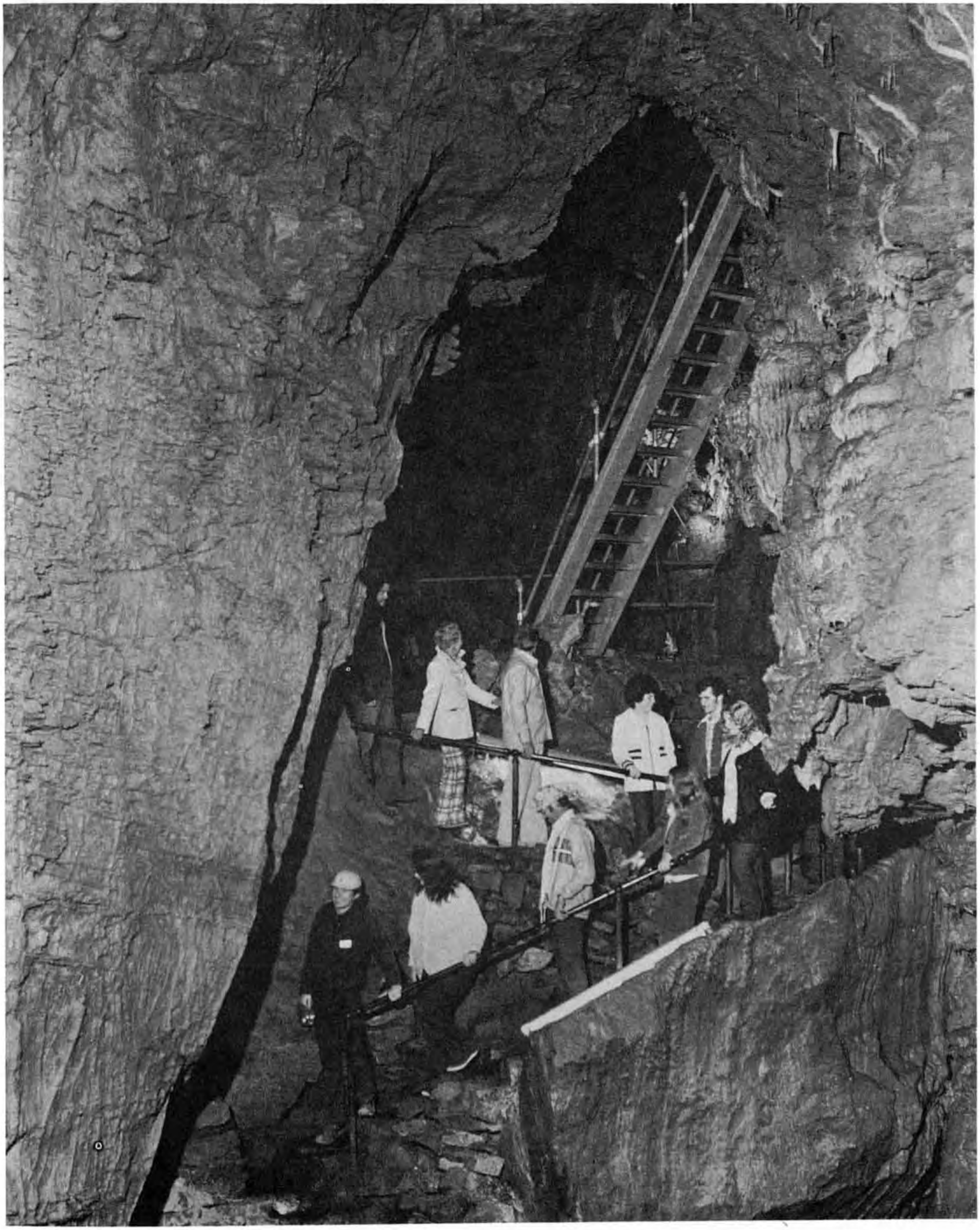
Carrying Capacity



Deep vertical pits such as this may reduce the carrying capacity of a cave. (*Photo by Don Martin.*)

The Concept of Carrying Capacity and How It Relates to Caves

Scott E. Forssell

ABSTRACT

Carrying capacity is currently one of the most discussed concepts in the field of cave management. There are actually four components of cave carrying capacity: (1) management objectives, (2) visitor attitudes, (3) recreational impact on physical resources, and (4) impact of the resource upon the visitor. No single component may be used to measure carrying capacity; all four interdependent components must be considered together.

The management objectives of a cave become the limits of acceptable change which the manager will tolerate within the cave environment. Through the use of visitor attitudes, the manager can try to maximize the visitor's satisfactions, which is assumed to be the goal of recreation management. There are several techniques that a manager may utilize to prevent physical changes due to recreational use of a cave, including interpretive techniques, access controls, and the use of permits. He may also reverse adverse changes wherever possible. The impact of the resource upon the visitor includes physical hazards which are present in a cave. These hazards tend to limit carrying capacity in a rather absolute fashion.

Since all cavers do not attach the same value to a caving experience, management needs to make a variety of caving experiences available to the public. Opening some caves, and even modifying them to some extent, can provide inexperienced cavers with a fulfilling experience while, at the same time, relieving a large amount of pressure from caves which should be closed or restricted. Management should work hard to overcome an "either/or" attitude towards public access to caves, and should try to be more aware of visitor management methods available to them.

One of the most discussed concepts in the field of cave management today is that of carrying capacity. It is also a topic upon which there is little information. In this paper I would like to share with you some of the past research involving carrying capacity, and the direction in which cave managers should be focusing their attentions. Much of this discussion has been drawn from two publications by Lime and Stankey (1971) and Lucas and Stankey (1974) concerning the carrying capacity of outdoor recreation areas.

WHAT IS CARRYING CAPACITY?

Because carrying capacity is most easily applied to fields such as range management, some people have suggested that carrying capacity is inappropriate to the recreation field because of its complex nature (Lucas and Stankey, 1974; Wager, 1974). The rationale for applying the carrying capacity concept to recreation is that (1) recreation provides a particular service to people, (2) the service is a result of the interaction between the user and the resource, and that (3) beyond certain limits, this resource is adversely affected by excessive congestion and/or resource deterioration (Lucas and Stankey, 1974).

In discussing recreational carrying capacity, I assume that the goal of recreation management is to maximize user satisfactions within certain budgetary, administrative, and physical constraints. This is an important point, and is generally the dividing line in the potential controversy surrounding the applicability of the carrying capacity concept to cave management. Some cave conservationists argue that a user's satisfactions are of no consideration in cave management because of the nonrenewable nature of cave resources. However, I think that cave managers are becoming intensely interested in what is generally termed the "physical carrying capacity," or the recreational impact on the physical resources of caves. Certainly this is important, but it is only a part of the larger problem.

There are actually four components of cave carrying capacity: (1) management objectives, (2) visitor attitudes, (3) the recreational impact on physical resources, and (4) the impact of the resource on the visitor. No single component may be used to measure carrying capacity; all four interdependent components must be considered together.

MANAGEMENT OBJECTIVES

The carrying capacity of a cave can be judged only in light of the management objectives for that particular cave. These management objectives must identify the type of recreation experience that the cave is intended to provide.

* Bureau of Land Management, Denver, Colorado.

Most of the caves managed by public agencies are in a wild, or undeveloped condition. Some contain rare or unusual geological, biological, or archeological materials; others contain conditions which are particularly hazardous to the cavers' safety. Most of us agree that this type of cave should be used by those cavers with sufficient skill and/or appreciation of the cave environment to use it properly. Should we turn back cavers who do not possess the skills required for this type of cave? Yes, we definitely should, although at the present time the BLM's authority is limited to strongly discouraging an unqualified caver from entering a cave open to public use. BUT—should we deny **any** caving experience to the cavers we turn back? This is unacceptable to public land management agencies because not all caves contain unique values or dangerous conditions and most people would be excluded from the enjoyment of caves.

The reasonable alternative is that management needs to make available a variety of caving experiences, so that all users have the opportunity to maximize their satisfactions with the caving experience. This spectrum of opportunities does not need to be all-encompassing, but an attempt should be made, on at least a regional basis, to expand the different types of caving experiences open to the public.

A realistic assessment requires a concerted effort on the part of the manager to evaluate a cave for hazardous conditions and for unique and easily disturbed values. Assuming that there are other wild caves in the area and that a particular cave has few special significant values, the manager may be filling a gap in the spectrum of caving opportunities if he were to modify the cave for less experienced cavers, while at the same time relieving pressure on other caves of greater significance. It should be emphasized that management objectives must consider the number, type, and significant values of other caves in the area, which would best be accomplished through a cooperative inventory of regional cave resources.

Management objectives become the limits of acceptable change which the manager will tolerate within the cave environment. These objectives are flexible, bending in response to public pressure, policy, and other reasons. Similarly, the carrying capacity of an area must change in response to changing management objectives. In the absence of clear objectives it is not possible to make consistent and defensible judgments about carrying capacity (Lucas and Stankey, 1974).

VISITOR ATTITUDES

Implicit in the above discussion concerning management objectives is that not all recreationists attach the same value to a certain caving experience. Let us examine the cave experience of Carlsbad Caverns with its miles of trails, lighting, cafeteria, and elevators. For the vacationing tourist (whom we might call a totally inexperienced caver), this may be a very satisfying cave experience. However, for many of the attendees of this conference who regularly enter unexplored caves, this type of experience may not be acceptable. The point here is that not all recreationists perceive the environment in the same way. Recreationists seek many different types of experiences in caves—the excitement of exploration, companionship, solitude, the element of danger, and others. The manager then faces the perplexing problems of trying to determine just what type of experience the users desire. The practice of using the manager's perception of user desires in the formulation of management policy can lead to some very inaccurate conclusions (Lucas, 1964; Hendee and Harris, 1970). A more objective measure of public attitude is the use of questionnaires. Questionnaires can be very helpful in determining both the recreationists' desires and their satisfactions with present management practices. Questionnaires also provide some logical defense against a vocal special interest group by providing a solid understanding of the feelings of a majority of cavers. There are several hazards involving the use of questionnaires, such as sample bias and questioning techniques, and the manager should make himself aware of these hazards before a survey is initiated.

Once a manager has information regarding the attitudes and expectations of the visitor, he is in a much better position to maximize the visitor's satisfactions. Consider the diagram shown below (Driver, 1975).

Before beginning a caving activity, a caver has certain expectations of either what will happen or what he will derive from that activity. He retains certain satisfactions or consequences after he finishes the activity. When a caver receives everything he expects from the caving experience, he has *maximized his satisfactions*, which is the goal of recreation management.

The manager's role in making these experiences available varies considerably. By utilizing visitor attitudes, the manager can match the caver with a cave that provides the setting in which he can maximize his satisfactions. This matching process retains the individuality of a cave in supplying a portion of the spectrum of opportunities. The cave should be managed to make a specific experience available to the visitor. This process does not put the manager in the position of trying to manage for several different types of experiences at one time; if a cave is managed for this mythical "average" user (Shafer, 1969), no one receives maximum satisfaction. The variety of caving opportunities which are needed within an area or region can also be determined by examining visitor expectations.

RECREATIONAL IMPACT ON PHYSICAL RESOURCES

If caves were managed strictly for the preservation of the resources, no one would be able to venture even past the entrances (Van Cleave, 1975). Any use of an ecosystem will cause some alterations and these alterations are magnified in the cave environment where the resources are considered basically nonrenewable (Aley, 1975). It is for this reason that the recreational impact on the physical resources is the most limiting of the four carrying capacity components. The other components are quite often determined within the confines of the capabilities of the physical resource to sustain use. It is important to realize that trade-offs will inevitably occur between social pressures and resource preservation. However, when significant or unique resources are involved, it is the manager's responsibility to establish management objectives which can adequately protect those resources.

What the manager needs to know about recreational impacts on the physical resource is the change that will occur under specific levels and types of use, and how the predicted change relates to the management objectives of the area (Lime and Stankey, 1971). The ecological change that occurs with recreational use in caves is not well known, and is currently the subject of some intense study. If the predicted change caused by recreational use is inconsistent with the management objectives of the area, the manager has four options: (1) ignore the problem and take no action, (2) change the management objectives, (3) prevent the predicted change through design, restrictions, or facilities, or (4) undertake remedial action where possible to reverse adverse changes. The manager must base his actions on how the change relates to his management objectives. Given the fragile and generally nonrenewable nature of cave resources, it is not practical for us to ignore the problem. We might consider changing the management objectives of a low-use cave that is receiving heavy visitation to the management objectives of a high-use cave, if there are other caves to provide the experience that the low-use cave provided. In many cases, however, our only feasible alternatives are either to prevent the predicted change or undertake remedial measures.

There are several techniques that a manager may use to prevent physical changes caused by recreational activities in a cave. I must emphasize, however, that not all controls are consistent with either the management objectives or the visitor attitudes, and all three must be considered together when selecting a proper method of controlling damage.

An indirect method of controlling damage that is usually well accepted by recreationists is the use of educational and interpretive techniques designed to make the caver more aware of the fragile cave ecology. Much of the unintentional damage that a cave receives can be prevented by informing cavers of the potentially damaging effects of their actions.

However, interpretive techniques will probably have only limited effects on intentional damage caused by vandals. Rockhounds should be included in this vandalism category. While their damage is not hostile in its intent, it is still intentional damage. Their activity in a cave should be treated much the same as motorcycling in wilderness areas. While motorcycling is certainly a valid outdoor recreational activity, it is inappropriate in a wilderness area where it destroys the environmental values which so many people seek. Preventative measures for this type of impact include signs warning of heavy penalties involving the alteration or removal of any cave formation. Obtaining vandalism reports from cavers as part of the use process may help to develop a feeling of stewardship towards the resource and involve them in its protection (Brucker, 1975). Regular patrols by area rangers are also a strong deterrent, but this is usually limited by the small number of personnel in most land management agencies. As a partial solution to this problem, some agencies are experimenting with electronic surveillance of cave entrances, gates, and interiors. The results seem to be quite promising, the major disadvantage of the system being the cost.

Access is one very common and effective method of controlling cavers. The most obvious access control is gating the cave entrance. Gating may be used for protection from vandalism, overuse, and lawsuits resulting from injury inside an ungated cave (Hunt and Stitt, 1975). There are also other types of access control which are often not considered. For example, a manager may increase either the difficulty or the length of an access trail to a cave, or may deliberately reduce the available parking area near a cave to discourage visitation (Van Cleave, 1975). Access may also be used to increase carrying capacity, as in the case of Carlsbad Caverns. Although that cave's development has certainly altered its ecosystem, it would not be possible to provide a cave experience for all its visitors without making the cave more accessible. Various methods of *hardening* the cave may be utilized, including the use of trails, handrails, and other methods which control the area and direction of visitor traffic. The appropriate control will depend upon the type of visitor experience desired.

Permits are another method of controlling physical impacts by regulating the number of visitors. Although the amount of use a cave receives is not the sole determinant of resource deterioration, it is unquestionably a major factor. Through the use of permits, a manager can control both the number of visitors and the group size, while at the same time obtaining basic information about the cave user which can help to shape future management actions.

Another action that the manager can take is to reverse adverse change wherever possible. Even though many cave resources are nonrenewable, there *are* certain adverse changes which can be reversed. Although the list is far from being complete, a few reversible changes are: removing algae with a hypoclorite solution, removing graffiti with either a brush or a commercial product, obliterating tracks in sand by flooding or raking, and removing trash by regular pick-up (Brucker, 1976). These are only a few suggestions; what stands out here is that broken formations and animal populations cannot be reversed or replaced. Graffiti and trash tend to accumulate at a much faster rate if not quickly removed, so these remedies should be initiated as soon as possible after discovery of the problem.

IMPACT OF THE RESOURCE ON THE VISITOR

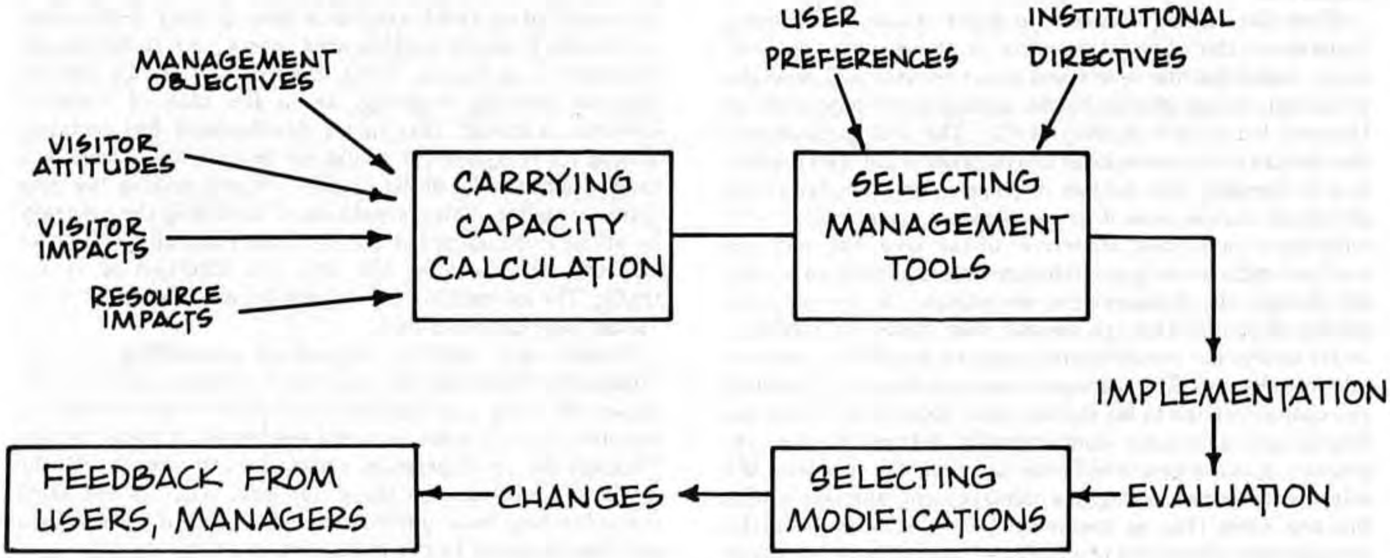
The fourth component of cave carrying capacity is the impact of the resource upon the visitor. This category includes the physical hazards which are present in a cave. This component is much more important in a cave than in other recreation areas because there are many things in caves which are real dangers. The hazards tend to limit a cave's carrying capacity in a rather absolute fashion. Consider as an example a deep vertical shaft or body of water. These features drastically reduce the carrying capacity of the cave, even though the rest of the cave may be suitable for visitation by even a novice. Most hazards are skill-related; i.e., an obstacle is less of a hazard to an experienced caver than an inexperienced one. For this reason, the carrying capacity of a cave is reduced simply because of the number of cavers who are capable of negotiating these hazards.

Caver classification has been the subject of much controversy. However, federal land management agencies no longer require a skill test as a prerequisite for participation in any recreation activity, including caving. There is serious doubt as to the legality of such a requirement because of the infringement on personal choice. Instead, these agencies are adopting a registration system. This registration system presents a fine opportunity for the manager to explain the different types of opportunities, hazards, and experiences which are available to the caver in each of the caves open for use. He can also point out the minimum amount of equipment necessary to explore certain caves, and recommend specific areas based on a caver's desires, experience, and equipment. This system goes a long way in providing a means of matching the caver with a cave that can fulfill his expectations. It is also the most practical method available for minimizing the impact of the resource on the visitor.

USING CARRYING CAPACITY

What happens after carrying capacity is determined? For a brief look at how carrying capacity relates to cave management, examine the diagram shown below (adopted from work done by Brown, Driver, and Stankey, 1976).

Once the recreational carrying capacity has been determined using the four previously described criteria, management tools are selected to achieve that carrying capacity. The management tools are based on both the user preferences for certain tools and the institutional directives (usually agency policy) which guide management decisions. After implementation of the management tools, it is necessary to evaluate their effectiveness in achieving the calculated carrying capacity. Modifications of the management tools are selected and implemented if necessary, and feedback from users and managers is used in the continual evaluation of the carrying capacity of the cave.



SUMMARY AND CONCLUSIONS

Much emphasis has been placed on the *physical carrying capacity* of caves. This discussion has not attempted to de-emphasize the importance of physical carrying capacity, but has tried to make the manager aware that it is only one component of the carrying capacity concept. The other three components, which have received little attention in cave management, are the management objectives of the area, the attitudes of the visitors who use the area, and the impacts of the resource on the visitor. All four components must be considered when determining the carrying capacity of a cave.

At first glance, this discussion may have appeared to argue for the opening of all caves to recreational use. This is not true. There are some caves which contain either highly significant values or dangerous conditions that preclude recreational use or restrict it to highly qualified cavers. What we cannot justify is the public closure of a cave which does *not* contain those significant values or dangerous conditions. Opening these caves, and even modifying them to some extent, will provide inexperienced and intermediate cavers with a fulfilling experience while, at the same time, relieving a large amount of pressure from caves which should be closed or restricted.

The need for cooperation between federal, state, and private land managers has constantly reoccurred throughout this discussion. Only in very rare circumstances will a single management agency control all caves within a region. For this reason, there must be cooperation in the regional inventory of caves to determine the available resources. There should also be cooperation in the provision of caving opportunities so that a wide range of experiences are available to the public.

Although a workable carrying capacity program for caves has been outlined, there are several areas of deficiency. One is the lack of information regarding the attitudes and expectations of cavers. Most of our information in this area is limited to conversations with articulate cavers. With a better idea of what appeals to cavers, it is easier to make available areas in which they can maximize their satisfactions. Another problem area is that management does not seem to be aware of the many alternative objectives regarding cave resources. Management should work hard at overcoming an "either/or" attitude towards public access to caves, and should try to be more aware of the wide range of visitor management methods available to them.

There may be reluctance on the part of the manager to institute the carrying capacity program described previously because there is information lacking in several areas. I encourage the manager to proceed (if with caution), even with the scarce information available. Although better information will eventually surface, it is important to act now with some data, however imperfect, than to postpone our actions while we continue to wait for "perfect" information.

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Practical Experiences with Carrying Capacity

Geoff Middaugh *

ABSTRACT

The Recreation Management Concept of carrying capacity is widely misunderstood. Much of the misinformation about carrying capacity comes from the narrow interpretation of its utility. Carrying capacity determination is cave management because it provides a framework to make cave preservation work. To understand carrying capacity, one must first dispel the myths surrounding the concept. Then the utility of the concept applied to fragile resources must be stressed. Carrying capacity is a heavily researched concept in today's recreation management literature. The concept is easily applied to the bureaucratic structure of land management agencies, and the concept is better than using no framework at all. The carrying capacity management framework is many faceted. The concept, nonetheless, depends on the critical evaluation of public interest groups. The National Speleological Society (NSS) is a sophisticated volunteer public interest group affecting agencies today. The NSS itself must help make the carrying capacity determination work by a diligent effort to establish sound cave management objectives.

The recreation management concept of carrying capacity is widely misunderstood. One reason for this is its verbal relationship to a concept of range management. Another is that it is often associated with the calculation of numbers instead of achieving a specified objective. A question put forth for this symposium is "How should carrying capacity be incorporated into cave management?" I will try to argue that recreation carrying capacity determination is cave management for a number of explicit reasons.

I will do this by (1) dispelling popular myths concerning the carrying capacity concept and (2) defining the utility of the carrying capacity management framework to the preservation of fragile resources such as caves. I hope to also emphasize how the carrying capacity management framework needs and requires input from organizations such as the NSS.

I first would like to dispel some long cherished misconceptions concerning carrying capacity. In discussing these, I will be formulating some basic assumptions for the second part of this paper concerning the utility of the carrying capacity concept for cave preservation. I first submit that most of the following assumptions are basically my own judgements and philosophical viewpoints, consequently, they cannot be disputed by facts or statistics; only by the persuasion of argument.

First of all, caves have no value to managers as caves *per se*. Caves only have value because people are concerned about their existence as caves and, consequently, spend time and money in seeing that they are preserved and protected. In resource management, this is an established principle, although you will seldom hear a resource manager say this in public. The exact same principle is true concerning wild horses and burros, desert pupfish, rare and endangered species of animals, cave formations or wilderness areas. People place a value on a given resource and consequently make the preservation of that resource "important" to a land manager. People place these values on the resources in peculiar ways. Wild horses are important to federal agencies because Congress and the courts have decreed to the agencies that they must consider these animals when making land management decisions. Things as ambiguous as the "quality of the human environment" are important now because Congress has dictated so in the National Environmental Policy Act. Today managers are concerned about caves because there is a segment of the public willing to give up time and money to see that caves are preserved and protected. Consequently, to the cave manager it is equally important for him to consider the people behind cave preservation as it is to consider the cave itself. This may be a hard principle for some to swallow and it is an extremely utilitarian approach to something we all wish were more benevolent.

Secondly, it follows from the above that the concept of carrying capacity is increasingly concerned with the expectations, attitudes and objectives of people who are interested in caves. Consequently, it is important for the cave manager to have an understanding and knowledge of the expectations, attitudes and objectives of those people concerned with caves. Only by understanding these people can he know what values of caves require preservation and protection. The manager is expected to reach out to these people so he can learn their attitudes and objectives. It is equally important for those concerned about caves to articulate their concerns about caves by writing letters, attending meetings, and making themselves heard to cave managers.

Thirdly, cave managers function in an environment of competing pressures and interests. Consequently, the maxim about the "squeaky wheel getting the grease" is certainly true. When the cave manager becomes aware of a squeaky wheel, he can apply the grease (i.e., money and manpower). It is this "grease" (money and manpower) that is no doubt the reason we talk about cave management.

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Money, manpower, and management are the methods by which cave preservation can be accomplished. It is the effect of focusing the money, manpower, and management on defined problems that brings us back to the carrying capacity concept. Now that I have outlined the strategy that gives bureaucrats excuses not to act, and the reasoning behind the familiar bureaucratic slowness, I would like to reemphasize and continue to relate these phenomena to the carrying capacity concept.

Another familiar myth of carrying capacity is the belief that carrying capacity determination is basically the calculation of a number. Carrying capacity determination is the definition of a problem, the definition of objectives to solve that problem and the implementation of management to solve the problems. Calculating a number is only part of the implementation. Calculating a number is simply a tool to achieve the objective and there are many other tools that can be used besides numbers. Most of this symposium is concerned with the tools of implementing carrying capacity objectives. Briefly, such tools are gates, permits, signing, and manipulative methods such as not publishing locations, keeping cave locations off maps and simply keeping a tight lip about caves.

Another, often forgotten, aspect of carrying capacity is its major concern about "quality" as compared to "quantity." The quantity argument, I think, is an overtone of carrying capacity's preoccupation with numbers. The carrying capacity model is as equally concerned about "quality" as it is about "quantity." Some researchers define "carrying capacity" as the amount (quantity) of use that can occur within given bounds of quality. It is the equal consideration of quality that provides a framework in which a very high level of resource preservation can be achieved and an equally low level of resource utilization can be under-emphasized. Simply, a carrying capacity determination allows a specified allocation of agency time and money to achieve a disproportionate amount of resource preservation. Cave conservation can be done within a carrying capacity management framework and specified levels of preservation can be achieved. Also, BLM's management framework plans (MFP) or planning system calls for a strong input and increased accountability to make the agency focus on cave management problems. The carrying capacity management framework creates a pedestal for managers to make decisions in full view of the public. This makes the decision-makers accountable for his decision, and in effect, should cause better cave management decisions.

Which brings me to the second aspect of the carrying capacity concept concerning the utility of the concept to cave conservation goals. Let me emphasize that the carrying capacity concept has great value for cave management because of three reasons:

(1) It is a heavily researched and proven technique for similar types of resources:
(2) It is easily applied to the rigor and caprice of any land management bureaucracy;
(3) It is better than no framework at all.

First of all, Forsell (1976) has defined a theoretical framework for carrying capacity. I would like to expand on this framework and discuss its applicability to protecting fragile resources such as caves. I should point out that the recreational carrying capacity framework is now a popular and vogue recreation management concept that is being widely studied and applied to such resources as wilderness areas, wild and scenic rivers, and generally to dispersed recreation areas. Applying the concept to cave management is merely an exercise in changing words, the constraints of the physical resources, management objectives, and the user groups concerns about the resource.

The carrying capacity model allows for management emphasis on fragile resources. Caves, rivers and wilderness areas are prime examples. All of these resources have a certain physical attraction which make them important for recreation purposes. Caves have challenges, pits, and beautiful formations. Wilderness areas have solitude, challenges, and scenery. River running too has the challenge and the thrill of rapids, and beautiful scenery. The debate could become quite philosophical, but regardless, caves like other wild land recreation values have some recreational (as well as scientific) value to people, or otherwise we would not be at all concerned about them. The key is that the values which make caves important are normally the values that make caves fragile. Caves attract people because of beautiful formations, and as we all know, too many people can cause the destruction of the values they seek. This principle is equally grim but true for wilderness areas: the opportunity to seek solitude is a value of a wilderness and is the exact same value that attracts hordes of people.

The carrying capacity model allows the manager and the interested public to concentrate their management efforts on the values that make caves important. For example, as Aley (1975) points out, in resource management the limiting factor is usually the most important consideration to a decision maker. The carrying capacity framework allows the decision maker to concentrate on these limiting factors (and they are usually fragile resources) and emphasize them as criteria for management. The limiting factors of a cave, whether it be a population of bats, fragile formations, archeological values or whatever, are brought forth (i.e., emphasized to the manager) and lay the ground work for establishment of management objectives. The carrying capacity concept is ecosystem management with a "concern" for people interjected into the model.

The destruction or change of fragile resource values are the limits of change that the caving public will not accept, and the manager must strive to avoid such occurrences. In fragile and simplified ecosystems such as caves, these limiting factors become increasingly important. When slight disruptions are magnified a hundredfold in the cave ecosystem, and are so readily visible to the caving public, it is important to define these disruptions and concentrate cave management on preventing them, mitigating them, or accepting them.

The second useful aspect of carrying capacity is its applicability to the idiosyncracies of any land management bureaucracy. Carrying capacity builds in a high degree of accountability. It is a simple principle. If management objectives are defined and decided upon by managers and the user public, then there are visible (both written and on the ground) criteria against which the performance of an agency can be evaluated.

I see the greatest value of the carrying capacity concept for management to be the determination of management objectives for a cave or for a specific cave region. Forsell (1976) has defined how these objectives could be set and how they relate to the final cranking-out of a number which would eventually be called the "carrying capacity of a cave". The management objectives specify the limits of unacceptable change (or damage) that you, the caving public, will accept or reject for a specific cave. It tells the managing agency that a certain cave must be preserved with no damage or another cave can handle minor damage (and more people) than another. It is the determination of these management objectives that all volunteer caving organizations should concentrate upon. It is by determining sound and practical management objectives that a specified state of cave preservation can be achieved. And, in a more important sense, it is cave management objective determination that gives the unknowing and unknowledgeable cave manager a specified direction toward which he can allocate time, money and personnel.

The third aspect of carrying capacity utility is that the carrying capacity management framework is better than nothing at all. Little can actually be said about this except that cave managers can fumble for a long time with cave resource protection but they will be stumbling in the dark without definite guidance around which they can strive to protect one cave at a specified point in time. Brushfire management has got to go. Brushfire management solves only short term problems. Brushfire management concentrates on one specific symptom to a problem while the basic problem goes unchecked.

I should explain that I am not talking against a national policy on cave preservation, or national legislation on caves. I am more concerned about outlining a uniform methodology for cave resource protection (which I believe carrying capacity to be) and then seeing the implementation of that methodology at the lowest level of government and the lowest level of organization within the NSS. This, briefly, would be a close working relationship between a grotto and a BLM District, a Ranger District or a National Park.

This brings me to the third and final point of the paper concerning the importance of an NSS-type organization to (1) cave management agencies, (2) to carrying capacity determination and (3) to cave resource preservation.

A volunteer organization, such as the NSS, is faced with constant changes, turnovers, and internal weakness. The NSS is a special interest group, similar to the AFL-CIO, the AMA or the teamsters. I only bring this out because the NSS is basically different from the AFL-CIO, or the AMA, or the teamsters union. The difference is that there is usually no economic incentive to keep most cavers active in the NSS. Action is strictly volunteer. This principle is true of most recreation groups and even applies to consumer groups or organizations such as Common Cause or Nader's Raiders. The point I am trying to make is that NSS members are nonetheless very highly motivated individuals. Their concern about caves goes above and beyond the normal advocacy of a cause. NSS cavers act. This phenomena is similar to the environmental movement of the late 60s and 70s and is often looked at with disbelief by the old-line special interest lobbyists of by-gone days. This phenomena, I think, is one of the more amazing aspects of volunteer groups and I would say that NSS members are as highly motivated and sophisticated as any special interest group affecting public agencies today.

There are a number of reasons for this and I should point these out. The point I am trying to make is that the aspects which make the NSS strong are the very aspects which make it valuable to management agencies and to carrying capacity determination.

First, NSS cavers, without a doubt, know more about caves than cave managers. So cavers know more about the resource that someone else is to manage. Obviously the cavers hold the trump card if resource inventory is to have anything at all to do with cave management, or carrying capacity determination.

Secondly, NSS cavers have a monopoly on the technical skills required of caving. Such skills include mapping, rope work, science, geology and so on! Few cave managers would know the difference between a Jumar and a Gibbs ascender.

Thirdly, NSS cavers are usually not constrained in their actions by time, paperwork, and bureaucratic delay. Simply, they can speak and say what they want. They are a part of that big group of people called "the public."

Fourthly, the NSS has very precise social sanctions which give the organization a high degree of predictability. This does not mean to say that all NSS cavers are alike, but they have many things in common and cave preservation happens to be number one. The social sanctions of caving organizations are simple: the organization simply would not condone cave formation collectors or vandals. Even the present internal dispute within the NSS over the publication of guidebooks on caves gives the group high predictability on this one aspect of cave protection.

Fifthly, NSS cavers are scientifically more sophisticated that normal, volunteer groups. The level of knowledge within this group is far above the average of most volunteer (nonprofessional) organizations.

And last of all, the NSS is a grass-roots organization. Its strength comes from individual grottos from throughout the country who concentrate their efforts on local problems. The dispersed nature of NSS grottos allows for a slow but steady growth in cave user/cave owner relationships. It takes time, but local grottos get the job done. The job could not get done by centralization of all cave conservation projects in the national headquarters.

You may ask again about this time, what do all these factors have to do with carrying capacity? I hope it is clear (or clearer) that carrying capacity is concerned with a desired state of resource preservation and a desired state of resource utilization. The decision that defines these desired states is what carrying capacity determination is all about. Carrying capacity provides the framework to make "good" decisions and to make cave conservation goals workable and achievable.

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Regulation of Sport Caving on Public Lands

Steve Knutson *

ABSTRACT

The regulation of sport caving activity in wild caves of public ownership is in an early stage of development. In many areas regulation does not exist. In others growing concern for, and pressures on caves have led to implementation of strict rules. Useful prototype cave management systems already exist. These involve relative degrees of freedom for the sport caver. An interesting parallel may be drawn with mountaineering in national parks. Scuba diving is a similar adventurous activity which has gone quite a different direction.

INTRODUCTION

In the western states public land constitutes a large percentage of the total land area. In a recreational sense much of this land sees little use pressure. Since caving is a relatively unpopular sport in the west, it is not surprising that caves on public lands are generally not subject to regulation. In a few areas, however, caving pressure has led to management plans of various sorts. If caving pressure increases as have other forms of recreation, it can be presumed that present management plans will be prototypes for caves as yet unregulated.

In this country there is, at present, a single national caving organization; the National Speleological Society. From cave register data it has been estimated that this group represents about one fifth of the total caver population.** From many people comes concern over the freedom of action to be expected under the emerging management plans. Such concern often blossoms into lively controversy. For instance, some feel that the use of caves for recreational purposes is incompatible with the pursuit of speleology and cave preservation. It might prove interesting to briefly examine some existing systems to see what potential freedoms they offer and what may occur in the future. It should also prove interesting to examine the sports of mountaineering and scuba diving to see what regulatory directions they have taken.

MANAGEMENT OF A GROUP OF CAVES

The example here is the only one existing, namely the caves of the Guadalupe Mountains in the Lincoln National Forest of New Mexico. This system is very important, not only because it is a prototype, but because it seems to be working.

First, the caves were evaluated for recreational, scenic and scientific values, and were classified both for relative recreational hazard and fragility. All that need be done to grant entry permission to an applying caver is to classify that caver in terms of technical ability, experience and conservation awareness. Budgetary considerations do not as yet allow the agency to do this, however, and no standardized system exists within the caving community. The requirements for the caves are as follows:

"A" Caves
1. Party of at least two persons, one of which is an experienced spelunker.
2. Hard Hats for each person.
3. Two light sources per person.
4. Shoes with nonskid soles.

"B" Caves
1. Party of two persons, both experienced spelunkers.
2. Hard hats for each person.
3. Three light sources per person.
4. Boots with nonskid soles.
5. Rope with breaking strength of 2000 lbs and/or equivalent climbing gear.

"C" Caves
1. Party of at least four persons, two of which are experienced spelunkers.
2. Hard hats for each person.
3. Three light sources per person.
4. Boots with nonskid soles.
5. Vertical descent and climbing gear.

"D" Caves
1. Party of at least six experienced spelunkers
2. Hard hats for each person.
3. Three light sources for each person.
4. Boots with nonskid soles.
5. Vertical descent and climbing gear.
6. Foul air detection equipment.

"E" Caves Entry requires that a qualified Forest Service employee accompany the group.

This system appears to some to be very restrictive. At the Lincoln National Forest the feeling seems to be that it is working and that it will be continued.

MANAGEMENT OF ISOLATED CAVES

In recent years a number of isolated caves have come under management. The following three examples are from California, and each is governed by a different agency. Each

* P.O. Box 1, Mammoth Cave, Kentucky 42259
or 505 Roosevelt St., Oregon City, OR 97045

** *Editor's note:* See Nick Noe's article "Who are cavers", pp. 9-11, *National Cave Management Symposium Proceedings*, Albuquerque, NM, 1976.

cave contains vertical drops and the first two contain fragile formation areas.

Soldiers Cave, Sequoia-Kings Canyon National Park

To gain access to Soldiers Cave, one must be part of a group of from three minimum to eight maximum; one member must have had prior experience in the cave. Prior to the trip, the group presents itself at the district office to sign waivers and have equipment inspected. Equipment must conform to listed minimums. Included at that time is an informal discussion of cave conservation and safety. The inspection is done by knowledgeable rangers. Only one group is allowed in the cave at a time.

Church Cave, Hume Lake Ranger District, Sequoia National Forest.

Entry to Church Cave is gained in a fashion similar to that for Soldiers Cave. The caver undergoes on-the-spot certification by discussion and inspection of equipment. A waiver must be signed. Each party must have a certified trip leader. Part of the requirement for such status is to have visited the cave with another certified trip leader.

Crystal 67 Cave, Mountain Home State Park.

Requirements for this cave are similar to the previous two. In addition, a support/rescue party must remain at the entrance while a group is in the cave.

Discussion with cavers experienced in these caves indicates that there is less vandalism in the caves now that they are managed. The governing agencies seem to feel the same. Overall, the evaluation of these systems indicates success.

ALTERNATIVES TO AGENCY MANAGEMENT

It is appropriate to include here a few alternatives to agency management. Such systems have been applied where the agency is unable or unwilling to participate.

One such alternative is the *use permit* or *use agreement*. Under a use permit total responsibility for a cave is given to a private party or group. Such private management is potentially the most restrictive of all. A private party is not obligated to be objective in granting access to the cave to others. A number of these have been pursued successfully, however.

Another alternative is a complete *lack of management*. Such a system is actually workable in isolated areas of low caving pressure like the Bob Marshall and Scapegoat Wildernesses of Montana.

Secrecy is also an alternative. There would be no restrictions except to those not party to the secret.

MOUNTAINEERING IN NATIONAL PARKS

The sport of mountaineering provides an interesting policy analogy. Mountaineering is hazardous and accidents/rescues are relatively common. In national parks this naturally led to restrictions and regulations. At Mt. Rainier National Park permission for a climb was obtained by presenting equipment for inspection/testing and citing previous climbing experience. At Mt. McKinley National Park certified backup by a recognized rescue group was additionally necessary.

In the early 1970s, however, pressure from the mountaineering community caused a relaxation of nearly all restrictions. The present situation is that at Yosemite there are no requirements (there were none before),* at Grand Teton one need only register, at Mt. Rainier one must register and have at least two in the party, and at Mt. McKinley one must register and carry a radio for communication. It should be noted that Mt. McKinley is re-evaluating their situation due to increased accidents/rescues. Yosemite on the other hand is quite content and comfortable with the situation. Obviously different conditions require different policies.

SCUBA DIVING

While mountaineering has moved toward freedom, the sport of scuba diving seems to have gone the opposite direction. In scuba diving one has a great deal of trouble operating unless certified by an accredited school of scuba instruction. It may be that the sport is so dangerous that such regimentation is necessary. It must be noted, however, that once one is certified, there is no restriction as to where and when one goes diving. In the end, this is a situation of considerable freedom.

SUMMARY

It appears that the sport of mountaineering has achieved outstanding freedom of action and choice. Can caving achieve similar conditions? Perhaps, but there are some glaring differences between the two sports as they exist at present in this country. First, mountaineering is much more popular and the mountaineering community has utilized this manpower to form rescue groups and taken it upon themselves to adopt the stance of rescuing their own. Thus agencies in charge of mountains have good reason to believe that in case of an accident, voluntary rescue groups will be able to assume much of the burden. This is not, at present, true of caving and may never be possible unless caving becomes much more popular (heaven forbid). Second, the same freedom may not be possible in caving due to the fragile nature of the contents of many caves. The management of caves should always involve more than purely recreational considerations.

It is proper to ask if cave management should be equivalent with cave conservation. If we assume the agency charged with management looks upon the cave in question as a resource, then it should manage that resource in accord with its greatest value. Evaluation of the cave should involve scientific, scenic and recreational aspects. In an area

* *Editor's note:* Yosemite National Park did regulate climbing, at least in the late 50s and early 60s. The system kept track of who went where, and whether or not they got back; the system gave some consideration to competence and equipment. TA

of numerous caves all caver interests can be served, but in the case of an isolated cave it is obvious that conflicts will arise. It must be said that proper cave management will not equal cave conservation in its strictest sense.

It would seem that management requires the gating of a cave. Yet this may not always be necessary. In wilderness areas where permit systems are used and guards are on patrol, the threat of a fine may be sufficient to deter illegal caving. Also, any cave difficult to enter (pit drop, long crawl) will in essence have a natural gate for some people.

It is obvious that management systems, where implemented, are restrictive to a caver's freedom. It is apparent, however, that nearly any patient caver can qualify to enter most caves. More importantly, the caves themselves appear to be better off than if not managed. It seems doubtful that cavers will be able to achieve the same freedom as mountaineers; perhaps the relative freedom of the certified scuba diver will be more easily attained.

Report on Workshop I: Carrying Capacity of Caves

Charles Larson *

This session began with a question from moderator Milford Fletcher, regarding the appropriateness of the cave resource's impact on the cave visitor as an element of carrying capacity determination. Before the session concluded, exchanges had drifted from carrying capacity through cave conservation ethics, conservation techniques and evaluation of caves; all the way to the philosophy of use of natural resources in general. There were, however, few corollaries drawn between commercial and scientific/recreational uses of caves.

A need was voiced for guidelines for establishing management plans. Communication, or education, as a means of establishing carrying capacity was not mentioned. For example: agencies need input from the caving community, but receive precious little. (No one disagreed with the inappropriateness of complaining about a management policy if an opportunity to be heard was not taken during the formulation of that policy.)

Many aspects of cave visitation were described as contributing to the cave's impact on the visitor. It was brought out that even the cave's name—especially suggestive names—could affect user appreciation; that some names had more "market appeal" than others. Most agreed that carrying capacity is affected by the level of visitation, the user's experience, concern for preserving the cave, cave appreication education, motivation, sensibility and, finally, the cave user's expectations. All agreed it would be a mistake to generalize about the user's caving experience. It is best not to assume anything about the user's wants.

Most felt that cave values must first be identified before management objectives are established. Others, who agreed with the foregoing, felt that determination of cave values must rely heavily on input from the scientific community. Others stressed that the highest of many contemporary cave values would dictate management objectives. One person felt that carrying capacity was primarily a biological consideration, but was too seldom a consideration when management objectives were established. It was generally acknowledged that such was the case, primarily because other cave values—visible things like speleothems—were much more obvious. All seemed to agree that some kinds of cave uses must necessarily be exclusive.

The session ended with a discussion of how many cave users exist. Varying estimates of the total number of cave users in the United States placed the number in the scientific/recreational sector alone as high as 250,000.

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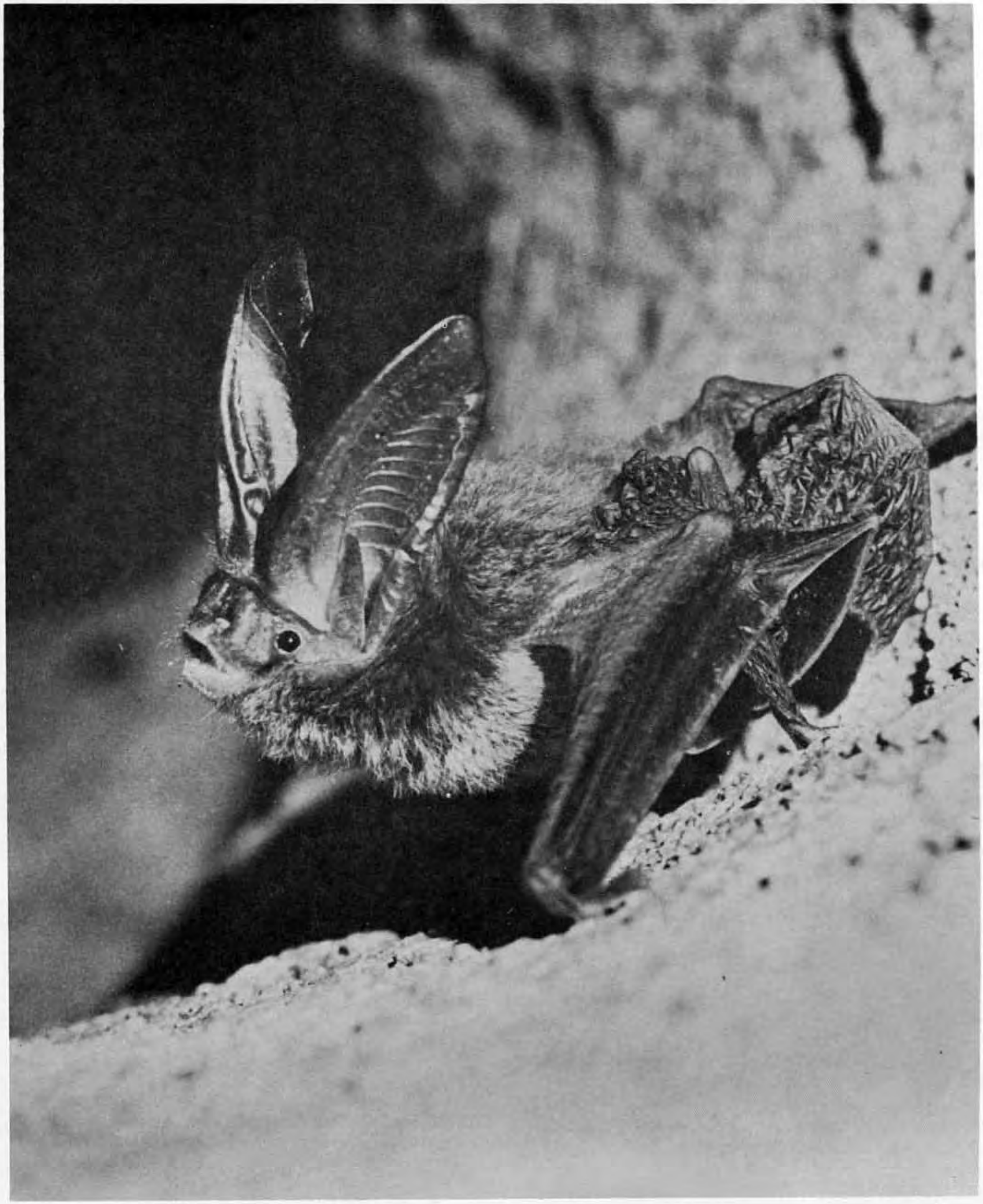
Cave Inventory, Valuation, and Assesment



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Evaluation and Management of Caves in a State Natural Area System

R. Roger Pryor

ABSTRACT

Nearly half of the states have some form of protected natural area system in operation. The goal of such a system is to inventory and protect worthy examples of natural diversity. Missouri's Department of Conservation has established a natural area system on its lands. Included among the 48 natural area tracts are two cave natural areas: Bat Cave in Miller County, a maternity site for Myotis grisescens, *and Powder Mill Creek Cave in Shannon County, a hibernaculum for* M. sodalis. *The Department's authority on acquiring and protecting caves is clear when endangered species are involved, but without such a species' presence it is a different story.*

A number of agencies [federal and state] and private organizations are cooperating in an on-going survey of potential natural areas in Missouri. Certainly, the most difficult natural feature to inventory, evaluate and ultimately protect is the cave. In a state with over 3300 known caves the job is made even more exhausting. How does not set out to evaluate which caves are suitable for natural area preservation? What makes a cave significant in a state perspective? How many caves should be included to make a state system of natural areas truly representative? What real protection can be afforded those caves which are included? What about those that are not? What authority is needed to protect caves as landforms, as part of the natural diversity? These are the questions that this paper will attempt to answer using Missouri as the example. A look at existing "protected" caves will provide some of the answers as will the experience of those who have been inventorying natural area resources.

This paper was not submitted in time for inclusion in these Proceedings.

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Underground Nature Preserves in Indiana

James H. Keith *

ABSTRACT

In 1967 the Indiana General Assembly passed an Act that enabled the State of Indiana to recognize, acquire, manage and protect unique natural areas in the state. In 1968 the Division of Nature Preserves was formed to carry out this function as defined by the Act. To date, the division has dedicated 41 tracts of land totalling 6424 acres at State Nature Preserves. The paper discusses the recent dedication of two caves as nature preserves, their significance as natural areas, and management goals, methods, and problems. Our criteria for the dedication and management of other underground natural areas is presented.

In 1967, the Indiana General Assembly passed an act which enabled the State to recognize, acquire, dedicate and protect unique natural areas. In 1968, the Division of Nature Preserves was created to allow the State to do this. At this time, the Division manages 41 State Nature Preserves totalling 6430 acres.

Tracts owned by state, county and local governments, conservation organizations and private individuals can be dedicated as State Nature Preserves. Generally, natural areas must be located and appraised in terms of uniqueness. Next, the property is acquired, either by a governmental agency or a conservation organization. After acquisition, the tract is dedicated by action of the Indiana Natural Resources Commission. The tract must then be managed and protected, and interpretive aids installed if necessary.

Nature preserves are dedicated natural areas which Lindsey *et al.* (1969) describe as "any outdoor site that contains an unusual biological, geological or scenic feature or else illustrates common principles of ecology uncommonly well." They are set aside for scientific, educational and aesthetic reasons.

To date, most nature preserves have been centered around areas of unique floral and/or geological significance. More recently, emphasis has been shifted toward protection of rare and endangered animals and their habitat, and to the protection of caves.

Indiana has an abundance of caves: over 1400 known to date, so some method of sorting and classifying is necessary. It was decided that length or depth alone would not be suitable criteria for uniqueness. In the first place, such caves (at least in Indiana) seldom have other unique features. In the second place, their size and depth make it practically impossible for an agency with limited funding to protect them. Long caves may have multiple entrances or run under several tracts of land. Vertical caves are usually protected by their entrances.

The alternative is to select smaller caves harboring unique features: minerals (including dripstone) and rare and endangered (or unique) animals. Historical significance is not considered because this exceeds the scope of the Division of Nature preserves.

Indiana has several small, unvandalized caves containing outstanding displays of dripstone formations. All but one have generally unknown locations and are so remote that secrecy is probably the best protection for the formations.** One cave is owned by another state agency and attempts are being made to dedicate this one as a nature preserve. Caves containing sulfate minerals (gypsum, epsomite and mirabilite) are rare in Indiana, yet a few do exist. Several are on state-owned land and one of these may be dedicated as a nature preserve in the future. Fauna such as the cave blindfish *Amblyopsis spelaea*, and the Indiana bat, *Myotis sodalis*, also merit protection through the preservations of critical habitat.

One part of Donaldson Cave in Spring Mill State Park is already a State Nature Preserve. Since this cave system supports a rather large population of *Amblyopsis spelaea*, an attempt is currently being made to set aside an upstream section of the system as blindfish habitat.

Although *Myotis sodalis* was first described from Wyandotte Cave, Indiana, the largest hibernating colonies have been found in the caves of Kentucky and Missouri. With the completion of a stretch of route I-64 through Southern Indiana, many formerly remote ridges became relatively accessible to cavers searching for more caves.

In January 1976, the Indiana Division of Nature Preserves received a report of a 32 ft. deep pit cave containing "wall-to-wall fur". An investigation showed that the cave (previously unreported) had about 15,000 hibernating bats inside, most of them *M. sodalis*. A second visit to the cave with Dr. James Cope of Earlham College revealed a much larger area of bats that had been missed on the first trip. The estimate made in March was 100,000 $\pm$ 10% *M. sodalis* in this cave. The cave is on state-owned land so there was no delay in dedicating a 40-acre tract containing the cave as a State Nature Preserve.

The cave is open to qualified scientific investigators only. To protect the bats during hibernation, only two trips are permitted into the cave from October 1 of each year through May 31 of the next year. Each trip, no matter what time of year, must have written permission from the Division of

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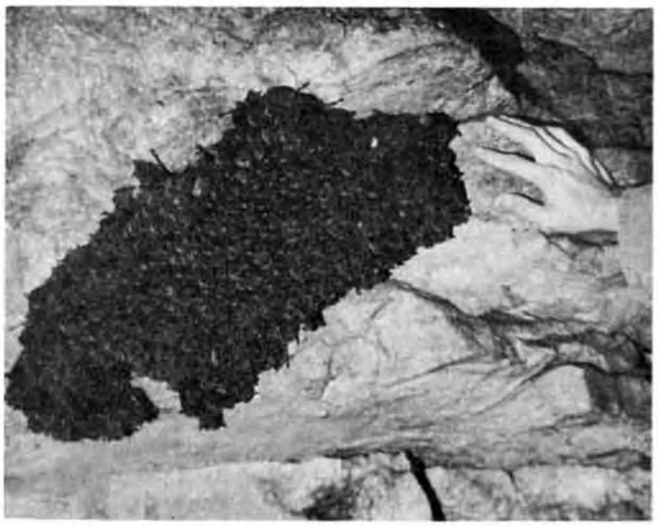
** *Editor's note:* Experience in the Western U.S. has shown that secret caves rarely remain secret. Secrecy is not an effective method of cave protection. DR.



Two views of a hibernating cluster of *Myotis sodalis* in an Indiana cave. *Photo by James H. Keith.*

Nature Preserves and the landholding Division.

The opening of route I-64 led to the discovery of this cave. It has also resulted in several independent "discoveries" of the cave. In view of this fact, and the importance of this cave, it was decided to post a sign at the cave explaining its significance and to erect a chain link fence around the entrance. This work is currently being completed. The cave is quite small, so a map will be posted inside the fence to satisfy curiosity.

It is believed that:

1) Most spelunkers are sufficiently concerned about the welfare of *M. sodalis* such that a sign will turn them away.
2) The entrance drop has an inviting look to any vertical caver approaching it. However, placing a map next to the drop may convince many that this cave is not worth the trouble.
3) If people want to enter the cave, there is nothing that will really stop them, including a chain-link fence. However, it is anticipated that other people will begin to walk this area. It would not be difficult for a hiker to fall into the cave through carelessness. The chain link fence will be there to prevent accidents.

Surveillance of parked cars along the Interstate by the state police and occasional checks of the cave by other enforcement officers should also help to reduce illegal entries. There are no trails or parking lots at the nature preserve, and none are planned.

Currently research is being conducted on the hibernating bats there, and at nearby Wyandotte Cave, to see how cave temperature affects the weight loss of *M. sodalis* through the winter. It is believed that this study and future studies will enable those interested in *M. sodalis* to formulate plans for the protection and management of this species.

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Ecological Diversity and Stability: Principles and Management

Thomas L. Poulson * and Thomas C. Kane **

DIVERSITY AND STABILITY

Environmentalists would like to argue that the presence of many species (i.e. complexity) confers stability and, thus, that the need for stability is a strong rationale for protecting all species in an ecosystem. There is both theoretical and experimental support for this idea but the picture is confused by problems of terminology and criteria. For this reason we first present some criteria for stability and some definitions.

Definitions of Stability

A. Response to different magnitudes of disturbance
   1. local stability = return to previous state after slight disturbance
   2. global stability = return to previous state after great disturbance

B. Kinds of stability
   1. resilience = adjustment stability = *elasticity* i.e. rate of return to the original state after disturbance.
   2. persistence stability: relates to the amount of change in the face of disturbance (less variation around a mean = more persistence)

Stability can only be assessed in the context of reaction to a disturbance so we next examine kinds of disturbance important to biological systems in caves. Table 1 gives an

TABLE 1. Kinds of Disturbance (example-result-mechanism)

I. Removal of one species	II. Simplify Habitat Structure	III. Physical-chemical stress	IV. Nutrient stress	V. Toxin stress
A. cave rat or cave cricket or bat (breeding) **result** loss of whole community or more **mechanism** foundation species that provide food for for a component community B. Predator **result** decrease diversity of prey species **mechanism** keystone predator eats prey species that monopolizes a resource e.g. space C. Detritivore **result** little effect except in simple system with few species **mechanisms** remove species responsible for process of succession	A. Remove rocks, fill up mud cracks, spread out pile of rat feces **result** more fluctuations in populations and local extinctions **mechanism** lose refuges from predators and flood or microclimate stress = fewer sources for recolonization B. Remove patch of habitat (on a larger scale a cave) **result** more fluctuations in populations and local extinctions **mechanism** lessens "spread of risk" e.g. different patches have different susceptability to different risks and species show local adaptation to patches and caves = genetic variation = ability to adapt to changes in in environment	A. Flood (e.g. channelization) Cold-dry air (e.g. new cave entrance) **result** decreases diversity of species especially predators **mechanism** larger predators less tolerant of stress B. Lessen moderate stress of seasonal floods **result** decreases diversity of species **mechanism** food renewal less; may allow some species to escape predation as predators are food limited	A. Excess nutrient 1. people litter **result** little change **mechanism** flash cubes, etc. inert; wood and paper like natural input and not easily monopolized by noncave species (if not in excess wood may favor specialized cave species) 2. Domestic sewage with high inorganic nutrients and toxins. . . see V **result** domination by spp at beginning of food chain (e.g. bacteria) and may kill large spp (e.g. cave fish) **mechanism** favor fast-reproducing decomposers which may use up oxygen B. Remove food type (see I A) re all removed and see II A,B if remove a patch of food	A. Heavy metals (e.g. (e.g. mercury) and pesticides (e.g. DDT, PCB) **result** simplified community (dominance of small species and loss of large e.g. fish) **mechanism** toxins accumulate since since ingestion egestion + excretion + detoxification and magnification of toxins along food chain to long-lived top predators (e.g. fish and crayfish) B. Carbide **result** local loss of whole community if small or destabilization (see II B) **mechanism** temporary high pH (caustic alkaline) kills microorganisms on which other species depend

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example of a kind of disturbance, the result of that disturbance, and the presumed mechanism behind the effect.

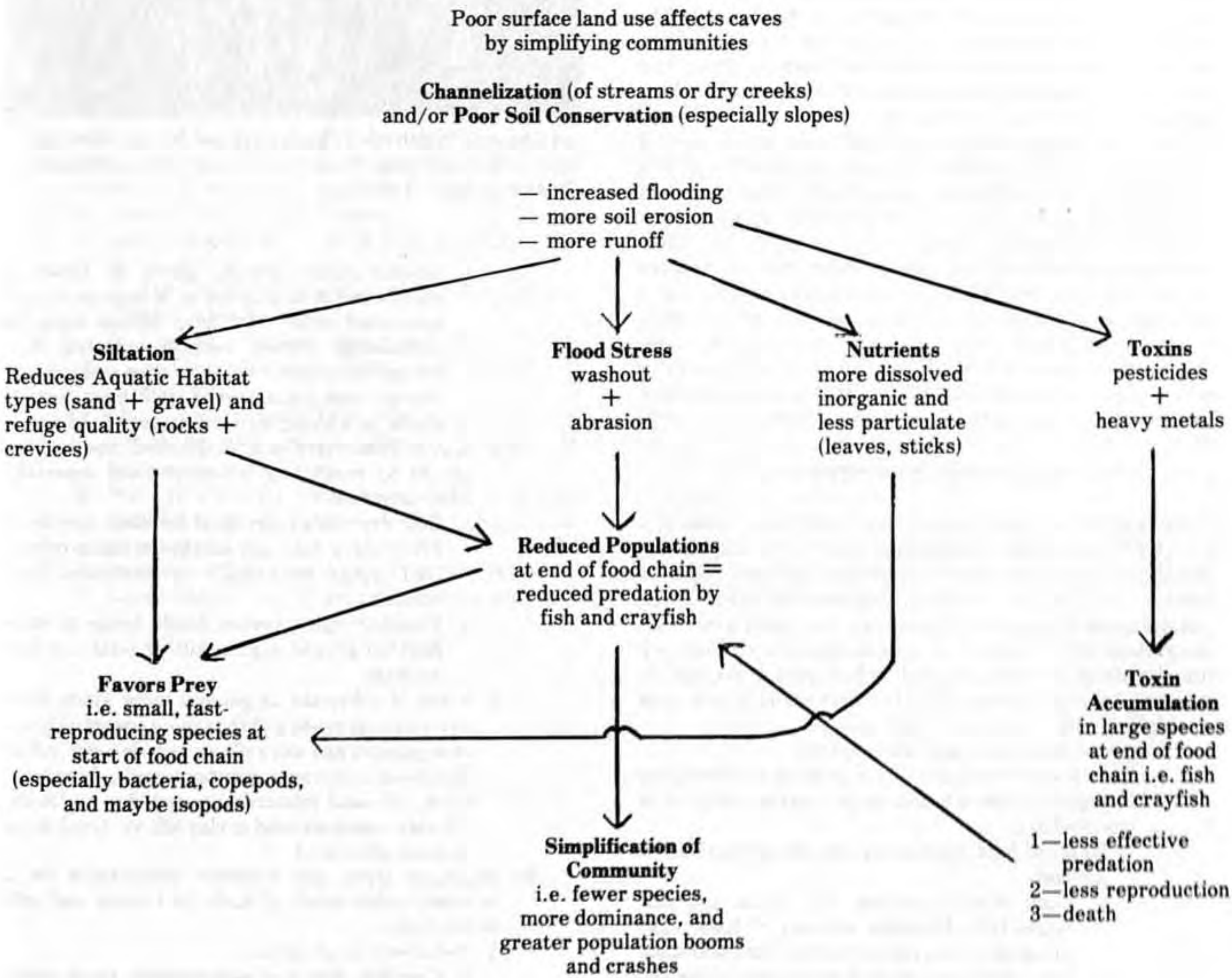
Many of the disturbances have multiple effects and are more likely to disrupt a system than one might expect from the simplified categories shown in the table. In particular, surface disturbances have a far reaching effect if they add to or modify the natural amounts, patterns, and timing of natural input. The possible kinds of disturbance interrelations are shown in Figure 1.

A next level of resolution of management problems is possible if one knows a cave system and its biota well enough to predict *a priori* the kinds of events that would disrupt the system or to deduce *a posteriori* which, of several disturbances, is the most likely culprit. An example of this is the case of the Mammoth Cave shrimp, *Paleomonias ganteri*, which has not been seen since 1967 despite intensive searches in its prime habitats. Is it extinct or have the modifications in timing and intensity of backflooding of Green River into karst springs, due to various dams, merely forced the shrimp into habitats which are not readily censused (e.g. Roaring River)?

Shrimp used to occur under Flint and Mammoth Cave Ridges at the interface between the downstream flow from master drains of local valleys and vertical shafts and the upstream flow resulting from seasonal Green River backflooding. The shrimp feed at the mud/water interface on bacteria and protozoa. These prey increase in numbers after spring backflooding renews organic silt and the shrimp reproduce in early fall when the prey density is maximal and the chances of flooding are minimal. After breeding many of the shrimp apparently die. They are not as long lived as crayfish and fish which are farther removed from the base of the food chain.

The decrease or extinction of the shrimp can be explained by a combination of habitat destruction and unnatural floods during the critical fall breeding season. Habitat destruction started with the building of lock and dam 6 at Brownsville.

Figure 1
Interrelations of Kinds of Disturbance



This ponded the Green River and the lower reaches of the Echo-Styx Rivers in Mammoth Cave and thus increased the deposition of sand and silt during normal spring floods from upstream Green River. Historical records show that cavefish and cave crayfish were common in Echo-Styx; they are no longer present. Whatever restricted their habitat may also have restricted the shrimp to the pools at the beginning of Roaring River. In that habitat they were common through the early 1960s. A restricted habitat area means that there is little *spreading of risk* in case of disaster. The disaster could have been either modifications of Green River flood timing and intensity associated with the Nolin Dam or the newer dam upstream on Green River. Most likely, water released from Nolin Reservoir during fall backflooded the shrimp habitat at the time of reproduction when the young would be most vulnerable. With a 1 to 2 year life span the loss of most of a year's reproduction may have been the proverbial straw that broke the camel's back.

There are particular management problems inherent with different kinds of cave passages but the need for maintaining normal patterns, intensities, and timing of water, air, and animal movements to and from a cave is applicable to any system. We suggest that a specific management scheme can be applied to the regions around any known cave when the system is well understood. The Cave Research Foundation has suggested a cave passage zonation scheme for Mammoth Cave National Park and surroundings based on this premise (Davidson and Bishop, 1971).

The cave shrimp example emphasizes the importance of baseline data against which managers can judge the effects of advertant or inadvertant disturbances resulting from management decisions. The data presented in this paper outline the potential kinds of problems which affect biological systems but there may be other effects which are not presently known. These effects can be deduced only if an inventory is made of the biological resources in our caves before disturbances occur. On a more positive note, disturbances can be avoided if we know ahead of time that a cave is of great interest biologically. This makes a procedure for biological resource inventory of significant importance.

An Eastern Pipistrelle (*Pipistrellus subflavus*) hibernating in an Oklahoma cave. Its fur is covered with condensation. Photo by Merlin Tuttle.

BIOLOGICAL INVENTORY

We suggest three hierarchical levels in the evaluation of a cave for its resources and potential uses and management. The first two levels can be modified for each class of resource (biological, archeological-paleontological, and mineralogical-hydrological-geological). The third level is an integration which results in recommendations. Here we concentrate on the first two levels of biological evaluation. It is best to census in early fall when terrestrial populations are highest and streams are clearest.

I. Biological reconnaissance: an overview
   A. Habitat characteristics (listed in order of importance in regard to the decision as to whether level II is worthwhile):
      1. Kinds of food input and a general assessment of amounts
         a. Biotic input organism, i.e. guano and carcasses from breeding colonies of bats, eggs and guano from cave crickets, litter and dung from cave rats, roots from plants above the cave, etc.
         b. Abiotic input: gravity input of litter at entrances but mainly input of organic matter associated with water (e.g. diffuse input by percolating water, semiconcentrated flow around breakdown below surface sinkholes or valleys, and concentrated input from vertical shafts or sinking streams or backflooding).
      2. Microclimate rigor (e.g. desiccation) and indirect effects by restricting access to food, especially near entrances
         a. Cold-dry winter air: good for some species of hibernating bats but makes entrance-related food inputs unavailable to terrestrial cave animals.
         b. Flooding rigor: severe floods bring in more food but abrade, injure, kill, or wash out cave animals.
      3. Kinds of substrate (in general more kinds mean more habitat types and thus more potential kinds of organisms and more places to hide): e.g. riffles and pools in streams, rimstone pools, flowstone, sand, silt-sand mistures layered due to floods, silt-clay, rocks on sand or clay-silt vs. breakdown in loose piles etc.)
   B. Organism types and numbers determined for a representative patch of each food input and substrate type:
      1. Relatively large species
         a. Crayfish, fish, and salamanders: count every individual for a measured (about 50 m),

representative part of stream habitat.

b. Bats and cave crickets

(1) bats: estimate only the area covered by roosting bats and do it quickly so that they are not disturbed.

(2) Crickets: estimate number per m^2 in roost and total m^2 of roost.

1. Small organisms: get down on knees or belly and look—think small since animals range from 0.5 to 10 mm in length

a. obvious food patches: intensive search of 30 cm x 30 cm area is best—

(1) Count the numbers of each kind of organism (you need not know the names).

(2) More sophisticated: as in (1) but give a description of each kind of organism by size range, shape, color, and behavior.

b. No obvious food but obvious cover as rocks or mud clods; count numbers of each kind under about 30 rocks (good for streams and pools also)—organisms must be common.

c. No obvious food or cover or organisms are rare: timed census of 20 person-minutes (e.g. two people for 10 minutes).

II. Detailed biological census: Level II requires help of someone familiar with organisms and/or following the guidelines given by Cooper and Poulson (1968). Level II is warranted only if the level I reconnaissance suggests great biological interest or if there is some biological interest along with value of other resources (i.e. the cave is a fair example of a number of kinds of resources). A detailed base map with a copy for annotation of each kind of resource should be prepared.

A. Habitat characteristics: (as in I but in addition...)

1. Kinds of food input

a. Total area and relative proportions of each food input type.

b. Number, relative sizes, and distances between each type of input, whether biotic or abiotic

2. Microclimatic and flood rigor: estimates of variability and predictability by location, by by season, and by year

3. Sizes of substrate patches and extents of pure patches vs mixed patches of food and substrate near entrances.

B. Organism censuses as in Level I but in addition...

1. Large species: count every individual and note the size (length in mm) of each and note any obvious reproductive activity (e.g. crayfish carrying eggs or bats with young). Again note the problems with hibernating or nursery colonies of bats as detailed in Tuttle's paper elsewhere in these proceedings. A good census method for streams is to keep track of organism positions by pace number and key obvious features in the cave to pace numbers for later inclusion on a map survey.

2. Small species: In streams use a random number table to decide where you will do an intensive search (about 10 searches for 1000 m of stream passage). Key these search locales to the pace survey of the preceding step and describe the area searched. For terrestrial areas, search about 10 randomly placed 30 cm x 30 cm areas for every 100 m^2 of each food type and for each 1000 m^2 of area with no obvious food. For rock surveys do about 100 rocks and keep track of the number (including zeroes) of animals beneath each rock and the rock sizes (roughly).

3. Identify each species seen by detailed notes and collect one specimen of each (in 70% ethyl alcohol as the best single preservative) so that an expert can tell if it is worth collecting others for scientific determinations (not to be done with bats, fish, or salamanders). Use your field note description and locality data for the penciled label (on good paper) in the specimen bottle or vial used for each species.

III. Cross disciplinary team at regional or national level assesses results of levels I and II and makes recommendations for preservation, and management (i.e. kinds of use, chances for protection, amount of visitation tolerable, etc.

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The Butler Cave – Sinking Creek System and the Butler Cave Conservation Society

John W. Hess *

ABSTRACT

The Sinking Creek Cave System in Burnsville Cove, Virginia, is an important integrated karst drainage system made up of 5 individual caves. The largest of these, Butler Cave, is owned and managed by the Butler Cave Conservation Society, Inc. The Society promotes the exploration and scientific study of caves in Burnsville Cove. The roots of the Society go back to January 1954 when nine Nittany Grotto cavers made their first trip to Breathing Cave. Butler Cave was discovered in May 1958 by Ike Nicholson. The owner at the time, Carl Butler, asked from the beginning that he not be bothered by cavers seeking permission to enter the cave and that Ike Nicholson control cave access. The entrance was locked, with limited success, with various crude gates over the next 10 years. Breaking-in and vandalism increased during this time. The idea of a society of concerned cavers to tackle these problems was formulated in 1968. By November 1968 a group had formed that was to become the BCCS. A lease to the Butler property containing the cave entrance was secured and construction of a new adequate gate was begun. On 15 April 1970 the BCCS was incorporated under the laws of Virginia. The Society bought the Butler property and cave entrance in January 1975. Entrance policy has evolved over the last 8 years until the present workable policy was developed. The BCCS now designates three or four weekends each year during which Butler Cave is open to responsible and capable persons who may enter the cave for society objectives. At other times of the year all cave trips, no matter what the objectives, must include a BCCS member.

INTRODUCTION

The Butler Cave Sinking Creek System in Burnsville Cove, Virginia, is an important integrated karst drainage network made up of five individual caves: Boundless, Butler, Breathing, Better Forgotten, and Aqua Caves. The largest of these, Butler Cave, is owned and managed by the Butler Cave Conservation Society, Inc. (BCCS), a nonstock, nonprofit organization incorporated in the Commonwealth of Virginia. The Society promotes the conservation, preservation, and scientific study of caves.

This paper is a brief description of the Butler Cave Sinking Creek System and the BCCS. Information for this paper is drawn from many sources. Chief among them are Davis and Hess (in press), Hess and Davis (1969) and Wefer and Nicholson (in press) which describe the hydrogeology, geology and history, respectively, of the Burnsville Cove area.

A two-year systematic exploration carried out in the Burnsville Cove area of Virginia resulted in the discovery of Butler Cave on 30 May 1958. Discovery was made when Ike Nicholson dug open a small hole from which a strong draft of air flowed. The existence of a large cave system had been suspected for many years. Hydrogeological evidence in Burnsville Cove pointed to its existence. Drainage in Burnsville Cove is subsurface; all of the drainage from both Chestnut Ridge and Jack Mountain disappears underground. Along the Bullpasture River 5.6 kilometers (km) to the northeast of the cove there are four major resurgences; Emory Spring, Cathedral Spring, Lockridge Aqua Spring and Cave, and Blue Spring.

The Butler Cave Sinking Creek System, with 24 km of known passage is the largest cave in Virginia and one of the major caves in the United States. Also part of the integrated karst drainage network are Breathing Cave with 6.7 km of passage, Boundless, Better Forgotten, and Aqua Caves. In addition many smaller caves which may or may not connect to the Sinking Creek System lie within Burnsville Cove.

HYDROGEOLOGY

The entrance to Butler Cave is under a sandy ledge on the west side of a large sink 1.28 km north of Burnsville and 2.40 km southwest of the entrance to Breathing Cave. The entrance is a chance opening on the western limb of the Burnsville Syncline and is located where erosion has cut into the end of a joint passage.

The Sinking Creek System is developed along a plunging syncline in the Tonoloway and Keyser Limestones of Silurian Age in the Ridge and Valley Province of the Appalachian Mountains. Development of the cave is stratigraphically and structurally controlled, following the structure of the enclosing limestones and sandstones.

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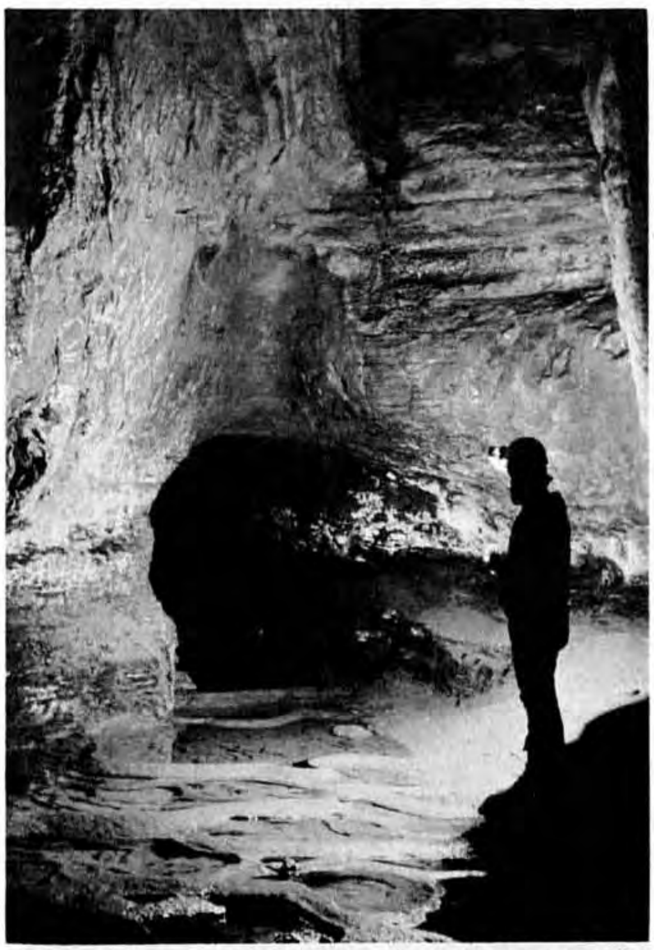
Passage directions are joint controlled with the limits of vertical solution being controlled by tongues of the Clifton Forge Sandstone. The cave system consists of a main trunk channel following the plunging Burnsville Synclinal axis and a network of side caves developed on both flanks of the syncline which connect at or above grade.

The main trunk channel is 10 to 20 meters (m) high and wide and may be characterized as having long expanses of flat unsupported ceilings and level boulder and cobble floors. Upstream the trunk channel terminates by breaking up into several smaller stream canyon passages which are terminated in fill. Downstream the trunk channel narrows into parallel stream canyons developed on two levels. These passages terminate as the ceiling plunges toward the cobble filled floors. The streams continue through siphons and finally resurge in Lockridge Aqua Spring 4.0 km away.

There are several side caves on both sides of the trunk channel which drain down dip into it. These side caves consist of a network of passages developed on the regional dip, the regional strike, and a joint set striking N60°E. These side caves can best be described as a maze of parallel passages on multiple levels with minor folding playing a small role in their development. The passages range from narrow stream canyons to large secondary trunk channels.

The hydrology of the Burnsville Cove area is complex with both surface and subsurface drainage. The subsurface drainage has many inputs and four resurgences. The resurgence for the Sinking Creek System is Lockridge Aqua Cave and Spring located along the Bullpasture River 4.0 km from the end of the humanly passable passage. Lockridge Aqua is within the Keyser Limestone and has an average flow of 210 liters per second.



Rimstone Pools developed along a typical joint controlled passage in Butler Cave. *Photo courtesy of Butler Cave Conservation Society*

Stalactites along the main downstream passage in Butler Cave. *Photo courtesy of Butler Cave Conservation Society.*

HISTORY

The roots of the BCCS can be traced back to January 1954 when nine cavers left State College, Pennsylvania on the first Nittany Grotto trip to Burnsville Cove, Virginia. They spent six hours in Breathing Cave on that trip. During the 1950s efforts were concentrated on mapping Breathing Cave and helping George Deike with his master's thesis (Deike, 1960) on the cave and Burnsville Cove.

Mill Run, a prominent tributary to the Bullpasture River, was the next focus point for the cavers. The upper course carries an intermittent stream, but approximately 0.4 km upstream from the Bullpasture River a large spring rises. In July 1956, the spring (Aqua Spring) was dove revealing a large cave containing dry passage (Aqua Cave) beyond the submerged spring orifice. Later trips explored and mapped the cave. Siphons found at the end of the cave were dove in hopes of finding more cave. The divers, however, turned around 120 m into the submerged passage and 25 m down. The 1.5 m high by 4 m wide passage was still going down.

The third cave to become part of the Sinking Creek System was Boundless Cave, found and explored during the period of 1957-1958. It was a low, tight and just plain miserable cave which did not lead to the hoped-for large cave underlying Burnsville Cove.

On 30 May 1958 the entrance to Butler Cave was found by Ike Nicholson after a two-year search. He pulled some loose rocks out of a small hole under a sandstone ledge high on the side of a large sinkhole and crawled into a small room with 10 m pit in its floor. Later trips revealed that the object of the two year search had at last been found. Work on exploration and mapping has continued since that time with contributions from many groups and individuals. These efforts continue today under the direction of the BCCS.

Better Forgotten, the fifth cave in the system, was discovered in November 1959. It was reported at that time to end in a dead bottomed 30 m pit. The cave was forgotten until the summer of 1967 when it was entered because it lies on a straight line between the end of Butler Cave and Aqua Spring. On this trip, the 30 m pit was not found and the cave was forgotten again until fall of 1969. A party of cavers on that trip found the 30 m pit. Several more trips followed which pushed the cave beyond the pit. A major stream passage was found, but it turned out not to contain water from Butler Cave. Better Forgotten Cave is itself a separate tributary to Aqua Spring.

THE BUTLER CAVE CONSERVATION SOCIETY

The general caving public has been primarily interested in visiting only two caves of the Sinking Creek Cave System, Butler and Breathing. Aqua, Boundless and Better Forgotten have always been open, but except perhaps for Aqua, little interest has been shown in visiting them. Breathing Cave also remains open to all cavers.

The discovery of Butler Cave, in May 1958, was kept something of a secret from the start. Only people directly involved were to know about it, but word spread rapidly. The almost inevitable problems of vandalism and injuries were discussed with the owner, Carl Butler, who decided that entry should be restricted. He did not want to be bothered by cavers seeking permission to enter and so gave the responsibility of control to Ike Nicholson. The entrance was locked with a chain which was fastened to rods set in concrete at each side of the entrance. During the early days there were three keys, which were not loaned or mailed and only work parties were allowed to enter.

During the middle 1960s the work restriction was relaxed somewhat and people were allowed entry for purely sport caving. This was tried because of the large number of requests and the frequent breaking of the locks. Groups were sometimes loaned a key so that the key-holder would not have to go to the entrance to unlock the cave. Instantly there arose the problem of key copying, necessitating still more new locks. In addition it had been discovered that exceptionally small cavers could squeeze under the chain. Parties which had legally entered the cave often left the key in the entrance room so as not to risk losing it farther in the cave. Whole groups were found to have gained entry when a small caver went under the chain, found the key, and opened the cave from within. Even though these groups almost always took both the key and the lock with them, the potential for disaster existed since legal entrants sometimes carried new locks with different keys!

In an effort to curb the practice of going under the chain, a two inch diameter pipe was placed over it preventing it from being bent upwards. After an unauthorized party was discovered in the cave, three large spikes were welded to the pipe so that not even a baby could have gotten under. The response to this was a return to the more direct method of breaking off the locks. The problem actually reached the point that it became necessary for every authorized party to carry a replacement padlock. There was naturally considerable apprehension on the part of the person responsible for controlling access, lest some unauthorized entrant be injured or locked in.

The idea of a society of concerned cavers to tackle these problems, rather than one private individual, was formulated in July 1968 by Nevin C. and Thelma Davis and Ike and Connie Nicholson. The idea was enthusiastically supported by a number of cavers approached as prospective members. On 2 November a group met in Nevin's cabin on the Bullpasture River in Burnsville Cove to form what became the Butler Cave Conservation Society. A lease was secured for the property containing the single entrance to Butler Cave. News of the formation of the Society was released to the caving public in the November 1968 issue of the NSS News. Plans were quickly begun to replace the padlock system of entrance control and to incorporate the BCCS. On 15 April 1970 the BCCS with 17 members was incorporated under the laws of Virginia. In May 1970 BCCS members presented a slide show and talked with the people of the Burnsville Cove area, the aims being to make the Society known to them and to establish better relations with the land owners.

Work on the installation of the new gate began on 29 May 1970. It was finished by the end of the first week in June 1970 when the door was hung. Butler Cave has been successfully locked since.

Meetings were held on 13 and 14 June 1970 during which bylaws were written, debated, and adopted by the Society. The incorporation of the BCCS and its policy of entry were brought to the attention of the caving public in an article in the NSS News by Stellmack (1971). The cave has been kept locked in order to control traffic. The original policy of the BCCS was to allow entry to qualified cavers for any reasonable purpose, including sport caving. Keys were not mailed to individuals or groups, rather the cave had to be unlocked for them by a BCCS member. A relase form was

Crystals lining the cave floor in Butler Cave. ***Photo courtesy of Butler Cave Conservation Society.***

Articles of Incorporation
of
The Butler Cave Conservation Society, Incorporated

We, the undersigned incorporators, hereby associate to form a non-stock corporation under the provisions of Chapter 2 of Title 13.1 of the Code of Virginia (1950), as amended, and to that end set forth the following:

(1) The name of the corporation is The Butler Cave Conservation Society, Incorporated.

(2) The purpose or purposes for which the corporation is organized are as follows: to promote the conservation, preservation and study of caves within and without the Commonwealth of Virginia; to promote and support such other conservation, scientific and educational programs as the board of directors shall from time to time decide to engage in; to acquire and dispose of real and personal property, by lease, ownership or other means, in furtherance of the above purposes; to do any and all things necessary or convenient in the furtherance of any or all of the said purposes, and specifically including all corporate powers conferred on the corporation by virtue of the laws of the Commonwealth of Virginia, all of which purposes are to be carried out for conservation, scientific and educational purposes and not for profit, and without issuance of stock. The corporation is to be a non-stock, non-profit corporation.

Under no circumstances shall any dividend be paid to, nor any part of the net earnings of the corporation be distributed to any member, director or officer of the corporation, though the board of directors may authorize the corporation to pay compensation in a reasonable amount to members, directors and/or officers for services rendered and expenses incurred in conducting the affairs of the corporation. Under no circumstances shall any of the assets of the corporation be distributed, in liquidation or otherwise, to any member, director or officer of the corporation.

No substantial part of the activities of the corporation shall be the carrying on propaganda or otherwise attempting to influence legislation, and the corporation shall not participate in, or intervene in any political campaign on behalf of any candidate for public office.

Notwithstanding any other provision of these articles, this corporation is to be operated solely for conservation, educational and scientific purposes and the corporation shall not have power to engage in any activity, or use its funds in any manner which would deny it exemption from taxation under the provisions of Section 501 (c) (3) of the Internal Revenue Code.

(3) The corporation is to have one class of membership, consisting of all persons who have applied for membership and been accepted as members by a majority vote of the board of directors and who are in good standing in accordance with the by-laws and other regulations of the corporation. Each member in good standing shall be entitled to one vote, and shall be permitted to vote for directors of the corporation at the time of the annual meeting of members, and to vote on such other business as may come before regular or special meetings of members. Voting shall not be cumulative.

(4) The directors of the corporation are to be elected by the membership, one vote per member in good standing, at the annual membership meeting. The president, vice-president, secretary and treasurer shall be ex-officio directors.

(5) Upon the dissolution of the corporation or the winding up of its affairs the assets of the corporation shall be distributed exclusively to conservation, scientific, and/or educational organizations with purposes similar to those of this corporation which would then qualify under the provisions of Section 501 (c) (3) of the Internal Revenue Code and its regulations as they now exist or as they may hereafter be amended.

(6) The post office address of the initial registered office of the corporation is Post Office Box 28, Staunton, Virginia, 24401, and the street address of the initial registered office is Law Offices, Mason M. Sproul, Room 203, Professional Building, Frederick Street and Central Avenue, Staunton, Virginia, and the initial registered office is located in the City of Staunton, Virginia. The name of the initial registered agent is Mason M Sproul, who is a resident of Virginia and is a member of the Virginia State Bar, and whose business office is the same as the registered office of the corporation.

(7) The number of directors constituting the initial board of directors is seventeen (17), and the names and addresses of the persons who are to serve as the initial directors are: (*Deleted by editor*)

(8) The duration of the corporation is to be perpetual.

WITNESS THE FOLLOWING SIGNATURES AND SEAL THIS 25th DAY OF MARCH, 1970.

(*Deleted by Editor*)

required to be signed by each individual entering the cave for the first time, and each group was required to submit a short field trip report. Exploration and mapping activities continued, and the participation of nonmembers was both encouraged and appreciated. At the time of the 1971 annual membership meeting it was clear that this policy would have to be changed. On work trips, which were usually lead by BCCS members, vandalism was both avoided and actively discouraged. Areas visited mainly by sport cavers, on the other hand, had begun, in only one year, to suffer trash, carbide dumps and trail markers. Regrettably the liberal policy of entry had to be changed. The BCCS now designates three or four weekends each year during which Butler Cave is open to responsible and capable persons who may enter the cave for society objectives. These range from exploration, mapping, lead pushing, and digging to orientation and photography. At other times of the year all cave trips, no matter what the objectives, must include a BCCS member.

In 1974 the opportunity to buy the Butler property (65 acre homestead) including the cave entrance presented itself. After much discussion within the Society as to how to handle the purchase, the BCCS purchased the Butler Cave and farm in January 1975. Money for the purchase came almost entirely from donations by the BCCS membership.

On 11 February 1971 a meeting of the directors of the BCCS was held at which a proposal for a comprehensive study of the Burnsville Cove area was discussed. The study was to be as complete in depth as practicable, the results to appear in the NSS Bulletin. This effort is due to be published during 1977 in the NSS Bulletin and will include seven articles covering geology, geomorphology, hydrogeology, hydrochemistry, history, mineralogy and biology.

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Report on Workshop II: Cave Inventory, Valuation and Assessment

John W. Hess, Recording Secretary *

The main questions that this workshop concentrated on were what is a cave inventory, what should it include and who is qualified to do it? Also discussed were cave protection laws, what is a high value cave, how do you take into account the long-term protection prospects of a cave, managing cavers, under what conditions should a cave be inventoried; and should all caves be inventoried?

Workshop II could be best summarized in the following manner. Cave inventories should be approached in three steps. First, since there are not enough *experts*, a preliminary inventory and assessment could be done by properly trained *lay* cavers. Cave inventory should include at least biology, geology, archeology, and history. The diversity of the cave setting, environment and life must be an important consideration. The inventoried cave should then be evaluated and placed in some sort of a ranking system.

Second, the long term protection and management possibilities should be considered. Questions to be considered are: What has been the past-use history? Is access controllable? How does the cave relate to the surface environment and can the surface be managed in a manner to protect the cave?

Finally, armed with the above information, bring in a team of experts in the fields of importance to assess and evaluate those caves determined to be possible candidates for protection or special management alternatives.

The federal National Landmarks and National Registry of Historic Sites programs include many caves across the country. The Programs provide a degree of evaluation and assessment with limited protection. Many states are now trying similar programs which will include significant cave or karst resources. Many states also now have cave protection laws which will aid in the protection and management of high value caves.

In carrying out cave inventories and assessing which caves should be protected, the biology aspects at the present time are the easiest to handle because of the rare and endangered species lists. Caves containing species on these lists must be managed in order to protect the species. It was felt by the Workshop that a list similar to the rare and endangered species list should be made up for other cave features. Lists for cave minerals, significant geologic features and significant hydrology aspects are needed.

The federal agencies responsible for cave management felt that they need guidelines regarding what is cave science and who is a cave scientist. In the past, much damage has been done to caves in the name of science. The past treatment of bat populations offers the best example of damage that can be done by scientists. One does not need a degree to be a scientist; what is needed is an understanding of the problem and of the fragile cave environment. It does not take an "expert" with a degree to inventory caves. Information, not samples, should be collected when doing initial inventories. In order to facilitate cave inventories a manual for the lay caver on how and what to inventory is badly needed.

In judging what is a high value or significant cave, it is important to consider if the cave can be managed at all. A very important concern is what has been the past-use history of the cave. A cave that has received heavy recreational use over the years will be difficult to manage and limit access to, no matter how valuable it might prove to be. A regional and systems approach to assessing cave areas is also important. The cave's relationship to the surface environment may determine if it can be managed successfully. Surface activities may affect water supply to the cave or introduce pollutants to the cave system which could cause damage to the cave environment. In that case, just managing the cave itself is not sufficient to protect it and its contents.

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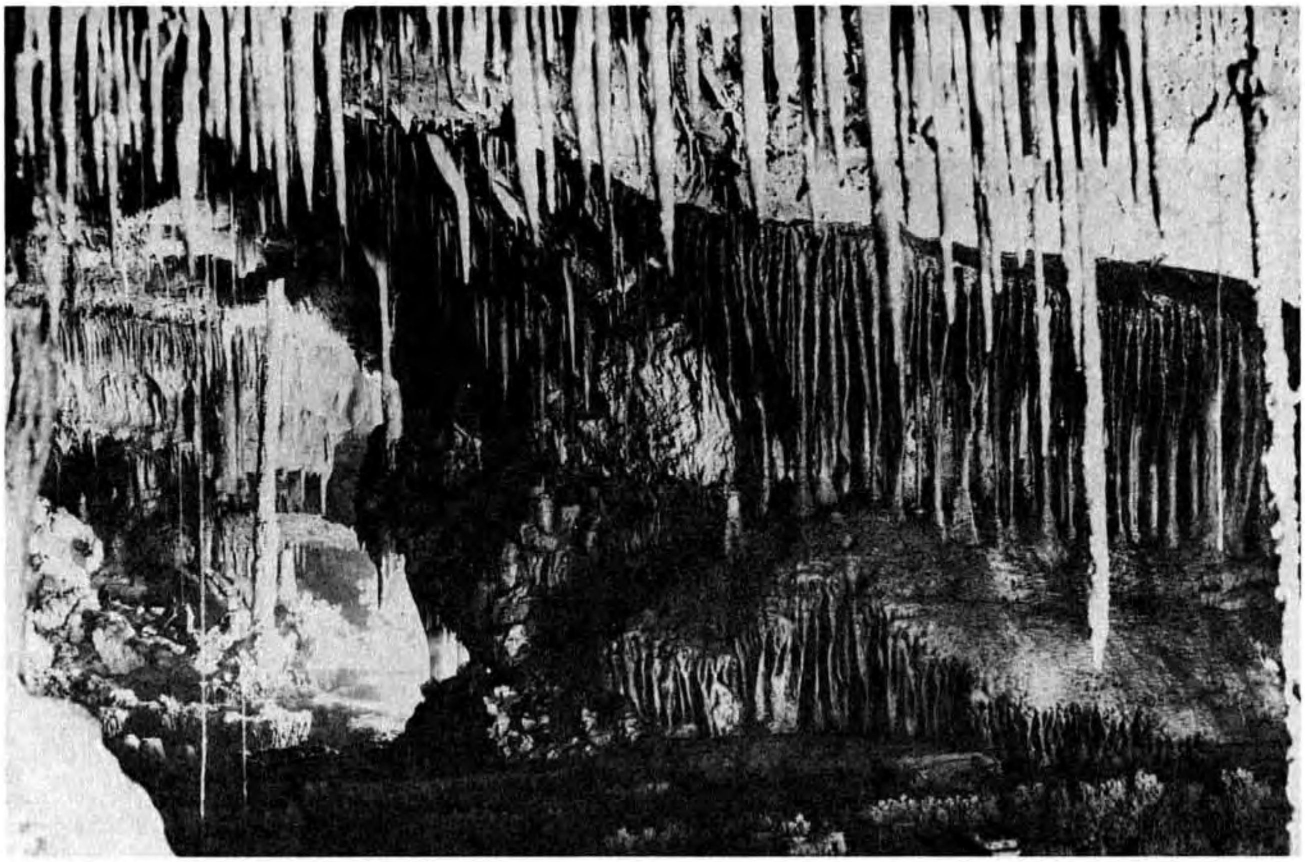
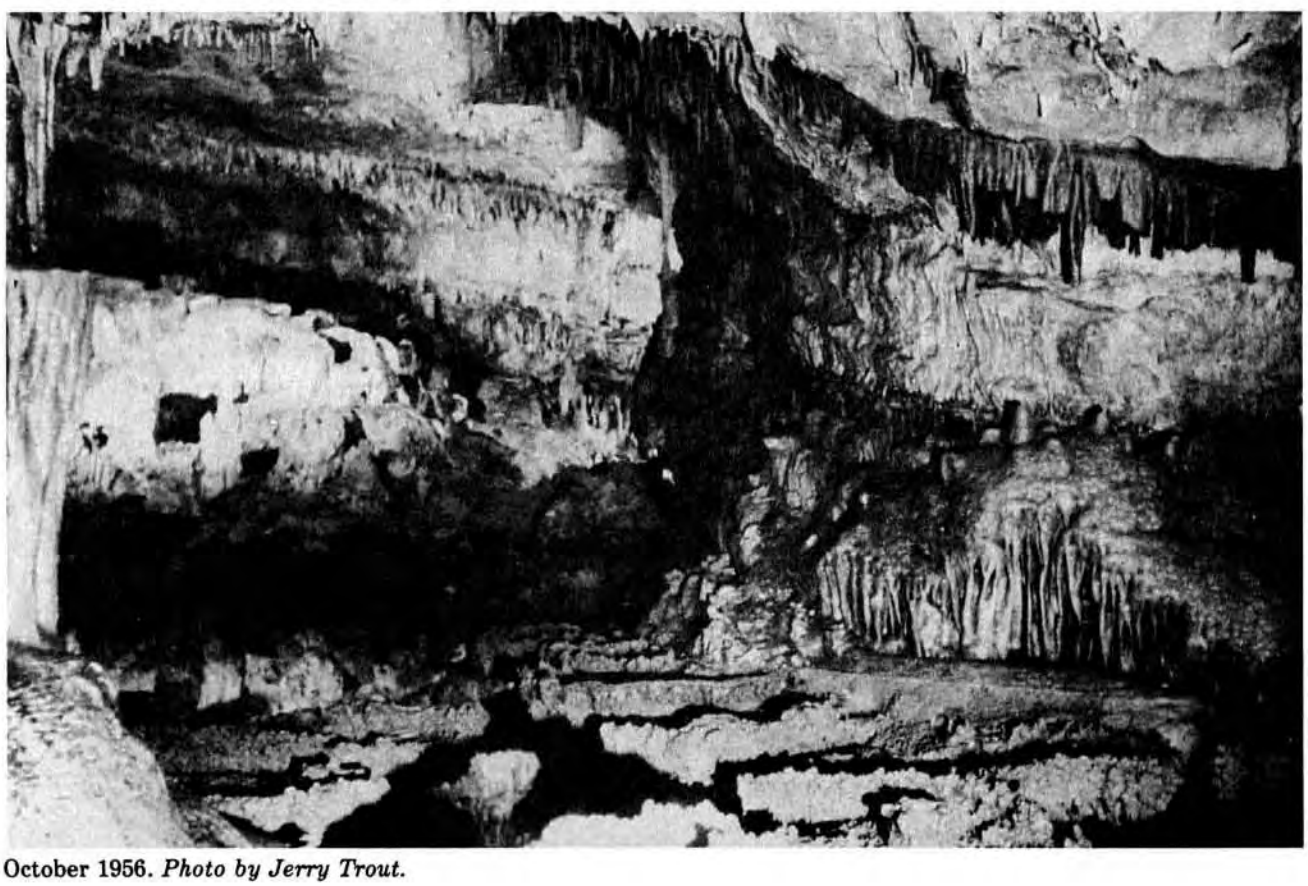
Subsurface Management as a Component of Land Management

Two photographs of Endless Cave, New Mexico, taken from the same location.



March 25, 1934. *Photo by Robert Nymeyer.*



October 1956. *Photo by Jerry Trout.*

Subsurface Management as a Component of General Land Management in Soluble Rock Landscapes

Paul E. Petty *

In preparing for this paper, several persons were contacted who have had experience with surface/subsurface management situations. Through their experience, the author came up with several examples of actions made on the surface that adversely affected subsurface values.

This paper discusses these examples from the standpoint of what was done or what should have been done to prevent or correct the damage being done to cave resources. Most of the situations discussed in this paper fell into the following categories of damage causing factors:

1. Human Abuse
2. Construction
3. Drying
4. Flooding
5. Pollution

HUMAN ABUSE

Man, being a surface creature by nature, has had a tendency to exploit cave resources as something to use up or get rid of rather than as a valuable nonrenewable resource. Vandalism, abuse through overuse, hobby collecting and commercial collecting have all taken a devastating toll.

Endless Cave, a Bureau of Land Management (BLM) cave near Carlsbad, New Mexico, was exploited for years for its priceless formations. A set of railroad tracks were laid down to help with the gutting of the cave. The back of the cave is in fair shape, but the front has been reduced to a hollow tube. The cave is now gated, but this protection measure came too late to save most of the cave.

Gates have been widely used as a protective device. The BLM has protected 20 caves in this manner in southeastern New Mexico. Permits are required in order to keep track of numbers, control party size, and to give the managing agency a chance to talk with the visitors in advance of their trip.

Another example of damage through improper use occurred at Ape Cave, a Forest Service cave located in the Pacific northwest. Ape Cave was pristine until a logging road was constructed to harvest timber near the cave. The road made the cave accessible and it was quickly vandalized. Had the road not been necessary, the damage might have been minimized.

This brings up another strong protection action—limiting access. Caves located in official wilderness areas or areas managed as roadless or primitive areas are generally not heavily damaged. This form of protection, however, is not without its drawbacks. Caves in these areas are definitely harder to reach since several miles of walking may be required just to get there. A permit is usually required to enter both the wilderness and the cave. The permit may not be readily available and it may be necessary for visitors to schedule trips at inconvenient times.

Much of the Guadalupe Mountains in southeastern New Mexico is being considered for wilderness designation. Several caves will be included if all the wilderness study areas on USFS and NPS lands are established by Congress. Now that the BLM has an Organic Act, we may also have cave areas which may eventually be included under wilderness designations.

Limiting access, gating, wilderness designations and other restrictions may be regarded as a cop-out by some cavers. They may contend that these measures are done because they are the easiest way of achieving what management wants, not what the users want. The truth is that all protection measures are costly and all of them are unpopular with some people. We cannot ignore the problem, however, and must do whatever is necessary to save the resources. Guided tours in noncommercial caves are definitely not a universally popular way of controlling damage. However, few can argue against its effectiveness.

Cottonwood Cave, a beautiful cave on the Lincoln National Forest in southeastern New Mexico was receiving considerable damage through vandalism and heavy use of over 1000 visitors per year. Fortunately, the Forest Service could see the trend of increased vandalism and decided to take strong measures to stop it. A section of the cave was gated and use was limited to trips supervised by a USFS employee. This strong action certainly would not be suitable for all caves, but it is an approach worth considering if someone is available to do the guiding. It has the advantage of controlling misuse without shutting down the cave completely. The obvious disadvantage is that people cannot come and go at will and the cave must be visited on specific days and at specific times.

A permit system, close use supervision, interpretation, protective hardware such as gates, and good public relations all help to keep human abuse at a minimum. All of this is to no avail, however, if management does not give caves the same resource protection and management priority as they give the range, minerals, forestry, recreation, and other programs.

CONSTRUCTION

Ironically, some of the worst environmental impacts on caves result from actions we take to benefit the cave program. The development of unnatural entrances or construction of gates are good examples. The first gate we constructed on BLM lands in New Mexico was a bar gate on Dry Cave. The bars were spaced far enough apart, we thought, to allow bats to pass, but the bat populations disappeared. A couple of vertical bars were cut to make an

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opening five inches by ten inches. That apparently did the trick because the bats have reinhabited the cave.

In the late 1960s a Job Corps Center was established in Mammoth Cave National Park to carry out a backlog of conservation projects in the park. To obtain water for the camp, a spring was capped and the water diverted for domestic uses. The result was a drying trend in the underlying cave and a threat of upset to the ecological balance.

A sewage lagoon was also constructed to serve the center. Problems associated with this first lagoon led to sewage effluent overflowing and entering the cave system beneath. This problem was temporarily corrected by the addition of two more lagoons and piping the chlorinated effluent to the Green River.*

The Park Service is fully aware of the sewage, water and other environmental effects associated with the center. Their master plan recommends discontinuation of the Job Corps Center as soon as possible.**

CAVE DRYING

The drying out of cave formations and water bodies in caves is a major problem throughout the country. Though serious in consequence, cave drying is usually a reversible situation. The opening of a second entrance has been the primary cause of drying. The second opening creates a draft situation resulting from differences in wind velocity, temperature, and atmospheric pressure. Carlsbad Caverns suffered from this problem until air tight doors were installed to eliminate air loss up the elevator shaft.

A private cave in Virginia was found to be drying out because of a more unique reason. Growth of a dense hardwood forest in the area that drained into the cave was transpiring available moisture before it could reach the cave. The situation was remedied by selectively cutting the hardwood forest, thus reducing density to what it was before the cave started to dry up.

We have observed a drying trend in Fort Stanton Cave that has continued over 20 years or more. Probably, this drying trend cannot be attributed to any one cause. It is typical of the problems we all frequently face because the causes are not always obvious. Bonita Lake was constructed 20 years ago about 10 miles upstream to provide water for the railroad. Later, the water rights were sold to Alamogordo, a community in the region. Water which once made its way down the valley had been diverted.

Another contributing factor may have been heavy grazing in the cave vicinity. It is highly possible that the loss in ground cover reduced the amount of water retention and rate of percolation directly into the cave system. Other variables may have been the weather itself—wet and dry years have caused a noticeable change in cave water levels.

The point is that problems and solutions can be over simplified. It might take years to isolate the many factors contributing to a cave problem such as at Fort Stanton Cave. Very frequently problems can be tied to surface management in some manner.

* Mammoth Cave—Final Environmental Statement

** Mammoth Cave—Final Master Plan, April 1976.

FLOODING

Flooding and the erosive effects of rapidly moving water are very damaging and may be more difficult to control than drying. A fluctuating water table, increased hydraulic head caused by reservoir construction, and damage to watershed cover as a result of development, over-grazing, etc., all contribute to an increased amount of unnatural erosion within caves.

Some New Mexico caves are highly susceptible to flooding because much of our rainfall is associated with summer downpours. A major dry wash empties into Millrace Cave, near Carrizozo. Heavy summer storms often cause flash floods in the wash and completely flood the cave.

There are also a large number of gypsum caves in southeastern New Mexico that are very hazardous in this respect. Certainly, any management action taken on the surface that increases the rate of runoff would add to the flooding associated with these caves. Overgrazing, heavy logging, juniper chaining and other vegetation manipulation projects are all possible contributors to increased runoff and cave flooding.

Flooding through reservoir construction is very familiar to many of you. Probably most of you can think of at least one good cave that has been lost in this process. A good example of this kind of surface/subsurface relationship is the Corps of Engineers Meramec Basin Project in Missouri. If the dam project is completed as planned, over 100 caves will be inundated by Meramec Lake. Some of these caves are among the most impressive caves in the country (*NSS NEWS*, Vol. 30, page 154). Onondaga, Cathedral and Dixon are among the better known caves that would be partially submerged.

In addition to being devastating to caves, reservoirs in cave country frequently are ineffective in holding water. Increased water pressure and more rapid rate of fall turn small passages into effective drainage tubes.

Flooding by reservoir may be difficult to combat because it requires a great deal of political pressure and public involvement, but it has been done and the caving communities have proven themselves to be an effective lobbying body.

POLLUTION

Pollution of the cave environment through careless disposal of garbage, sewage, petroleum products, and other waste products is a well known serious problem. All too often the source of the problem is some distance from the cave and correction may require major changes in county or state laws and community cooperation.

A case in point is Mystery River Cave near Horse Cave, Kentucky. This was a rather unusual cave in that a river flowed through it enabling power boat tours several thousand yards in length. The flow of the river was great enough to run a power generating plant for the city. The stream was very rich in biota and included a substantial population of blind fish. The local creamery did what was common several years ago; they dumped their waste into the river not thinking or caring about the consequences. Normally sunlight dependent bacteria would work on waste of this nature, but in a cave environment, these bacteria were ineffective.

Over a period of months, waste material accumulated and became very obvious to the cave visitors. Foul water and strong odor finally increased to the point that the cave had to be closed. Before the situation was corrected, the city lost its water source.

The cave has still not completely cleaned itself and many forms of biota (including the blind fish) may never be present in the same numbers.

The *out of sight-out of mind* philosophy is so basically wrong that it is hard to believe that it still goes on. It does, however, and there will always be a crisis for cave environmentalists to tackle. Sources of pollution are not always miles away. All too frequently they are just a few feet directly above the cave on the surface.

One of the worst disasters in recent caving history happened as a result of nearby surface pollution.* This incident, which killed three men, happened in 1966 at Howard's Waterfall Cave near Trenton, Georgia. Howard's Waterfall is an "easy" cave frequently visited by novice cavers and interested local outing clubs. A group of boyscouts and others happened to be in the cave when a carbide lamp ignited gasoline fumes causing an explosion. Everyone made it out alright except for one caver who was overcome by carbon monoxide poisoning resulting from incomplete combustion. A rescue team entered the cave and two more persons were overcome by the poisonous fumes.

Later, investigations disclosed that a gas station located above the cave had leaked about 200 gallons of gasoline through a damaged underground storage tank. The fumes had accumulated in the cave passage and gas floated on a body of water to the point where ignition was possible. Of course, the problem was corrected when discovered, but too late to save the lives of three cavers. Pollution such as this is difficult to detect until it reaches disasterous proportions.

You would think that gasoline pollution accidents would be rare, but apparently leaky gas tanks are everywhere. In 1969, a pool of gasoline floating on ground water in a karst area of Pennsylvania was found which covered over 200 acres. Over 200,000 gallons of gasoline were recovered from 40 wells. The only possible source was nearby gasoline storage tanks.*

In another example of gasoline pollution involved a private water well, which intersected a cave at a depth of 80 feet. One day the well exploded throwing debris for hundreds of feet. A crater 25 feet by 12 feet was the end result. A recent 200 gallon gas leak from a farm storage tank was the most likely source of the energy.**

About all a caver can do is be alert to possible pollution sources and do everything he can to see that they are eliminated before disasters occur.

SUMMARY

In summary, I would like to point out a problem common to most government agencies. We all have a fairly rapid turnover of managers, people responsible for what happens to the land. As a consequence, our memory tends to be short lived. Those of you who are familiar with a cave or caving area should be alert to this problem and help jog our memory from time to time. All agencies are required to hold public meetings to discuss how proposed projects affect the environment. This should give you an opportunity to let your desires be known and point out problems which may not be obvious to management.

There is no right way to do a wrong thing. If a mistake is made, it is probably very difficult to correct the situation. The best approach is to plan the project thoroughly, bring in available experts on hydrology, cave locations, etc., and make the right decision the first time around.

* Georgia Underground, March-April 1966

** Gasoline Pollution of Karst—*NSS NEWS*, May 1973

Federal Land Use Planning and Cave Management

Chuck Godfrey *

All management actions undertaken by the Bureau of Land Management (BLM) are supposed to come about as the result of comprehensive land use planning. Unfortunately, the Bureau has been all too frequently placed in the position of having to plan for and manage the lands it administers in a "reactive" manner rather than in a well planned "preactive" manner. The reasons for this "reactive" role are complex and varied, but are not critical to this discussion. One point that is critical to this discussion is that when a resource management agency plans and manages "reactively," it is frequently a result of resource loss or damage having already occurred. We are, to a degree, in this selfsame position in the realm of cave management. I say "to a degree" because so far I am not aware of any major crisis which has served to jolt us into action in the development of an active cave management program. Although caves located on BLM administered lands have, in the past, suffered vandalism and other forms of resource deterioration.

The second point, which is germane to this discussion, is that planning and management formulated in *reaction* to adverse occurrences tend to be aimed at curing symptoms and are not based on thoughtfully developed goals or objectives. Because of this, such planning and management cannot provide the long-term stability which is essential when dealing with what is basically a nonrenewable resource.

We in BLM still have an opportunity to plan for the management of caves in a "preactive" fashion. I feel we are doing just that and this is how we hope to accomplish this task:

Last year, Darrell Lewis, from our Washington office, told the first National Cave Management Symposium that Congress was considering an "Organic Act" for BLM. Earlier this month, both houses of congress passed just such an act and presented it to the President for his signature.

On October 22, 1976, President Ford signed the Act. This does not mean that we have an instant solution for cave management problems within BLM. What it does mean is that we have been provided with a few new management tools to use in developing solutions to our problems. Two of the more significant of these tools are the provision for law enforcement authority within BLM and the provision for review and reissuance of segregative classifications on national resource lands. These provisions will allow us to develop and enforce protective regulations for cave resources and to retain caves and their surface environments in federal ownership. In addition, we have the opportunity to ensure the protection of cave resources from the adverse effects of inappropriate surface management activities. None of this is automatic, but must follow from the development and implementation of comprehensive land use plans. How do cave resources fit into our land use planning system?

The first, and most critical element of a comprehensive land use plan is an adequate resource inventory. In reference to caves this inventory must include, in addition to the locations of cave entrances, an analysis of the scientific and recreational values within the caves, an interior map of the caves tied to a surveyed surface location, and an analysis of the hydrological and geological relationships of the caves to the surface. With this inventory in hand, the planner must then catalog all possible opportunities to develop, finance, preserve, and protect the scientific and recreational values of these caves. At this point, the planner must begin to apply the constraints of policy and economic and technical feasibility to the previously identified opportunities. Those opportunities which meet these constraints are then compared with similarly constrained opportunities for resource management which have been developed for other activities within the planning area. On national resource lands these other activities include mineral and energy development, domestic livestock grazing, protection and enhancement of wildlife habitat, protection and development of watersheds, surface recreation uses, and the provision of lands for urban, industrial and right-of-way uses. In the course of this comparison, it is inevitable that conflicts will arise. It is up to the land manager to resolve these conflicts and arrive at management decisions. In the resolution of these conflicts, the manager must consider the relative values of the resources involved, the public demand for these resources, and the environmental consequences of the management actions entailed. To do this, the manager must have at his disposal the best possible information relative to these elements. It is the responsibility of the planners to provide this information to the manager.

How will we do this for caves? In New Mexico, we are currently operating under a cooperative agreement between the National Park Service, U. S. Forest Service, and the Bureau of Land Management. The purpose of this cooperative agreement is to open the channels for a coordinated cave management program on federal lands within the state. As a result of this agreement, we have already settled on a procedure for inventorying and classifying cave resources within the state. In addition, we are in the process of finalizing a single cave entry permit system for joint use by the Forest Service and BLM. This entry permit system will allow both agencies to issue permits for caves managed by either agency. One benefit of this system will be to provide a single set of permit application procedures to the user public. Another benefit will be the compilation of a regional inventory of the caves which will allow us to better determine which caves require the highest degree of protection and which caves can tolerate more intensive visitor use.

The inventory and classification procedures we are using

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were initially developed by Jerry Trout of the U. S. Forest Service, in Carlsbad. We reviewed Trout's procedures at an inter-agency meeting and made some minor modifications so that they would be acceptable to the three agencies involved. The inventory procedures include documentation of both surface and subsurface features, including hazards, related to the cave in question. The classification procedures are based both on a rating of the inherent hazards associated with a particular cave as well as a rating of the contents of the cave. The content rating takes into consideration the biological, ecological, mineralogical, and hydrological aspects of the cave as well as the size and fragility of formations. All of this information is coded in a computer compatible format and is maintained in a master cave file. In addition, all of this information is made available to the managers that that they will have the best possible background on which to base management decisions in the karst areas.

We feel that through this system we are making considerable progress in providing the protection needed for our cave resources while at the same time providing an opportunity for a quality recreational caving experience.

REFERENCES

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Human Impact on Caves

Robert R. Stitt *

One requirement of the National Environmental Policy Act of 1969 (NEPA)** is that all federal agencies must prepare an Environmental Impact Statement (EIS) before carrying out any action which may have a significant effect upon the human environment. In the 7 years since the passage of NEPA, court actions initiated by environmentalists have gradually forced the various agencies to become more diligent in satisfying the requirements of the law, but the art of preparing adequate EISs is still far from perfect. For example, several EISs prepared by the National Park Service and the United States Forest Service for projects which would have impacts upon cave resources failed to adequately discuss those impacts.†

One of the main reasons these EISs appear inadequate from the speleological viewpoint is that there is no organized body of information available on environmental impact on cave systems.

This paper reports on an ongoing research project aimed at identifying and determining the effects of human activities which have an impact on caves and cave systems. No claim is made that the list of effects presented is complete, and the author welcomes suggestions for improvement.

ENVIRONMENTAL PROBLEMS IN KARST REGIONS‡

The evaluation of environmental impact in karst regions presents some special problems which may not be present in nonkarst areas. The key factor in these problems is the high secondary permeability caused by fractures and caverns in the carbonate rocks comprising karst. Difficulties in determining underground drainage patterns lead to uncertainties in precisely predicting the effects of any action.

Karst areas are often characterized by a scarcity of and poor predictability of groundwater supplies. Water tends to flow rapidly in unevenly distributed discrete channels (caves, joints, and fractures) with little or no reservoir capacity. Since the water flows easily through the channels in the rock, karst areas often have few surface streams. This may produce competition between spring and well users for the scarce water supply. Because the underground environment is often used for both waste disposal and water supplies, water quality problems result from the interactions. The presence of subsurface cavities may result in ground instability. Collapse may occur as a result of groundwater recharge, excessive pumping of water from wells, or heavy structural loading. Reservoirs may leak or even fail catastrophically. Finally, karst terrains are a difficult waste disposal environment. Natural filtering and adsorption are frequently ineffective, and contaminants may move rapidly and for long distances through the groundwater system.

Trash left in a heavily visited Arizona cave. *Photo by Bob Buecher.*

How does this relate to the consideration of environmental impact in caves? First, caves are part of karst systems. Secondly, karst environmental problems are often related to the presence of caves. Finally, human attempts to deal with karstic environmental problems may have significant effects upon cave environments, and, conversely, actions taken inside the cave may affect the surface environment.

This is not to imply that the surface and subsurface cannot be separated for management purposes. An example is wilderness use in the subsurface and non-wilderness use on the surface, where separate management is not only desirable but necessary. However, because of the interactions and close relationships, management of either the surface or the subsurface must take into account the rest of the system.

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* Subcommittee on Environmental Impact, NSS Conservation Committee, 1417 9th Ave. West, Seattle, WA 98119.

** National Environmental Policy Act of 1969, Public Law 91-190, 83 Stat. 852.

† Stitt, R.R., "Environmental Impact in the Guadalupe Escarpment, New Mexico and Texas," unpublished manuscript, 1974.

‡ For a more detailed discussion of this topic, from which this section is condensed, see H.E. Le Grand, "Hydrological and Ecological Problems of Karst Regions," *Science*, Vol. 179. No. 4076, (2 March 1973), pp. 859-864.

THE NEPA MODEL APPLIED TO CAVES

Valid environmental analyses require definition of the parameters to be considered and establishment of a methodology to model the interactions of the actual situation on paper. One such model has been set forth by NEPA, which together with the Guidelines issued by the Council on Environmental Quality (CEQ Guidelines) requires that an EIS contain the following information:

1. Project Description
2. Environmental setting without the project.
3. Probable effect of the proposed action on the environment.
4. Any probable adverse environmental effects which cannot be avoided.
5. Alternatives to the proposed action (together with a description of the environmental impacts of each alternative).
6. The relationship between local short-term uses of man's environment and the maintenance and enhancement of longterm productivity.
7. Any irreversible and irretrievable commitments of resources which would be involved in the proposed action should it be implemented.*

Most of these headings are self-explanatory, but some require a more detailed discussion, especially in regard to cave resources.

Short-term Uses Versus Long-term Productivity

Many EISs have minimized this discussion, failing to recognize that caves and cave features are primarily nonrenewable resources. Thus any short-term use of caves tends to decrease the long-term productivity.

Irreversibility and Irretrievability

Because of the nonrenewable nature of the cave environment, most actions taken are irreversible and irretrievable. A broken formation is gone forever. A blasted passageway will not refill with limestone—it becomes an open passageway. The exceptions are few—some management devices (a gate, for example) may be removable, and removal of fill and sediment might be remedied by natural flooding action, although the new fill would certainly retain a different history of flooding than the original.

Forest Service EIS guidelines suggest that the irreversible and irretrievable discussion should "identify the extent to which the action curtails the range of potential beneficial uses of the environment."** This implies that the terms irreversible and irretrievable apply primarily to nonrenewable resources; thus they are certainly applicable to caves, which represent a resource almost entirely nonrenewable. In common usage the difference between the words irreversible and irretrievable is not clear. Sometimes they are used interchangeably, or together as if they constituted an indivisable phrase. For the discussion of speleological phenomena, however, it is useful to consider them as separate terms to aid in understanding the environmental impacts.

An irreversible commitment defines the end point of the process. If the process cannot be reversed, then it is irreversible. An irretrievable commitment uses up the resources concerned, so that they are no longer available for a particular use. Any action within a cave contains both reversible and irreversible components and makes both retrievable and irretrievable commitments of resources.

The installation of a cave gate, for example, is primarily a reversible action; gates can often be removed with little direct damage to the cave. But if it were to cause the extinction of a bat population in the cave, it would have an irretrievable effect.

OTHER PROBLEM AREAS

The NEPA model was designed by a legislative process early in the development of the art of environmental analysis. The stimulus of NEPA has led to advances in our ability to analyze the environmental affects of human actions, but the model is most useful as a communications device. It stimulate. research and provides a forum to involve the public in the decision making process.

The NEPA model is a discrete, noncontinuous process, applied to each project as it occurs, and usually addresses only the effects of one particular action. In the case of karst areas, this is a particular shortcoming, since environmental problems in karst areas are ongoing, continuous, and widespread, and may have synergic effects which cannot be predicted by a time- and space-isolated analysis. As usually applied to caves and karst the NEPA model has often been only a problem identifying process, with no guarantee that problem identification will lead to problem solution. Because there is no provision for on-going public review of the planning process, much information which may not be obvious to the planners may neither become part of an EIS, nor be used in planning! This is especially true in the case of caves, since much information on caves is held by a relatively small body of knowledgeable people who may not be known to land planners and environmental analysts.

Unfortunately, use of the NEPA model has produced an adversary relationship between some cave users (who tend to be vocal environmentalists) and agencies (who often ignore caves and their values in determining resource management plans). Thus, agencies tend to pay little attention to caves during the preparation of draft EISs, but are subjected to extreme criticism for not taking cave values into account. The critics have themselves been at fault for this situation because they have not developed a good working relationship with the agencies and have not provided unsolicited information. Because planners seem to be closemouthed until their plans are well along (probably for fear of criticism) the public feels left out of the planning process.

A BETTER MODEL FOR CAVES AND KARST

A more effective model for environmental analysis, especially in karst areas, should enable evaluation of the effects of actions and prediction of the probable outcome; be continuously updated by inputs from all persons concerned, including managers, planners, and users; include mechanisms for implementation of mitigation and suggested

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* 38 Federal Register 20549 (August 1, 1973).

** U.S. Department of Agriculture, Forest Service, "Environmental Statements—Guidelines for Preparation," 39 Federal Register 38244-38264, (October 30, 1974).

changes; and make it possible to break the system down into discrete and small parts to aid problem solving, as well as to provide a broad overview to aid understanding.

The tables included in this paper will help identify environmental impacts on caves and determine which impacts are indeed likely to be significant in a given situation. Research is needed to further develop criteria necessary for effective analysis, and to specify how the criteria can best be utilized.

HUMAN ACTIONS WITH IMPACT ON CAVES

Tables 1 and 2 list various impacts upon caves and identify the nature of their effects. These tables are useful to start a thought process in motion, but must not be used as a substitute for careful analysis and thorough investigation. To aid that goal, a detailed bibliography of the main works dealing with environmental impacts on caves is included at the end of this paper. A failing of many EISs has been that the preparers consulted one work, assumed that it was complete, and relied on it as an authoritative, universal source, when it was not.

The tables deal only with direct or primary effects. Indirect or secondary effects were not considered. Because indirect effects may often be more significant than direct effects, they must not be neglected. The Forest Service Guidelines distinguish between the two types of effects by pointing out that "project inputs generally cause primary impacts and project outputs generally cause secondary impacts."* For example, consider the opening of wilderness-type cave tours. The direct impacts would be those on the cave environment itself: wear and tear, vandalism, littering, etc. Indirect effects would include an increase in the regional economic base (more jobs); an increase in the number of people exposed to the wild caving experience, resulting in an increase in public appreciation of caving and a potential increase in the number of cavers; and the vandalism occuring in other caves because of the increase in the number of cavers, or the attraction of cavers to the area.

It is also useful to differentiate between the short- and long-term effects of an action. Impacts occuring during construction and installation are usually of limited extent and duration. But the long-term effects on the ecosystem, the hydrologic system, the cave climate, or the aesthetic or scientific values can be long lasting, widespread, and of great significance. Both short- and long-term impacts must be considered in a meaningful EIS.

In a sense, it is true that all activities in caves have an adverse effect on the cave environment. Environmental analysis identifies the various effects to enable management of the cave environment to minimize the adverse and maximize the beneficial effects, providing for the longest possible human use with minimum degradation of the cave environment.

EFFECTS OF VISITORS IN NUMBERS

Impacts on the cave environment produced by a single human visitor are presented in Table 2. Usually caves are visited by small groups of variable size at random intervals over a period of time. Precise data summarizing the total effects of visitation are not available, but it is possible to generally discuss the magnitude of impacts as a function of party size. The effects of a number of visitors may combine in three ways. Cumulative effects are those which add together and directly increase the magnitude of the impact. Synergic effects occur when the result of the combinations of two effects is greater than would be expected if they occurred independently. Independent effects have no influence on the impact produced by other actions. The combined effect of a number of cave visits will have cumulative, synergic, and independent components. Depending on the nature of the activity, these will occur in varying proportions. The impact of a party of ten is more than twice that of a party of five.

* 38 Federal Register 20549 (August 1, 1973).

TABLE 1. Externally Derived Impacts on Caves[1]

Action[2]	Source[3]	Part of Cave Affected[4]	Nature of Effects	Incidence: Time	Incidence: Space	Incidence: Degree	Irreversible?[6]	Irretrievable?[6]	Mitigation[7]
1. Pollution									
A. Water									
1. Municipal Wastes	city sewage systems, or lack thereof	P	water polluted, odor & methane gas, affects ecosystem	L	LR	V	N	M	proper tertiary sewage treatment
2. Industrial Wastes	factories, thru streams or direct seepage	PA	water polluted, odor & methane gas, affects ecosystem, and heavy metals	SL	LR	V	N	M	proper tertiary sewage treatment
3. Septic Tanks	homes, some small industrial	P	water polluted, odor & methane gas, high B.O.D., nutrients; affects ecosystem	M	LW	H	N	M	total retention system, or connect to tertiary treatment system
4. Agricultural Runoff	farm and pasture lands	P	siltation, pollution, odor & methane gas, upsets ecosystem, destroys lifeforms, increases nutrients, decreased D.O.	L	LW	M	Y	Y	careful land use
5. Urban Runoff	city streets, parking lots	P	petroleum poisoning, siltation, upsets ecosystem	L	L	H	N	Y	proper tertiary sewage treatment of runoff
6. Sinkhole Dumps Other Dumps Landfills	improper waste disposal	P	water polluted, remote and local	V	LR	M	N	Y	stop dumping, clean sinkhole, locate landfills on physically suitable site
7. Gasoline Spills Toxic Compound Spills Pipeline Leakage	gasoline & chemical storage facilities, filling stations, parking lots, streets, highways & pipelines	A	explosion hazard, destroys ecosystem, may damage formations	S	L	H	Y	Y	stop leaks, locate facilities elsewhere, use proper cleanup techniques
8. Sinking Polluted Streams	surface pollution sources	P	siltation, pollution, upsets ecosystem	V	L	M	N	Y	clean up sources of pollution
9. Thermal Pollution	power plants	PA	changes cave climate, upsets ecosystem	S	L	M	N	M	cooling towers, dilution
10. Stream Tracing	technical	P	no known adverse effects when properly used; high beneficial impact when used for identifying sources of pollution	S	L	L	N	N	use biodegradable, non-poisonous dyes
B. Air									
1. Surface Air Pollutants	cars, factories	A	increases solution rate of carbonate rocks	L	U	L	N	Y	clean up air and stop pollution
2. Smoke	fires on surface, cigarettes	V	air particulate matter, deposition of film on surface of formations	S	L	L	N	Y	no fires in or near cave, no smoking
3. Inflammable Gases	gas pipelines, vegetation decay	V	potential explosion hazard	L	L	L	N	N	repair leaks, use electric lights near pipelines
4. Airborne Herbicides and Pesticides	crop spraying	A	destroys ecosystem	L	L	M	N	Y	don't spray in karst areas, use biodegradable materials
2. Hydrological Modifications									
A. Surface Construction									
1. Roads	population proximity	A	diverts water sources, changes water source locations, dries out cave, destroys ecosystems, pollution (see above)	L	L	M	N	Y	reroute road, or restore original drainage patterns
2. Parking Lots	population proximity	A	stops infiltration, dries out rocks, destroys ecosystem, pollution, may cause rock falls	L	L	H	N	Y	relocate parking lot, re-inject properly treated runoff wastes
3. Buildings	population proximity	A	stops infiltration, dries out cave, interupts water flow	L	L	L	N	Y	move to or build at different location, re-inject treated runoff
4. Stripping Topsoils	land leveling, recreational development	A	flooding, siltation	S	L	H	Y	Y	alternate development location, restore drainage patterns, retain and filter runoff
5. Agricultural	farming operations	A	siltation, infiltration changes, flooding, pollution	L	LW	H	N	Y	good soil conservation practices

TABLE 1 (continued)

Action[2]	Source[3]	Part of Cave Affected[4]	Nature of Effects	Incidence: Time	Space	Degree	Irreversible?[6]	Irretrievable?[6]	Mitigation[7]
B. Water Projects									
1. Dams	need for flood control, power, and recreation	A	water level raised, inundation, increased recreational use	L	L	H	N	M	build dam elsewhere, don't build dam, manage nearby caves
2. Channelization	drainage, flood control	A	water level lowered, flooding decreased, may affect ecosystem	L	L	H	Y	Y	restore drainage patterns
3. Pumping of Groundwater	farming and ranching	P	water level lowered, possible collapse, increased siltation	D	LW	H	N	M	stop pumping, re-inject water
4. Capping Springs	need for water	A	reduction in water flow, upsets ecosystem	D	L	M	N	M	remove caps, re-inject water
C. Deforestation	conversion from forest to other land use	A	siltation, flooding, increased stream turbidity, changes ecosystem	L	LM	H	Y	Y	careful, conservation-wise logging practices
D. Overgrazing	ranching and farming	A	siltation, flooding, pollution	L	L	M	N	Y	careful grazing practices, reduced herd size
E. Siltation	deforestation, construction, agriculture, erosion, overgrazing	AP	fills passages with soil/sand/clay/ cobbles/wood, changes ecosystem	L	LW	H	N	Y	carry on activities elsewhere, and carefully
F. Flooding from External Causes	excess precipitation, poor farming practice, dams breaking, rapid snow melt	A	siltation, erosion, log jams and blocked passages, danger to visitors, provides nutrients for ecosystem	S	L	H	N	M	flood control projects, wise soil conservation practices
3. Vibration and Noise									
A. Blasting	construction, mining	FV	formation breakage, rock fall, may disturb bats	S	L	H	Y	Y	limit size and location of charges
B. Vehicles	highways, railways	FS	formation breakage, rock fall, collapse, increased breakdown	L	L	H	N	Y	locate transportation corridors away from cave areas
4. Limestone Mining and Quarrying	need for limestone	A	formation breakage, removal of cave	L	L	H	Y	Y	mine elsewhere, and selectively

Notes

[1]The arrangement of these tables is adapted from that presented by Max Nicholson in The Environmental Revolution, Annex 2, "Chart of Human Impacts on the Countryside." Nicholson was the first outside the caving community to delineate the effects of sport caving as entry 22.28 in his chart. The entry may be summarized as follows: The activity of caving affects limestone areas, and results in these effects: Responsible cavers take initiative for subterranean conservation but damage is caused by unskilled excavators and specimen collectors to scientific interest of caves; litter; pollution of subterranean waterways. Camping outside cave entrace also leads to litter and damage to vegetation. The incidence is all year around, of local extent (spatially) and of limited degree. (Note that this is based on the British experience.)

[2]Classified by physical nature, overlapping in some cases.

[3]Or the apparent motivation for the activity, as appropriate.

[4]Abbreviations used: P--phreatic (below the water table, i.e., the aquatic portion of the cave environment); V--vadose (above the water table); A--all of the cave; E--ecosystem; S--sediments and fill; F--formations and the surface of the rock.

[5]These are rough approximations only and incidence may be affected by local conditions. Abbreviations: Time: L--long term; M--medium term; S--short term; D--duration of activity. Space: L--local; R--remote; U--universal; W--widespread. Degree: L--low; M--medium; H--high; V--varies.

[6]Abbreviations: Y--yes; N--no; M--maybe.

[7]Actions which may mitigate or prevent some of the adverse effects. These are not recommendations, but merely a listing of some possibilities.

TABLE 2. Internally Derived Impacts on Caves[1]

Action[2]	Source[3]	Part of Cave Affected[4]	Nature of Effects	Incidence[5] Time	Space	Degree	Irreversible?[6]	Irretrievable?[6]	Mitigation[7]
1. The Lone Human Visitor									
A. Physical Disturbance									
1. Footprints	walking	SFE	destroys wilderness character, breaks formations, soils formations	S	W	H	N	M	careful walking, marked and builtup trails
2. Scratches	walking	SF	permanent or temporary surface scratches	S	L	L	Y	Y	careful movement, use of trails
3. Climbing Aids	cavers, pitons, bolts, ladders, stairs, etc.	SF	visual degradation, rock destruction, debris	L	L	M	N	Y	use clean climbing techniques
4. Digging and Dynamiting	urge to explore, ease of passage	A	destroys rock and fill, changes air and water circulation, breaks formations, upsets ecosystem, opens new areas to vandalism	L	L	M	N	Y	don't do it, or use care, or smaller charges
B. External Materials Brought into the Cave									
1. Air Circulation	passage of caver, artificial entrance	V	outside air brought in by body, changes in circulation, changes temperature, affects ecosystem (bats)	S	L	L	N	N	use airlocks or double doors, maintain natural circulation patterns
2. Micro-fauna & -flora	air circulation, clothing, equipment, light	AE	mold and algae growth	L	W	M	M	M	herbi- & pesticides, steam, remove nutrients, turn off lights
3. Faunal Transport	clothes, gear	E	introduction of exotic species, upsets ecosystem	SL	W	L	M	M	use care when entering to assure no hitchikers
4. Lighting Systems									
a. Carbide Lights									
1. Ions & Odor	flame, leaks	V	odor, explosion potential, CO/CO_2	S	LW	M	N	N	use electric lights
2. Spent Carbide	reaction product	AE	aesthetic, pollutes water, destroys ecosystem, odor	M	L	H	N	Y	remove from cave and dispose of properly
b. Portable Electric									
1. Spent Batteries	careless disposal	A	Aesthetic, destroys ecosystem, pollutes water	L	L	L	N	M	remove from cave, use chemical light or carbide light
2. Heat	lamp beam	E	can affect bats and other life	S	L	L	N	M	don't shine on biota
c. Chemical Lights	chemicals	A	pollute water, destroys ecosystem	L	L	M	M	M	remove from cave, don't break
d. Gasoline Lanterns	gasoline	A	beryllium poisoning from mantle, gasoline pollution, broken glass, mantle litter	L	L	M	M	M	fill outside cave, care in use, remove wastes from cave
e. Candles, Open Flame Lamps (same as Carbide Lights, above)									
f. Permanent Electric	desire to see	A	heat balance upset, aesthetic, breakage, algae growth and other ecosystem upset, localized drying	L	W	H	N	Y	use care in installation, hide lamps and wires, use fluorescent lamps
5. Litter	carelessnes	A	aesthetic, upsets ecosystem	L	L	M	N	M	trash receptacles, signs, education
a. Paper	snack foods, candy bars, Polaroid cameras	A	aesthetic, upsets ecosystem	M	L	M	N	M	remove from cave
b. Plastic Bags	food wrapping, litter bags	A	aesthetic (very slow biodegradation)	L	L	M	N	N	remove from cave
c. Wood	flooding, ladders, climbing aids	A	aesthetic, upsets ecosystem	M	L	M	N	N	remove what is carried in, leave what is naturally present

TABLE 2. (Continued)

Action[2]	Source[3]	Part of Cave Affected[4]	Nature of Effects	Incidence[5] Time	Space	Degree	Irreversible?[6]	Irretrievable?[6]	Mitigation[7]
d. Metallic Objects	ladders, walkways, railings, flashbulbs, batteries	A affe	visual, construction effects, may affect ecosystem, corrosion effects	L	L	L	N	N	corrosion resistant materials, aesthetically pleasing design
e. Human Waste	human visitors	A	odor, increased nutients, upsets ecosystem	S	L	L	Y	Y	abstain in cave, use plastic bottle, restrooms
1. Urine	human visitors	A	odor, increased nutrients, upsets ecosystem	S	L	L	Y	Y	abstain in cave, use plastic bottle
2. Fecal Matter	human	A	odor, upsets ecosystem, degrades slowly	M	L	M	N	N	abstain in cave, use plastic bag, restrooms
6. Grafitti	spray paint, lamp smoke, scratches, human visitors, young males most likely	FS	aesthetic, visual	L	L	M	N	M	remove with water jet, acid, or wire brush; legal approaches
C. Materials Removed from the Cave									
1. Mud	flooding, human visitors	S	upsets sediment record, dirties rest of cave	S	LW	L	Y	Y	avoid mudbanks, fill, etc.
2. Excavations	curiosity	SF	fills passages, covers leads, upsets sediment record, aesthetic, upsets ecosystems, outside environment despoiled if removed from cave	L	L	M	M	Y	use care in working, remove material from cave and dispose of properly
3. Scientific Samples	scientific curiosity	A	responsible collection is limited and selective, has little effect. irresponsible destroys rare specimens, decreases scientific value, upsets ecosystem	L	L	L	Y	Y	perform in situ studies, encourage selective, professional, and minimal collecting
4. Speleothems	collecting instinct	AF	aesthetic/visual, scientific value reduced	L	LW	M	Y	Y	make collection illegal, educate the public, control access

For Notes, see Table 1.

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Management of Ellison's Cave, Site of the United States' Deepest Cave Pit: Pigeon Mountain, Georgia

Barry F. Beck,* Stanley Ayer, Allen Padget **

ABSTRACT

Ellison's Cave is located on Pigeon Mountain in northwestern Georgia. Pigeon and Lookout Mountains are the eastern front of the Cumberland Plateau in Georgia. Geologically the mountain is a syncline with a resistant cap of Pennsylvania sandstone underlain by Mississippian limestones which are exposed on its steep slopes. Several deep solution pits have formed near the edge of the sandstone cap and numerous caves have been found.

In 1974, through the Heritage Trust Program, the Department of Natural Resources began purchasing the northeastern portion of Pigeon Mountain which is nearly in a wilderness state with only a few four-wheel drive roads. Purchase is nearly complete. The Game and Fish Division will manage this land primarily for Wildlife management and hunting, with secondary uses for backpacking and caving.

Although all the caves will require a management policy, Ellison's cave, 18.7 kilometers long with the two deepest cave pits in the U.S. (Fantastic Pit—176 m; Incredible Dome Pit—132 m) presents a special problem. Although the upper sections of the cave were known to local residents for years, only in 1968 and 1969 were the two deep pits discovered. These are now frequently visited by serious cavers from all over North America. The Department of Natural Resources wishes to preserve access for competent, conscientious visitors, but necessarily needs to restrict access by inexperienced persons for safety reasons.

The D.N.R. is presently proposing to gate the cave and administer a permit system for access. Gates would be within the cave in small, solid passages, but before the pits are reached. One steep-sided sinkhole entrance may be partially fenced to prevent unwary hunters from falling in. Permit applications would state experience and be processed by the Regional Game and Fish Office. Final on-site equipment inspection by the resident ranger would be required and a letter of introduction from one of the local chapters of the National Speleological Society would be requested. However, the question of legal liability still requires researching before the initiation of this plan.

INTRODUCTION AND GEOLOGIC SETTING

Pigeon Mountain is located in Walker County in northwestern Georgia (figure 1). It is a linear, flat-topped plateau rising approximately 360 m above the adjacent valleys and is approximately 22 km long, trending SW-NE. At its southwestern end it merges with the upland surface of Lookout Mountain, which is a longer, but otherwise similar, ridge extending from Tennessee, through Georgia, and into Alabama. Lookout and Pigeon Mountains are the easternmost expressions of the Cumberland Plateau in Georgia.

The basic geology of both mountains is similar. The flat upland cap is underlain by resistant Pennsylvanian sandstones and shales: from youngest to oldest, the Rockcastle Sandstone; the Vandever Shale; the Bonair Sandstone; the Whitwell Shale; and the Lookout Sandstone (Croft, 1959). Their combined thickness on Pigeon Mountain ranges from 60 to 100 m. These formations form a steep-sided scarp around the rim of Lookout and Pigeon Mountains. Below the cap, forming a somewhat gentler slope, are a sequence of Mississippian limestones and associated rocks: from youngest to oldest, the Pennington Shale; the Bangor Limestone; the Monteagle Formation; the St. Louis Limestone; and the Ft. Payne Chert (R. Schreiber, 1976, personal communication). Both mountains are synclinal as one can see from the slight upturning of the caprock scarps. The rocks are also fractured and faulted; the faults trend E-W. Some of these faults were first detected underground, in caves, and later confirmed on high altitude air photographs.

Water running off, or through, the sandstone cap sinks into joints, fractures, or faults in the limestone, seeping

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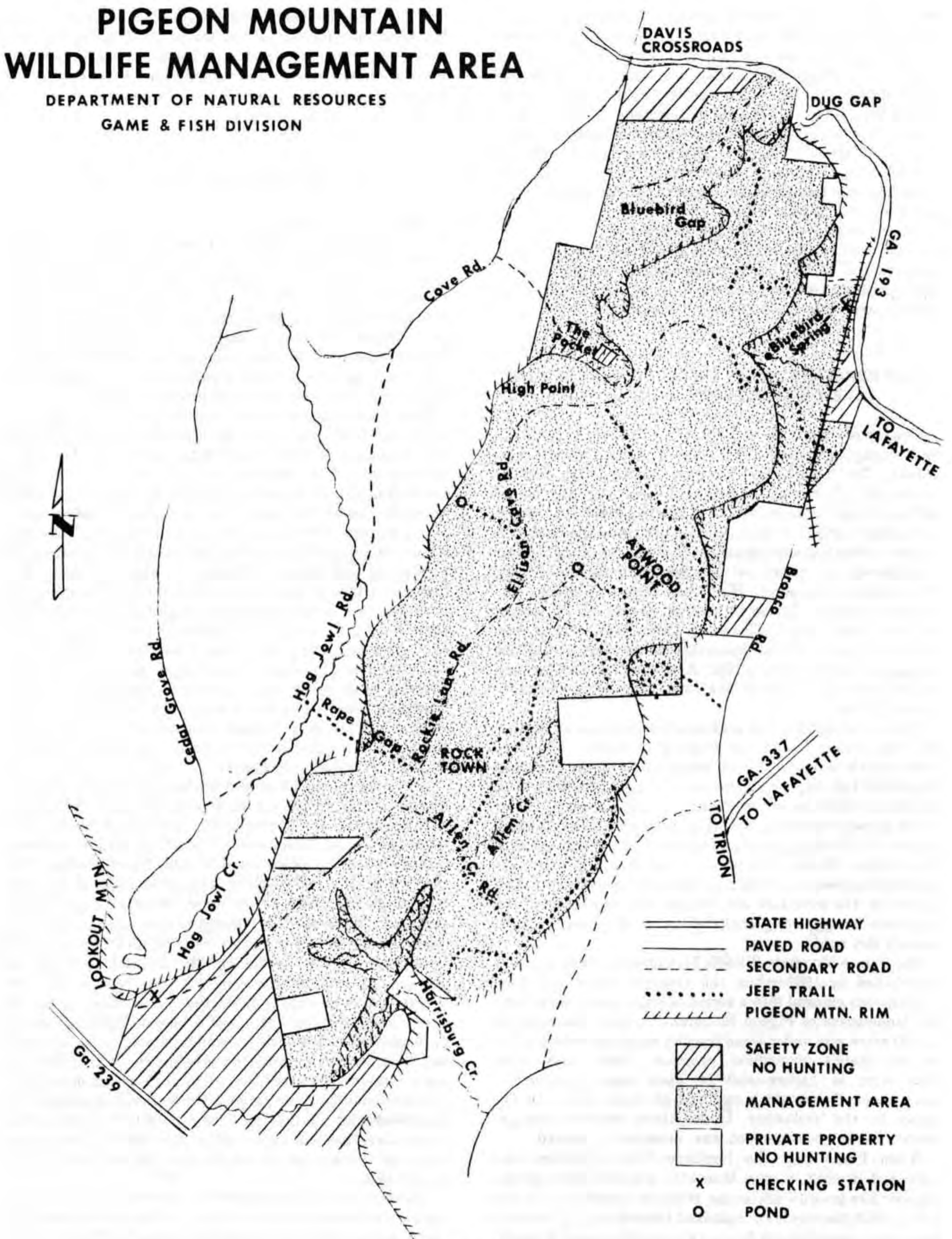
PIGEON MOUNTAIN
WILDLIFE MANAGEMENT AREA
DEPARTMENT OF NATURAL RESOURCES
GAME & FISH DIVISION
DAVIS CROSSROADS
DUG GAP
Bluebird Gap
GA. 193
Cove Rd.
The Pocket
Bluebird Spring
High Point
TO LAFAYETTE
N
Ellison Cave Rd.
ATWOOD POINT
Hog Jowl Rd.
Cedar Grove Rd.
Rape Gap
Rockie Lane Rd.
ROCK TOWN
GA. 337
TO LAFAYETTE
TO TRION
Allen Cr.
Allen Cr. Rd.
LOOKOUT MTN.
Hog Jowl Cr.
Harrisburg Cr.
Ga. 239
STATE HIGHWAY
PAVED ROAD
SECONDARY ROAD
JEEP TRAIL
PIGEON MTN. RIM
SAFETY ZONE NO HUNTING
MANAGEMENT AREA
PRIVATE PROPERTY NO HUNTING
X CHECKING STATION
O POND

Figure 1

downward and then moving laterally to emerge at springs along the base of the mountain. This water has absorbed carbon dioxide from the air and from decaying plant materials in the soil and becomes a weak acid. This acid reacts with the limestone and dissolves it, thus enlarging the cracks into pits or caves. The limestone flanks of both Pigeon and Lookout Mountains contain numerous caves, pits, and sinkholes. The groundwater flowing through the limestone is a very important part of the local economy providing both municipal and industrial water supplies from springs and high-yield wells.

The climate in northwestern Georgia is mild with an average January temperature of 5°C and an average July temperature of 25°C. Average annual precipitation is approximately 1400 mm and snow occurs occasionally. The growing season is about 190 days (Cressler, 1964).

THE PIGEON MOUNTAIN WILDLIFE MANAGEMENT AREA: DESCRIPTION AND HISTORY

The top of Pigeon Mountain is heavily forested, primarily with young hardwoods with isolated pockets of pure pine stands. The slopes are covered mostly with mature hardwoods. There are substantial areas in pasture or cultivation on the lower flanks of the mountain. The slopes and upland surface of the mountain are presently devoid of human habitation, although in the past the mountain top was a scattered community of families such as the Styles, McCutchens, McCartys, Hedricks, Rapes, Ellisons, and Averys. Indeed, Ellison's Cave is named for a former resident, A.P. "Gus" Ellison, a Civil War veteran who resided on top of Pigeon Mountain for at least twenty-one years prior to his death in 1912. Authentic dates as far back as 1856 are still visible in the cave today (Dogwood City Grotto, 1974).

Due to the instability of several of the bedrock formations and the steep slope of the mountain's flanks, it is very difficult to build and maintain roads up the sides of Pigeon Mountain. For this reason the top of Pigeon Mountain is all but inaccessible from the inhabited valley floor, a factor which greatly enhances the wilderness aura of the upland cap as well as aiding greatly in the control and management of activities thereon. At present, the few dirt roads are generally accessible only to four-wheel drive vehicles and all routes up the mountain are chained off. The base of the mountain is completely encircled by good paved or hard, smooth dirt roads.

The Pigeon Mountain Wildlife Management Area was first established in 1969 when the Georgia Game and Fish Commission entered into a series of lease agreements with the landowners of Pigeon Mountain. A total maximum of 17,500 acres was under lease from 38 separate owners prior to the State's acquisition program. The leases were short-term in nature and in each case contained a cancellation clause which required no more than a 60-day notice by the landowner. Under these tenuous arrangements, habitat management was, necessarily, limited.

When Phase I of the Heritage Trust Program was approved in 1973, Pigeon Mountain was identified as the number five priority site in the state for acquisition. In the fall of 1973 the newly-reorganized Department of Natural Resources began buying land on Pigeon Mountain. To date, 7300 acres of land have been purchased.

Since its beginnings in 1969, the Pigeon Mountain Wildlife Management Area has served the public hunting interests well. During 1974, for example, 1554 deer hunters used the area. In addition, the area remained open for hunting during the entire local seasons for all small game species.

THE CAVES ON PIGEON MOUNTAIN

There are numerous caves within the boundaries of the Pigeon Mountain Wildlife Management Area. However, three of these are more extensive and, for various other reasons, more important than the others. These are Ellison's Cave, Pettyjohn's Cave, and Anderson Spring Cave. Ellison's Cave is the most extensive cave in Georgia (18.7 km) and contains the two deepest underground pits in the United States. It is also scientifically valuable. Ellison's Cave and its management problems will be discussed in detail after the other caves are briefly described.

Pettyjohn's Cave is located near the base of the mountain on the eastern slope. It has considerable horizontal extent but, because it is near base level, it has very little vertical development. The entrance is a 1½ m x 1½ m semi-horizontal passage dropping roughly 3 m in a series of easily negotiated steps. This leads into the major room of the cave, approximately 180 m long, 10 m wide, and 4 to 7 m high. This room is heavily visited by local people and is extremely vandalized and littered. The floor of this big room is an uneven surface of large breakdown blocks. Several small passages can be reached by crawling below and between these blocks; these passages lead to the remaining 8 km of cave. However, only organized cave explorers presently know the location of these crawlways, and vandalism and littering have so far been limited to the big room. The remaining passage is interesting only for its multi-level maze development and some evidence of fault control; it contains no interesting or unusual speleothems, and no unusual fauna has been noted.

Anderson Spring Cave is also a base level cave, but it is located on the western flank of Pigeon Mountain. Its location is indicated on the U.S.G.S. 7½ min Cedar Grove, Ga., topographic map. Despite this, it is seldom visited, probably because of the entrance crawl in cold, flowing water. The cave basically consists of an estimated 2400 m of trunk stream passage with a dry upper level passage located approximately above this. The upper level can be reached by numerous areas where the intervening rock has collapsed. In some areas this had led to the formation of one tall passage integrating both levels. At the rear of the cave several tall domes spray down the water which forms the spring flow. The upper levels of Anderson Spring Cave are profusely decorated with stalactites, stalagmites, columns, helictites, rimstone pools, and cave pearls. Although these are not the rarer of the cave mineralogic phenomena, their pristine condition is rare and warrants special attention. The wide pools and the flowing stream present throughout the lower level are an ideal habitat for aquatic troglobites (obligatory cave animals) and warrant further investigation on this basis.

Ellison's Cave may be described in five distinct parts: the upper level, historic section; the Fantastic Pit area; the lower levels; and the Incredible Dome-Pit-Stairstep Entrance complex. Figure 2 is a diagrammatic cross-section

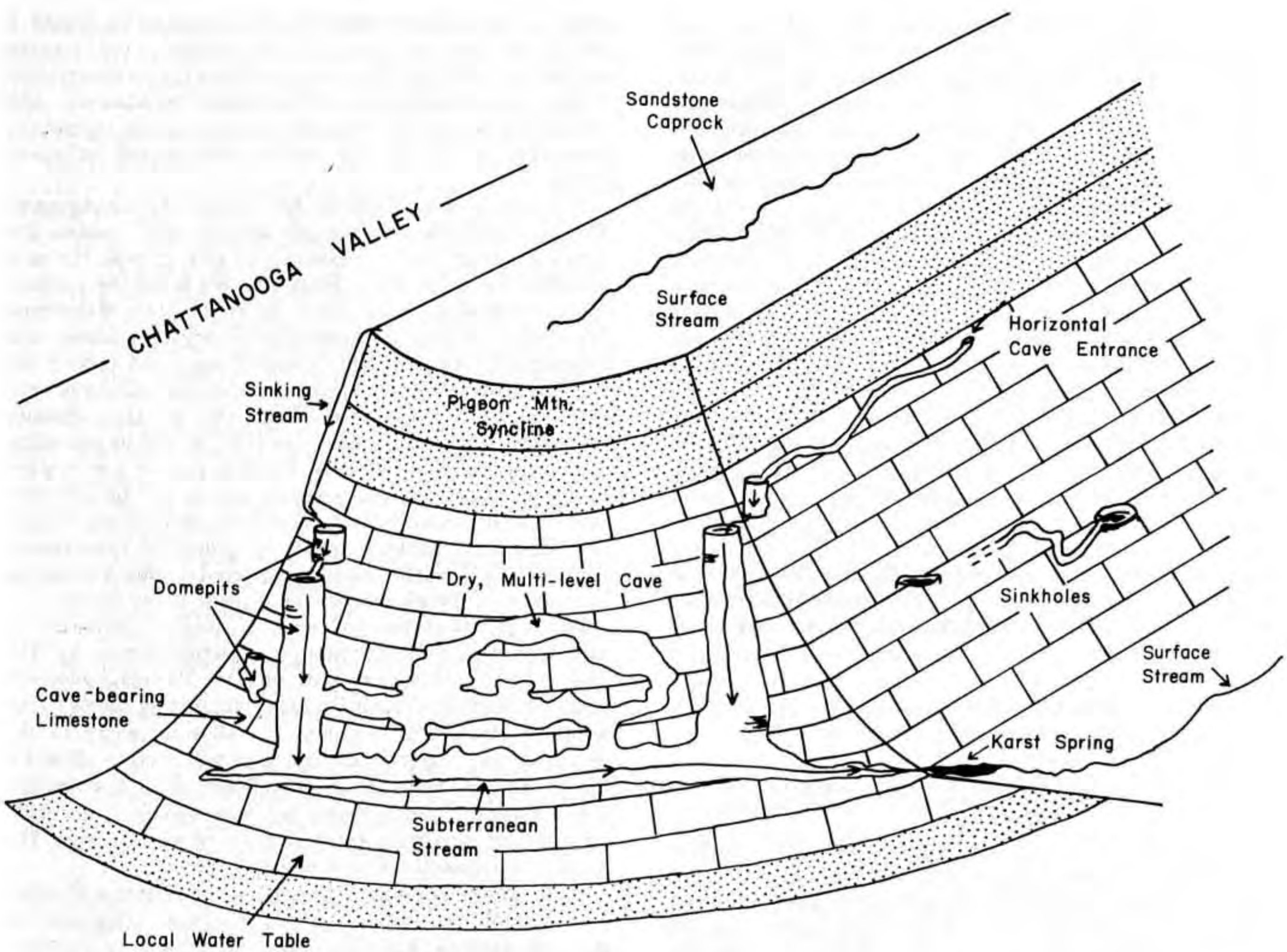

Figure 2

through Pigeon Mountain showing the relationship of the various sections of the cave. The historic upper level consists of three subparallel open, walking passages which merge into one to the south. All are relatively undecorated. A small stream flows along the floor. At the southern end the passage ceiling lowers and it is necessary to crawl over gravel and in the flowing water. This section is aptly known as The Agony; it extends 120 m, after which you can again walk upright in open, easy passage. The original, or historic, entrance is at the northern end of this upper level and the intervening, easily accessible passage between this entrance and The Agony are frequented by local visitors.

Just to the south of The Agony are two recently formed entrances to the cave. The Dug Entrance was purposefully excavated by cave explorers to eliminate the Agony crawl. More recently, the New Entrance opened-up only 30 m from the Dug Entrance by natural collapse. Continuing south from The Agony there is approximately 300 m of walking passage to the edge of the Warm-Up Pit. This easy passage is known as The Ecstasy. The Warm-Up Pit is the beginning of a series of vertically oriented pits and rooms culminating in Fantastic Pit: the deepest cave pit in the United States, 176 m from the highest entry point to the bottom. A partial profile of this area is shown in Figure 3a; the more recently discovered Attic area, above the pit, is not shown.

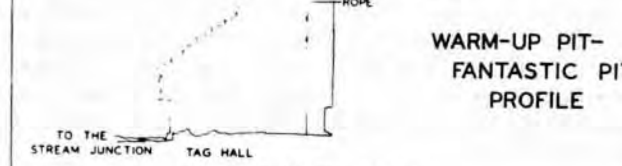

Figure 3a

The lower levels of the cave can only be reached via Fantastic Pit or the Incredible Dome-Pit, which will be discussed later. The lower levels are three vertically distinct passages, roughly one above the other. The lowest level carries the stream drainage which flows from the upper area of the mountain and down through the cave. At the eastern extremity of the lowest level this water emerges as a spring known as the Ellison's Resurgence. The extensive and diverse speleothem development within the lower three levels is unique within Georgia and rare for the entire Eastern United States. The more unusual mineralogic occurrences include epsomite (as flowers and needles), huntite, and mirabolite, as well as extensive deposits of moonmilk and gypsum needles and flowers (Dogwood City Grotto, 1974). In addition, the fauna of Ellison's Cave is also noteworthy: most notably the Indiana Bat (*Myotis sodalis*) and the Tennessee Cave Salamander (*Grinophilus paleucus*), both endangered species. Troglobitic fish and crayfish have not been found, but ideal habitats exist. Numerous troglobitic invertebrates have also been noted although they have not been identified exactly. There is great potential for biologic research (Dogwood City Grotto, 1974).

One could also enter the lower levels of Ellison's Cave from the western flank of Pigeon Mountain via the Stairstep Entrance which leads to the Incredible Dome-Pit, a 132 m drop which is the second deepest cave pit in the United States. The surface entry is through a steep-sided sinkhole which is actively eroding and enlarging. The profile shown in Figure 3b has recently been changed by collapse so that the initial pit is an almost continuous 30 m vertical drop. This entry is little known and little used; when used, it is principally for "cross-over" trips where two parties enter from opposite sides of the mountain, pass each other beneath the mountain, and exit using the climbing ropes left by the other party, thus avoiding any backtracking.

PROPOSED CAVE MANAGEMENT POLICIES

The primary use of the Pigeon Mountain Wildlife Management Area is hunting. Backpacking and caving are secondary uses. The specific management of the caves must consider both the protection of the cave visitor and the protection and preservation of the unique and valuable elements of the cave's geology and biology. However, these must be integrated within the primary goals of the Wildlife Management Area.

Pettyjohn's Cave contains no known unusual geologic or biologic features, and access of inexperienced people (who may misuse, vandalize, or litter the cave) is generally limited to the first big room which is already heavily vandalized. Further, the only serious abnormal safety hazard in Pettyjohn's Cave is that of getting lost in the maze passages, but since these are known only to the experienced cave explorers, this should not be a serious hazard. In view of these factors, no specific management policy will be designed for this cave. Permission to enter will be required, vandalism and littering will be prohibited and regulations will be posted immediately inside the cave entrance. However, no gates will be installed and the limited staff managing the mountain will not be expected to devote much time to this cave.

Anderson Spring Cave, on the other hand, is generally undisturbed. It has great potential for biologic study and its speleothems, although not rare geologically, are unusual in their profusion and inviolate condition. Because the cave entrance is close to a residence used by management personnel, a relatively simple exterior gate should suffice. The spring flow has traveled through relatively small cracks in the limestone prior to entering the cave and appears to contain no large debris, so this will not complicate gate design. Because of the unspoiled beauty of this cave and its potential for biologic research, it is planned to install a simple, inexpensive gate at the entrance and require permission to enter. The initial portion of the same permit form to be used for Ellison's Cave should be adequate, and the ranger issuing the key may make a quick equipment inspection, principally for warm clothing and sufficient lights.

Ellison's Cave is, of course, the crux of the management plan. Its deep pits are obviously dangerous! Of course, the simplest solution to this problem is to gate, or seal, the cave and allow no one to enter. However, this is not the purpose of the purchase of Pigeon Mountain by the State of Georgia. There are a significant number of Georgia's citizens, and citizens from all over the United States, and indeed the world, who derive great enjoyment from the activity of cave exploring. Ellison's Cave offers one of the ultimate challenges in cave exploring in the U.S., as well as providing a unique aesthetic experience. For this reason, a restricted access policy is selected, whereby access will be provided only to experienced cave explorers capable of negotiating the pits safely. Further, access to groups of experienced explorers will be scheduled in restricted numbers so as not to overcrowd the pit area or the delicate lower levels.

The implementation of such a policy, however, is complicated. First, in order to restrict access by the unwary, it is necessary to gate the cave. The main gate will be installed in the Ecstasy Passage, eliminating access to the entire Fantastic Pit complex, but allowing entry to the relatively safe upper level. This gate will need to allow for the stream flow along the passage floor and for the flooding which occurs in heavy rains, but since debris is normally strained out by a few narrow sections of passage near The Agony, this should not be a serious problem.

It will also be necessary to place a fence or series of cables on the uphill side of the Stairstep Entrance. This will not prevent entrance, but will prevent an unwary hunter from gaining too much momentum on the very steep hillslope and falling into the 30 m pit. This is a distinct possibility which we hope to arrest by this measure.

However, it will be impossible, because of the unstable nature of this sinkhole and its large diameter, to gate the Stairstep Entrance. Instead, a gate will be installed at the downslope end of the Waterfall Room (see Fig. 3b) in an area of solid limestone with a low ceiling, thus making gate construction easier.

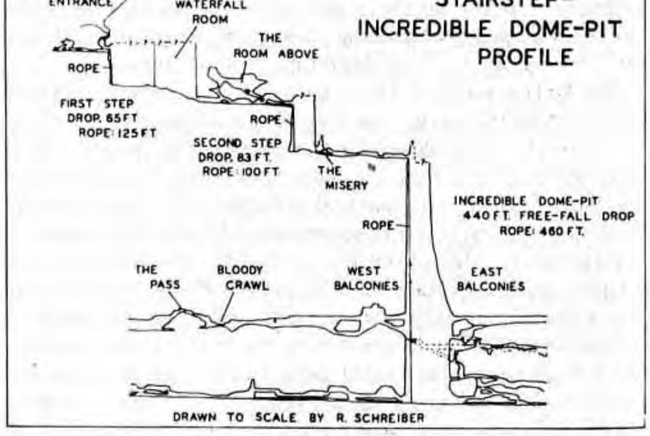

Figure 3b

The sinkhole entrance will be posted to warn of its vertical danger and to state that a permit is required for entry. It will also be noted that the cave is gated below the drop so that this should discourage unpermitted, and possibly incompetent, explorers from attempting entry by this route.

When the cave is gated, it will then be necessary to establish a permit system for gaining access. A permit system will be initiated with the following general criteria.

1. At least 30 days advance notice will be required.
2. Every party member will fill out an application stating:
   a. Experience in general caving;
   b. Affiliation with an organized group (not requried);
   c. Vertical caving experience, including other deep pits visited and frequency of climbing activities;
   d. Rescue/first aid training;
   e. Types of equipment to be used.
3. The trip leader will fill out a more detailed application stating:
   a. The purpose of the trip (research, sightseeing, climbing, etc.);
   b. The proposed date, time and duration of the trip, plus an alternate date;
   c. His experience with the other trip members in caving activities;
   d. His knowledge and experience in rigging vertical drops;
   e. His familiarity with Ellison's Cave and the route to be taken;
4. The trip leader will be asked (not required) to submit a letter of recommendation from one of the local chapters of the National Speleological Society or from an N.S.S. member whose experience and judgement are known by the local chapter.
5. Repeated applications may be waived for regular, experienced visitors.
6. Applications will be processed by the Game and Fish Division of the Department of Natural Resources at the Regional or State level.
7. Onsite equipment inspection will be made when the key is issued, and a deposit will be collected.
8. A brief trip report will be required before the deposit is refunded.
9. A list of regulations and restrictions will be included with the applications.

The trip report will hopefully keep officials up-to-date on conditions in the cave: high water, vandalism, rigging changes, etc. In order to make the onsite equipment inspection worthwhile, it will be important to have at least one of the local staff with some knowledge and experience in caving, although this may not be possible at all times. Game and Fish staff need not necessarily be familiar with rescue techniques because the Walker County Civil Defense Unit specializes in cave/pit rescues and is located in nearby Lafayette.

The major problem with such a system is legal liability. Having passed judgement on who may be allowed to climb the pit, is the person granting permission now liable if an accident should occur? This is of great concern to the Department of Natural Resources in protecting its game management employees from possible civil liability (the State of Georgia is legally exempt from suit). A solution to this problem is presently pending as one section of the Georgia "Cave Protection Act of 1977." This law, to be introduced in the 1977 session of the State Legislature by Senator E.G. Summers from northwest Georgia, is generally modeled after the West Virginia Act of similar intent. Among other intents, the anti-vandalism sections will help in the management of the many caves which cannot be gated. However, it will also contain a section on owner liability. Since Georgia already has a recreational liability law to protect landowners, this section will simply clarify and extend that law. However, it will be specifically written for the case at hand. The preliminary draft reads:

> *Section 8*. Liability of Owners and Agents.
>
> (a) Neither the owner of a cave nor his authorized agents, officers, employees or designated representatives acting within the scope of their authority shall be liable for injuries sustained by any person using said cave(s) for recreational or scientific purposes if the prior consent of the owner has been obtained and if no charge has been made for the use of such features and notwithstanding that an inquiry as to the experience or expertise of the individual(s) seeking consent may have been made.

If this law is not passed by the State Legislature in 1977,* then the question of legal liability will require detailed research before such a permit system can be implemented.

SUMMARY

The goals of this management plan are to protect both the cave visitor and the cave environment with minimum complications for the staff of the Pigeon Mountain Wildlife Management Area. Because of its dangerous pits and its unique geologic and biologic aspects, Ellison's Cave will be gated and access will be restricted to qualified cave explorers. An applicant will list his experience on a detailed permit application and will be requested to provide a recommendation from one of the local National Speleological Society chapters. Anderson Spring Cave will also be gated to preserve its potential for biologic research and the unspoiled beauty of its profuse speleothems. Pettyjohn's Cave will not be gated. The question of legal liability remains unanswered, but a proposed Cave Protection Law which absolves the owner from liability may provide a solution.

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* Note Added In Proof: The Georgia "Cave Protection Act of 1977" was passed and will become effective July 1, 1977.

Report on Workshop III: Subsurface Management as a Component of Land Management

Chuck Godfrey, Recording Secretary *

The workshop was opened for discussion by Paul Petty. Barry Beck, of the Georgia Department of Natural Resources, asked the group to comment on the proposed system of requesting permit applicants for Ellison's cave to submit a letter of recommendation from a well known, reputable caver attesting to the applicant's vertical caving abilities; and whether or not this would place liability on the caver making the recommendation. In addition, the possibility of getting a recommendation letter from a grotto rather than an individual was mentioned. The consensus of group opinion was that liability would probably not be a problem but that the question should be referred to a legal staff. In reference to this proposed system of recommendations, a question was surfaced as to whether or not this would act as a deterrent to public visitation of the cave. No answer to this question was forthcoming.

Doug Rhodes, Speleobooks, brought up the question of the federal government getting into a program of accompanied trips to high value caves on federal lands. Allan Hinds, U.S.F.S., Carlsbad, New Mexico, stated that this was being done with apparent success in a Forest Service cave he manages. Dan Baker, B.L.M., Wyoming, mentioned the possibility of a grotto acquiring a lease to conduct such trips under the authority of the Recreation and Public Purposes Act. Charlie Larson, President, N.S.S., indicated that the U.S. Forest Service had attempted a similar arrangement through special use permits in the Pacific Northwest. These were exclusive use permits, and it was believed that in most instances this had not been a satisfactory arrangement. Rob Stitt, N.S.S., stated that the N.S.S. had developed a sample lease form and protective covenant form for use with private cave owners which might be applicable to this situation.

Bob Martin, Corps of Engineers, raised a question as to what can be done to eliminate the adverse impacts of parking lots on the cave environment. Discussion on this question centered around the possibilities of collecting runoff water from the parking lots, treating with primary and secondary treatment facilities and then reintroducing the water to the hydrologic system of the cave.**

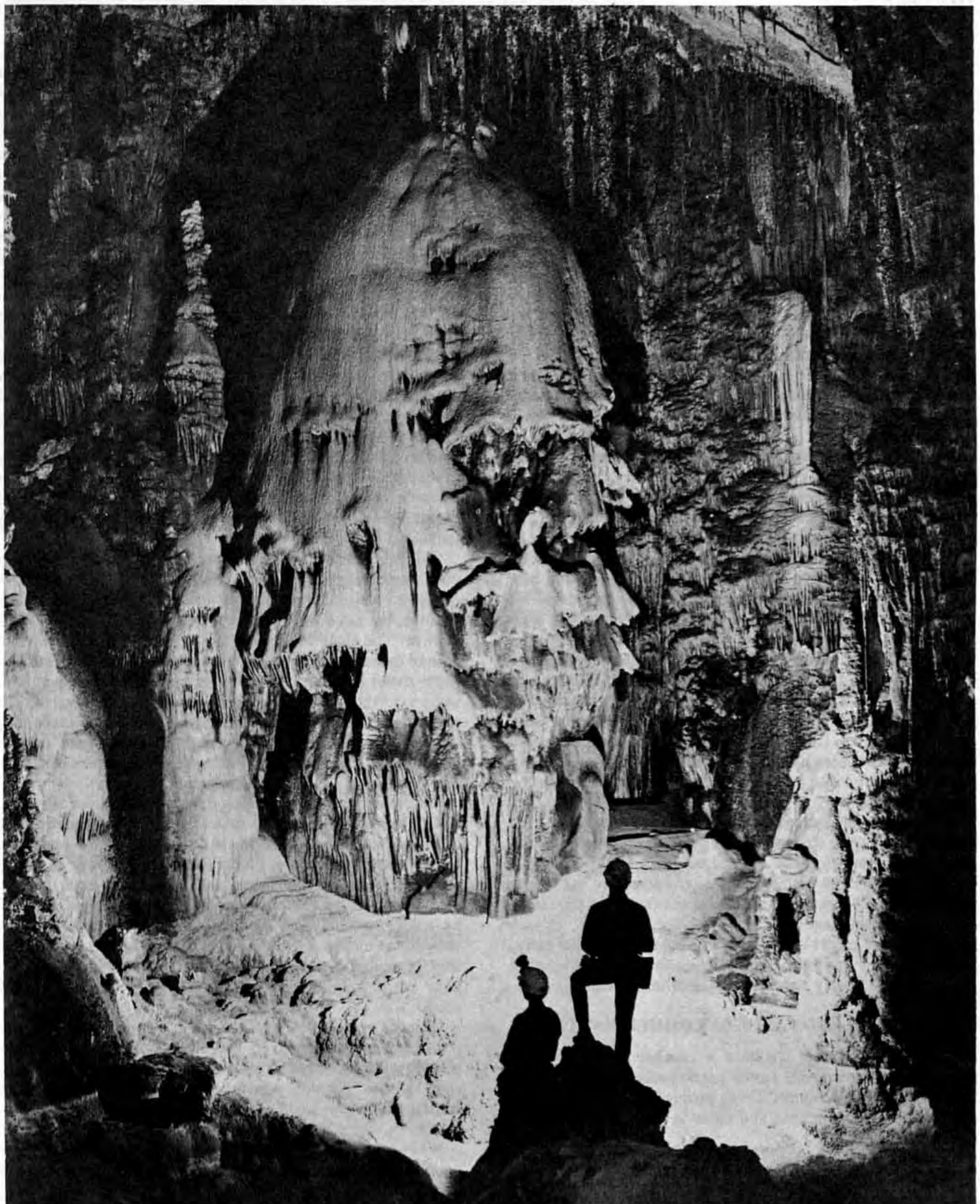
The discussion then turned to the subject of liability for damages done to cave resources. It was generally agreed that although in some instances minor criminal penalties may be imposed, there have been few, if any, examples of civil liability having been established. This led to a brief discussion of how can the loss of a cave resource be mitigated. Some suggestions here were substitution of another cave for the one lost, the relocation of cave species, and the cleaning/repairing of damaged formations. It was generally felt that the substitution of one cave for another and the relocation of cave species were not workable or acceptable.

It was the consensus of the group that there is a general need for cave protection laws and a great need for public awareness of cave values as well as public input into legislative actions involving the cave resources.

** *Editor's note:* At Blanchard Springs Caverns, Arkansas, the U.S. Forest Service conducted investigations of this problem. The solution for Blanchard was to pipe parking lot runoff water to an area remote from the cave. The parking lot contains unpaved islands which are maintained in grass to insure that some groundwater recharge will occur from the general parking lot area. TA

* Outdoor Recreation Planner, Bureau of Land Management, Roswell District, P.O. Box 1397, Roswell, N.M. 88201.

Management of Commerical and High Value Caves



Introductory Comments on Commercial and High Value Caves

Tom Aley *

I view this session of the symposium as particularly important, for I am convinced that the management of high value caves will largely direct the course of general cave management in the United States. Almost as if dictated by one of Murphy's Laws, problems always seem to strike first at those things we value most. With caves, problems strike first or most severely at high value caves. The approaches used to correct, mitigate, or offset the impacts of problems at high value caves will set precedents for more general cave management.

I sometimes detect an attitude that we can blunder into cave management, muddle around a bit, and ultimately (through trial and error) evolve skills and reasonable approaches toward cave management. Similar blunder in, muddle around, trial and error approaches in other facets of natural resource management have always resulted in erosion of the resource base. I hope we do not have to learn this all over again with caves. If we are doomed to repeat the approach, then it will be the high value caves which will feel the blunt of blunders.

An alternate approach is to initially concentrate management attention on particularly high value caves, and concentrate this management attention with sufficient intensity to insure that a good job is done. Much of our cave management has been a "lick and a promise," which has too often been translated into a gate and a prayer. A few examples of good cave management could go a long way toward sound resource management of caves in general.

Concentrating cave management initially on a few high value caves also seems appropriate when we consider the small number of people with cave management or cave resource expertise. The concentration of attention can make good use of existing expertise, and encourage the development of additional expertise. As agencies seek outside expertise, I hope they will bear in mind that a few visits to a forest does not make one a forester; a few visits to a cave does not make one an expert in cave management or cave resources.

Initially concentrating cave management efforts on high value caves may be a practical and prudent approach toward general cave management. However, it is imperative that we realize that caves represent a composite of many resources, and, thus, cannot all be managed in the same way. A good management approach for one cave, or one cave resource, might be devastating for another. Similarly, a management approach generally suitable for high value caves may be poorly suited to caves of lesser value.

IMPORTANCE AND VALUE OF COMMERCIAL CAVES

I am delighted that we have a number of owners and operators of commercial caves participating in these cave management symposiums. These people and their caves are of tremendous importance and value in the awakening field of cave management.

Every year millions of people visit the commercial caves of the United States. These people get at least some insight into caves from their visits, and are in a better position to understand the need for protecting caves as a result of their own experiences. I am convinced that there is broad-based public sympathy and support for cave protection; I am equally convinced that this public concern is due, in great measure, to the commercially operated caves. As commercial caves have helped build public sympathy and support for cave protection in the past, they will be invaluable to the cause of sound cave management in the future.

Another important characteristic of commercial caves is that they provide a visible demonstration that caves not only have intrinsic value, but also economic value. If you doubt this, try and buy an undeveloped cave. Many owners of wild caves are convinced that their caves have substantial economic potential, and great wealth could be realized with just a good road, a ticket stand, and underground lighting. Those of us truly familiar with commercial caves may chuckle at this attitude, but the attitude exists and is of great importance in protecting caves on private lands. The attitude is important because we tend to protect those things which we consider to be valuable or potentially valuable.

One problem which cavers have been experiencing is an ever-increasing list of caves the owners no longer allow cavers to visit. The problem is generally attributed to bad conduct by some cave visitors, but this is not the entire answer. The closure of caves to cavers may also be a result of land owners becoming increasingly aware of the value of their caves. These land owners may have realized that cavers can damage caves; damage decreases cave value. The exclusing of cavers from some caves on private lands may thus represent a movement on the part of land owners toward cave management. Closing caves to cavers is simple, but very effective, cave management.

I have been caving and doing cave work for over 20 years, and in that time have had many contacts with commercial cave operators. I want to thank the patient cave operators for their tolerance of me; I have seen many of your caves for free and roamed your back passages. You have fed me supper and let me sleep in your gift shops. And of course, I have squeezed between the bars on your gates in the winter and hidden on top of the Wedding Cake when an unexpected tour passed. I have also delighted in fishing pennies from your wishing wells to buy huckleberry pie at your snack shops.

In more recent years (when I could more readily afford pie) I have been involved in guide training and problem solving work for several commercial caves. As a result of all this I have become aware of some conflicts between commercial cave people and other people interested in caves.

When commercial cave people meet with other cave people, the commercial cave operators are too often treated

* Director, Ozark Underground Laboratory, Protem, Mo.

like prostitutes at a revival. They are chastized for the wares in their gift shops and the quality of their tours; they are urged to repent their alleged sins before gaining acceptance from the "true cave lovers." I can hardly imagine a more insensitive and counter-productive attitude.

I think it is time we acknowledge the important contributions of commercial caves to the whole realm of cave protection and cave management. Commercial cave owners have been involved in cave management for years; we can borrow some of their approaches for more general cave management, while discarding those approaches which do not fit the more general cave management situations.

Those of us with expertise in cave interpretation or in various cave resources can often help update information used in commercial cave tours. It is challenging work, because it is often difficult to explain things in a simple, understandable, accurate, and interesting manner. However, I think the benefits of increasingly better and more informative cave tours warrant our efforts.

Ultimately, I hope we can all come to view commercial caves as vital cave protection and cave management assets. Commercial caves provide a stage where millions of Americans are introduced to cave resources; it is a stage from which to urge cave protection and sound cave management as a national need. Who, after visiting caves like Luray, Onondaga, or Natural Bridge (to name only a few) could really believe that caves are only holes in the ground instead of valuable natural resources?

Elsewhere in these Proceedings are papers by Ahlstrand, Yarborough, and Aley on alpha radiation in caves. Because natural radiation exists in caves, there is an imminent threat that radiation standards and regulations developed for the mining industry will be applied to commercial caves without significant modification. If this occurs and the regulations are enforced, I am fearful that we will see some commercial caves forced out of business and others forced into ventilation schemes which will cause serious physical and biological damage to valuable cave features. The effects of this would extend far beyond the individual commercial caves, and would result in a major national setback to cave protection and management.

Boredom in Paradise: A Hard Look at Cave Guide Training

W. T. Austin and Tom Chaney *

ABSTRACT

More than 200 commercial caves in this country, operated either by public bodies or private owners, continue to offer a cave experience to a growing number of customers. This experience ought to be as delightfully informative as possible. We are concerned here with improving the traditional, guided cave tour as opposed to other methods of exhibition. Cave Management has invested heavily in publicity, advertising, grounds and surface facilities. Customers attracted by this investment usually spend a very small percentage of their time being influenced by these features in relation to the time spent in the cave with a guide. The care and attention devoted by management to guide training is small compared to that lavished on advertising, surface and cave facilities, and the conduct of the surface staff. We have been aware of many long-term problems in cave guiding at Mammoth Onyx Cave. This summer we looked closely at the performance of guides on random tours in about a dozen caves in Indiana, Kentucky and Tennessee—including our own.

Two basic elements of cave guiding are almost universally flawed. Most guides appear to possess little more than superficial knowledge of the cave they show. The information is generally presented to customers in a manner indicating the guide had either learned his spiel by rote or that he had given it so long that he had ceased to actively think about it. These flaws grow out of a universal system of guide training which employs imitation as its basic technique.

At Mammoth Onyx Cave we have become more aware of our weaknesses in training, and we are beginning to develop some new approaches. We are redoubling our efforts to see that guides have the most complete information about every aspect of the cave and the Kentucky cave area. We want our guides to help our customers capture a sense of wonder, discovery and fun as they tour the cave, therefore we are relating the craft of cave guiding to that of the actor and the public speaker. Finally, we are devising some new methods of continuing training for cave guides.

WHAT THE CAVE EXPERIENCE IS

For a long time management at Mammoth Onyx Cave (Kentucky) has been dissatisfied with the quality of the cave experience we were offering the public. In an effort to get our bearings, we decided to visit a number of commercial caves in Indiana, Tennessee and Kentucky to see just what others were doing. What we found was general confirmation of our own experience at Mammoth Onyx.

Cave management everywhere seems to commit most of its revenue to advertising and surface facilities, yet demonstrates only vague unease about the actual quality of the cave experience the ads tout.

We found guides who had either learned their spiel by rote or had given it so long without thought that the chief body of information conveyed was the guide's own boredom with his job. That appearance of boredom comes from some specific causes. And those causes have root in the guide's training and the way he proceeds on his job after training.

In nearly every cave we visited, we found the same terribly insufficient method of guide training in use. Reduced to its essentials, it is a "monkey see: monkey do" approach. A new guide trails other guides until the new man has learned what the old one knows. He is shown the light switches, given a flashlight, and put in the cave on his own.

Along the way he may be given a whole complex of rules having little to do with the tour. He will be told not to chew gum, to dress neatly, and not to make any passes at the opposite or same sex.

As a result, he is armed with second hand facts and second hand responses to the features of the cave—in short, a second hand tour. In reality, a third, fourth or fifth hand tour for that is the way his teachers were taught.

Facts get out of date. Events that happened "thirty years ago" in 1950 still happened thirty years ago in 1976.

There is very little follow-up on the work of guides in any cave we visited. Ruby Falls makes use of its guest register to check on glaring misbehavior of its guides, but the register does not provide any indication of what the guide could be doing but is not.

* Mammoth Onyx Cave, Horse Cave, Kentucky 42749

In conversations with the guides at Mammoth Onyx, we learned that the only question anyone in management had raised about performance was when a tour was too long or too short. This sort of training and lack of follow-up leads, it seems to us, to the boredom that most guides seem to communicate.

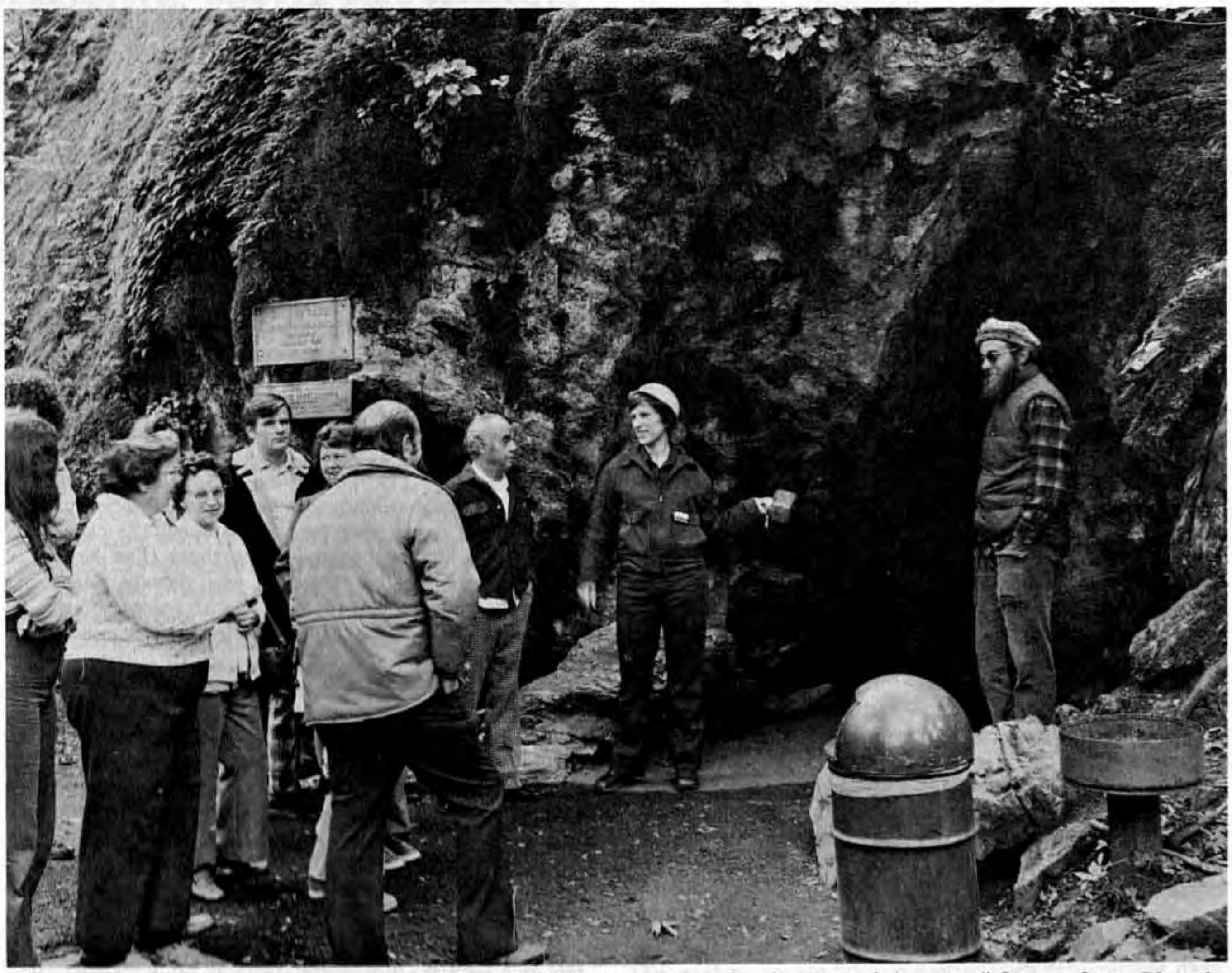
There are a number of elements involved in that boredom. In the first place, as we mentioned earlier, the tour is not the guide's own. He got it from another, with little added. Consequently, there is little sense of personal excitement possible.

To illustrate this, take one cave trip which was exciting and energetic, and on which the guide was worth the price of admission. At Blue Spring Cavern (Indiana) the party was small—three of us and a guide. The guide was one of the owner-developers of the cave; he had made the cave what it was, and he was eager to show others what he had found and improved. His involvement in the process was artfully communicated to us.

It is that sense of spontaneity that must be learned by most guides, since the caves that most of us show for profit have long since been explored, and the explorer and guide are no longer the same person. The guide, however, must act as if he were on his first return trip in a virgin cave—full of excitement about what he has found—eager to show it to others.

In short, cave guiding is a form of theatre in that it is the creation of an illusion—not a lie—but an illusion of a truth bigger than life—information selected and focused to involve the customer—whether sitting in a theatre or standing in a damp cave passage—in an experience related to his life. That involvement in a cave ought to do precisely what the actor and director seek in a theatre—delightfully inform the customers—extend the bounds of their experience—excite them about the special world of the cave.

That makes every cave guide a solo performer. Any actor who was party to the charging of admission for a boring play would be hooked off the stage in a minute. Yet guide after guide droned on and on this summer. At one cave the young man came rushing up from an adjacent swimming pool, changing from his life-guarding sun glasses to his cave-guiding jacket and voice on the run with no thought given to the difference between jobs. And it was evident all through the tour, of what might have been a most interesting cave, that the mind of the guide was back at poolside where girls were bathing in the sun.



"Cave guiding is a form of theatre and the craft of the guide is directly related to that of the actor." Oregon Cave. *Photo by Charlie and Jo Larson.*

At Mammoth Onyx we claim the second largest onyx column in the country. On tour after tour it is described in precisely the same tone as used to caution customers not to smoke or not to bump their heads.

In Tennessee a young guide greeted his group with a pleasant smile and a soft voice. On that tour there were two families of the worst possible variety of flatland touristers. They screamed, shouted, spewed flash cubes and candy wrappers from one end of the cave to the other. The guide's grin persisted, the voice never varied. His monotone had no emphasis. Neither his body nor his voice betrayed one gram of energy. He chose to ignore the outrageous behavior of the ugly Americans and the trip was spoiled for the rest of us.

These are some of the most glaring flaws in the tours we took. They should not be construed as exceptions. They are, unfortunately, simply the most vivid examples of 15 or 20 bad tours in about ten caves.

'Twould be nice if there were some evidence that our experiences were the exception and not the rule. We don't see it.

If we are going to invite customers to pay to see our caves, then we must give serious thought to what we are asking them to pay for and how we are going to show it to them.

WHAT THE CAVE EXPERIENCE OUGHT TO BE

We have looked at several of the electronically augmented tours and have decided they don't fit within our concept of what the cave experience ought to be. Since there is no way tape recordings can adapt to constantly changing groups, we are committed to individual guides.

Within certain limits, the quality of guide training in vocal techniques affects the size of group the individual guide can handle. As the actor adapts his voice and body movements when he moves from a small to a large theatre, so the well-trained guide can effectively communicate with larger groups without mechanical aids.

I have alluded to the relationship between the showing of caves and theatre. This is not a metaphor. Cave guiding is a form of theatre and the craft of the guide is directly related to that of the actor. Many of the same standards apply. Much of the intent is the same. It follows that acting techniques can apply to the guide as surely as they do to the stage performer.

In the first place, the cave is much like the play. The text of the play and the features of the cave remain constant. An audience brings a variety of different needs to both, and it has a right to have those needs gratified in all their variety within the constant cave.

The cave trip should be a blend of fun and information adapted to the specific group within the cave at the moment. The guide must take time early in his tour to discover something about the make-up of his group. If he has folks along who have never been in any cave before, then he must stress elementary information about cave development. Customers familiar with caves must be given information which will make some contribution to their needs at a more complex level.

You see, we have ruled out, at the start, the passive guide with a set spiel. What works at nine in the morning won't work at two in the afternoon.

The guide must have at his fingertips enough facts, and enough ideas about those facts and about people to adjust his focus to whomever comes along. Early in the tour he must take the necessary time to get enough information to know his audience. That means that just before entering, and for the time in the cave, that bunch of customers must be the most important thing in his life. The entire tone of his body—every nerve and muscle—must be geared to the performance he is about to give.

Not too many days ago two men active in theatre came to Mammoth Onyx Cave. They took a typical tour. After they emerged from the cave we asked for their response.

"My God!" they exclaimed, "Disney World spends millions to build what you have here. And the guide was as casual as if he were showing us the way to the bathroom!"

The potential was there. They liked the cave. They wanted something out of the ordinary. They were geared for caviar: the guide gave them cold oatmeal.

WHAT WE INTEND TO DO ABOUT IT

We have a serious problem. We believe we see some ways of solving it. The solution will not be easy, and it cannot be done once and forgotten.

A new method of training guides must be devised that is more than a reinforcement of traditional habits. In the imitative approach the new guide is never any better than his teacher—and he is usually worse.

We must break away from imitation so that while the new guide may adapt what works for the old into his own performance, he is encouraged to devise his own approach. The personality of the guide must be the mediator between cave and customer.

In the first place, the guide must have much more pertinent information about the cave and the area than he could possibly use on any one tour. What he uses must be only the tip of the iceberg.

Of course, he must be able to answer questions with authority, to admit he doesn't know the answer when he is stumped, and to know where to get the answer when he gets out of the cave. But he must do more. What he has to say must be so stimulating that he evokes those questions in the first place.

In the second place, delivery of the information is a problem. A guide at Mammoth Onyx Cave observed that he used to have many more people ask about the cave three years ago when he began leading tours than he did at present. He couldn't understand why nobody talked any more. The fault, he opined, was all with the customers. He couldn't see that he had raised subtle barriers to questions and discussions.

A few days before, I was in the cave with that guide. He described a colorful feature of the cave in a drab voice, and, as he turned to go on down the path, he asked over his shoulder whether there were any questions.

It became obvious that we had to work on these two facets of the tour at the same time. We had to provide the guides with sufficient information so that they were knowledgeable about every aspect of the cave. And we had to set to work improving the manner in which this information was presented.

After we decided to revamp our tour, the first step was to talk to the guides and include them in our planning. Those conversations revealed that the guides themselves were as unhappy with what they were doing as we were. All of them have been cooperative and have made useful suggestions.

After talking with each one, we asked them to jot down over a period of a few days every question that had been asked them that they could recall. We are in the process of researching in detail complete answers to all questions—however obvious or complex.

This led to a major decision about the organization of the cave tour. When a director of a play approaches a script, one of the first things he must do is to break that script down into its component parts. He must ask of each scene: "What do I want to accomplish here, at the opening of act one, that will contribute to the final, total impact of the play?"

That seems to be an appropriate approach to the cave tour. We asked ourselves just what it was that we wanted of our customers after the price of admission. In a general sense we want the tour to be delightfully informative about the cave and the people it has affected through the centuries (since 1000 BC). But to be more specific, we want to provide interesting information about the following: 1) The geologic process of the formation and decoration of caves; 2) How that process happened in this specific cave; 3) The relationship of Mammoth Onyx Cave to other caves in the Central Kentucky Cave Area; 4) How caves in general and this cave in particular were used by humans; 5) How the peculiar topography, of which the cave is a part, affects the lives of those who live in the area.

With these aims in mind, we decided to examine each stop in the cave tour. We defined a specific purpose that we wish the guide to achieve at each point, and we organized the information necessary to that point much in the manner of the pyramid style familiar to newspaper reporters. That means that the basics are given first, and succeeding elements are expansions of the opening paragraph.

The first stop on our tour will illustrate. Legend has it that a young girl, Martha Woodson, discovered the cave while picking berries on a hillside. She followed the draft of cool air, lowered an Indian ladder, and with her two brothers entered the vertical shaft and looked around. That happened in 1799.

That shaft is in an enclosed building and the tour visits that building before entering the cave by a man-made entrance nearby. Guides for generations have been droning the story of Martha and adding extraneous information at random. For a time, examples of cave life were kept in the room and they were discussed, as was the story of the commercial development of the cave.

We now have phrased a specific purpose that we want the guides to achieve in that discovery room. It has two related points: "To describe the scene around the cave in 1799, and to recreate the sense of anticipation which Martha Woodson felt as she found the cave and entered it." Now, any information that contributes to that purpose may be used here. Information not relevant is saved for another point in the tour.

We know a good bit about the deployment of Indians and settlers in the area at the time of discovery, and as customers are interested the guide is free to go into increasing detail. The guide is also free, within the confines of the stated purpose, to arrange the information in the manner which best suits his own judgement of the individual tour.

One of the crucial decisions we made had to do with the form of the information provided the guide. We phrased it in a terse, telegraphic style in order to force the guide to develop his own personal narrative.

We are providing the same approach to all aspects of cave formation, development, decoration, human use, etc. Of course, there is a great deal of information that is not necessarily related to any specific station in the cave. The guide is provided with this as well, and he may insert it where it is most appropriate, in his own judgement, to the group he is guiding.

Any well-written play employs "plants"—that is references to events which are to occur, and statements that will be clarified in a later scene. We are using the same technique in our organization.

For example, Mammoth Onyx Cave is so formed that there are fine illustrations of cave decoration just within the man-made entrance. At that point our purpose is to explain these formations, but we include allusions to the earlier, flowing water stage of cave development which will be explained later in the tour.

As we analyze the entire tour of the cave, we are providing guides with rough copies of information. By the time our larger summer crew is ready for training we will have prepared a series of panels containing the purpose for each stop in the cave and the information about that stop. These will be illustrated with a graphic design intended to give the purpose visual form.

The second part of the training program is infinitely more complex and individual. Before, during, and after the time the guides are being provided with the newly organized information, we are working with them on the basics of good delivery. This will include rigorous work in vocal production. Without destroying the savory elements of a rich regional dialect, we are trying to achieve good diction, audibility, and variety—three elements which seem to deteriorate as a spiel becomes rote.

Beyond vocal production, we are working on achieving a good, conversational, story-telling style. This involves developing a good rapport with the customers, eye contact, and a sense of what works at the moment and what doesn't. Out of this conversational, informative style comes a mood that encourages questions, and the questions, in turn, generate more delightful information.

We are in the middle of this process at the moment. We have a core of four or five guides who work in the winter season. When the summer 1977 season comes, they will be better able to participate in the training of the summer crew.

We have been slowly introducing the newly organized information to our guides at Mammoth Onyx Cave, and we have begun working with the most serious problems of voice. At this point our results have been somewhat mixed.

The younger guides have eagerly assimilated the new information and are working it into their performance quite well. The older guides are finding it difficult to break out of firmly entrenched habits. They tend to add some of the new information to the old spiel without grasping the sense of focus.

All the guides thus far have responded favorably to advice on the art of communication. One guide reports that his use of a more direct, face to face approach has noticeably increased the number of questions he is asked.

The training we envision has no terminus. With their knowledge, we are trailing guides. We are discussing their work on a regular basis. We will continue to encourage all guides to be aware of what others are doing and to discuss their common problems among themselves and with management.

In doing this we want to develop a delight and pride in the art of guiding—a pride that will cause guides to be eager to share the cave with our customers and to share guiding techniques and problems with each other. For, after all, the cave experience is total immersion of the customer in a world alien to his usual haunts. We provide him with an informational summary of millions of years of geologic history and three thousand years of human use of that geology. And we give him that information while he is surrounded by the sights, sounds, odors and touch of that very world.

With our resources we ought to be the envy of every director of theatre, movies and television who must cope with the distance imposed by their medium.

It is the guide who can make the moment magic.

Investigation of Radiation Produced by Radon and Thoron in Natural Caves Administered by the National Park Service

Keith A. Yarborough *

ABSTRACT

The National Park Service (NPS) has studied levels of alpha radiation in all NPS administered caves. This research and monitoring was stimulated by previous work of R. Breisch, J.B. Trout, M. Wilkening and D. Watkins. It has been carried out to protect the health of NPS employees, as required by the Environmental Protection Agency and the Occupational Safety and Health Administration radiation standards. While the NPS does not presume to impose on private cave researchers and managers NPS actions for the caves which NPS administers, individuals in the private sector may find the NPS results of interest and usefulness.

Natural cave radiation is produced by the radioactive decay of radon and thoron gases, which in turn result from uranium and thorium decay. These latter elements are found in all terrestrial rocks and soils, in varying though minute concentrations. The decay products of the two noble gases which constitute a potential health hazard are their short-lived "daughters." These are ionized solids which may become attached to dust and water particles in cave air. When inhaled into the lungs, they can cause radiation damage which can lead to lung cancer after prolonged exposures, because the radiation has large ionizing effects on lung tissues. Continuous exposures of many years usually are necessary before atypical cells appear. This has been documented to be anomalously high among uranium miners. Smoking has a contributory effect which greatly increases the radiation health hazard.

Radiation concentrations are measured by "working level" (WL). One WL is defined as any combination of radon and/or thoron daughters in one liter of air which will result in the ultimate emission of 1.3×10^5 MeV of potential alpha energy. Cumulative exposure is measured by the working level month. (WLM), defined as the exposure received from breathing air at one WL concentration for 173 working hours per month (40 hrs./work wk.), or other combination of time and radiation level.

Radiation Health Standards are set by several Federal agencies: Mining Enforcement and Safety Administration, National Institute for Occupational Safety and Health, EPA, and OSHA; as well as state health agencies.

The NPS research has dual but complementary objectives: 1) To safeguard health at the NPS administered caves; 2) to develop data on alpha radiation levels and on natural airflows in caves.

The results reported for NPS caves give WL ranges, show daily and seasonal trends, and show the influence of natural ventilation by air circulation for each cave investigated. This latter is most important in dissipating the radiation. Results of epidemiological tests on employees are reported, also. These facts can be used by various agencies to clarify health standards for exposures to the usually lower radiation levels found in cave environments.

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I. A CAVE-SIDE CONVERSATION

We are watching a yawning opening in the earth. A rope is tied to a large tree nearby and vanishes into the Stygian darkness of the hole. Some hours ago several people wearing hard hats with head lamps, very old clothes and sturdy boots dropped out of sight into the hole using the rope. These are cavers whom some view as amazing stalwarts of great skill, strength, courage and ingenuity. Others view them as members of the more abandoned portion of the general population's lunatic fringe. Others just view them.

In fact, a familiar figure in one of those funny, woodsy ranger hats has just approached the hole and stands peering down into it. The cavers, now muddy from head to foot, are struggling back up the rope, nearing the surface.

"Hi, there. What's going down (heh-heh—a caving sort of joke). I'm the Radon Ranger," says the figure in the hat. "I've come to tell you about a new hazard in caving."

"Stars and garters!" shouts the first caver, looking up with ascenders slipping. (There follow several gutteral grunts and obscene gestures; here deleted).

After arresting his slide, the first caver pauses, peering up in amazement.

"Where in hell did you materialize from?"

"Oh, I've just been waiting to tell you folks about this new cave hazard that's just been researched."

"Man, we don't need any more hazards! We just dropped down this pit about 150 feet, crawled several hundred yards through bat guano risking rabies, histo, and Lord only knows what, almost slipped off into another pit, nearly got brained by a falling rock, just missed drowning in a deep pool of water, nearly had our lights go out, ran into some bad air with low oxygen, got lost for a while, and just now have climbed back out. And now we have you standing there in the way with some new hazard. Hell, man, what could be any more hazardous than what we've just been through? Frankly, I'm not impressed. Now move over, so I can climb out and let the others up behind me."

II. WHAT THE RADON RANGER HAD TO SAY
(with a minimum of gutteral grunts and obscene gestures)

There are hazards involved in entering caves. This applies to both the casual visitor who takes an occasional guided tour along a paved path in a "developed" cave as well as to the sport caver or ardent speleologist who enters "wild" caves to explore and map, to sightsee, or to conduct scientific research. As the foregoing conversation shows, among these hazards are rock falls; slips and falls while moving around in the cave; high CO_2 and resulting O_2-deficient air; deep water pools and flowing streams; the danger of contracting rabies, histoplasmosis, and other diseases; —there can even be fires and explosions which produce noxious gases. In late 1968, Richard Breisch first described the possibility of a new hazard to U.S. cavers: natural radiation. Subsequently, Jo Bob Trout, Marvin Wilkening and David Watkins measured radon gas concentrations in caves of southern New Mexico, including Carlsbad Caverns. Their results suggested a possible health hazard for National Park Service cave employees under existing OSHA uranium mining radiation exposure standards.

The NPS is studying levels of alpha radiation in all NPS-administered caves in which tours for visitors are regularly conducted. The NPS research has the dual but complementary objectives: 1) To safeguard health at the NPS administered caves; 2) To develop data on alpha radiation levels and on natural airflows in NPS caves. The results reported for NPS caves can be used by various agencies to clarify health standards for exposures to low airborne alpha radiation levels in cave environments. These results show daily and seasonal trends and the influence of natural ventilation by air circulation for each cave investigated.

This radiation is produced by the radioactive decay of radon and thoron gases, which in turn result from uranium and thorium decay. These latter elements are found in all terrestrial rocks and soils, in varying, though minute, concentrations. Acidic rocks and weathered residual soils from such rocks usually contain the highest amounts of these elements. The decay products of the two radioactive gases which constitute a potential health hazard are their short-lived *daughters*. These are ionized solids yielding alpha radiation which may become attached to dust and water particles in cave air. When inhaled into the lungs they can cause alpha radiation damage which can lead to lung cancer after prolonged exposures, because the alpha radiation has large ionizing effects on lung tissues. Continuous exposures of many years usually are necessary before atypical cells appear. This has been documented to be anomalously high among uranium miners. Smoking has a contributory effect which greatly increases the radiation health hazard.

Radiation levels (i.e., exposure rates) are measured by the *working level* (WL). One WL is defined as any combination of radon daughters in 1 liter of air which will result in the ultimate emission of 1.3×10^5 MeV of potential alpha energy. The value of the WL is derived from the alpha energy released by the total decay of short-lived daughters in equilibrium with 100 pCi of radon per liter of air or 8 pCi of thoron per liter.

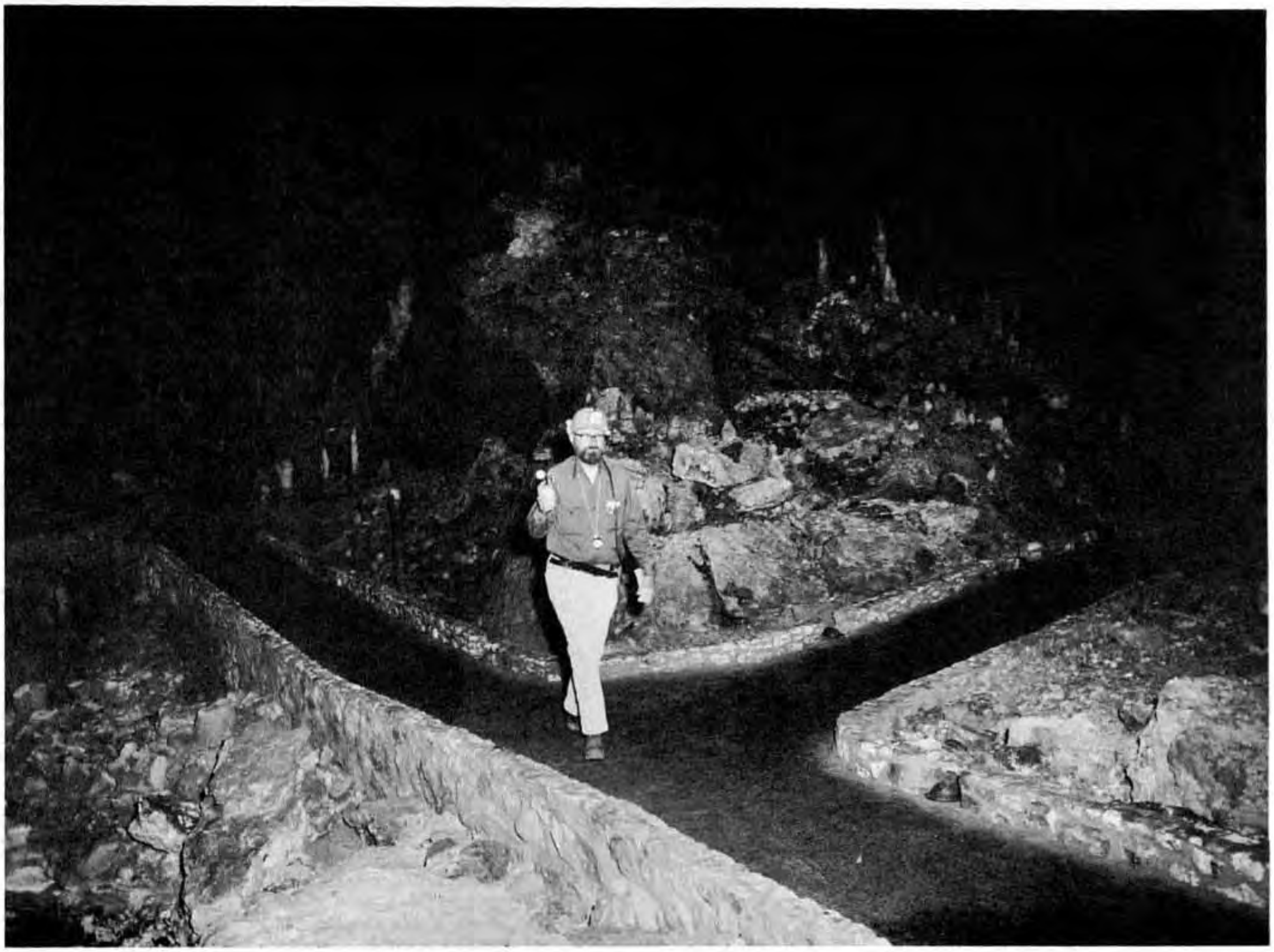
The total exposure accumulated by a person exposed to airborne alpha radiation in any underground environment, whether a man-made mine or a natural cave, is the most important health consideration. This exposure is computed as the product of exposure rate (in WL) and time. The cumulative exposure is measured by the working level month (WLM), defined as the exposure received from breathing air at one WL concentration for 173 work hours per month (40 hours/work week), or any combination of exposure rate (WL) and time which might give 1 WLM.

Radiation health standards are set and enforced by several government agencies: Mining Enforcement and Safety Administration (MESA), National Institute for Occupational Safety and Health (NIOSH), EPA and OSHA, as well as state agencies. These agencies have assisted the NPS in its cave radiation research. The most important health standards derived from uranium mining are probably:

1. Routine, weekly monitoring must be carried out in all underground areas which exceed 0.30 WL and cumulative exposure records must be kept for all employees working in these areas.
2. No employee can exceed 4 WLM cumulative exposure per calendar year.

A more complete list might also include the following standards:

3. People wear respirators in areas with radiation greater than 1.0 WL.



The author is shown here using the typical air pump and filter unit to collect a timed sample of cave air for airborne radiation determination. *Photo by Charlie and Jo Larson.*

4. Employees who go caving record exposures during off-duty hours activities in all caves.
5. Advise non-NPS personnel of hazard (NSS, CRF, NCA, etc.).
6. Apply the following scale to caves:
   0 — 0.1 WL; no action
   0.1 — 0.2 WL; annual samples
   0.2 — 0.3 WL; quarterly samples
   above 0.3 WL; weekly samples and records of employee exposure
7. No smoking in caves by anyone.
8. Have annual sputum cytology exams for employees in caves where records are kept and a pre-employment exam requirement, as well.
9. New employees advised of the hazard.
10. No use of cave air for ventilation of surface buildings.
11. No entry into areas which exceed 2.0 WL.
12. Credit given for wearing respirators, or a variance for their use from OSHA.

The airborne alpha radiation is measured by collecting timed samples of the air in work areas using special filters and air pumps. These filtered samples are read for their radioactivity levels in an alpha scintillation probe and scaler recording unit. Epidemiological studies among uranium and certain non-uranium miners have shown that the incidence of lung cancer is increased some three times for continuous exposure to greater than 0.30 WL. Smoking can increase the likelihood of lung cancer by some ten times after several years continuous exposure, especially to radiation levels above 0.30 WL. However, there is evidence that the continuous exposure is the significant factor and that lung cancer incidence is not exposure rate dependent. Furthermore, there is no threshold of safety limiting value for the exposure rate (in WL).

NIOSH has examined NPS employees from a number of the NPS cave areas for pulmonary cytology. These results have not been reported to NPS in detail as yet. However, preliminary data suggest some atypical cells which may be attributable to the airborne cave alpha radiation.

Table 1 shows the ranges of exposure rates (in WL) for radon daughter concentrations in the NPS caves which have been investigated. The NPS has initiated routine, weekly monitoring and employee exposure recordkeeping for those caves with exposure rates of 0.30 WL or greater.

TABLE 1: Summary of Radon Daughter Concentrations in NPS Caves

PART A: COOL WEATHER MEASUREMENTS:

Cave	Working Level Measurements (WL) Maximum	Minimum	Weighted Avg.
Carlsbad Caverns, New Mexico: (Sampled on Nov. 4-7, 1975 by MESA)	0.3		
Toured areas open to visitors:			
1) Main Corridor and Scenic Rooms	0.36	0.04	0.25
2) Big Room	0.40	0.20	0.30
3) Lunch/Pump Room	0.36	0.17	0.26
Lower cave—not visited by tours	0.99	0.33	0.65
New Cave, New Mexico: (Sampled on March 8, 1976)	0.35	0.27	0.20
Timpanogos Cave, Utah: (Sampled Jan. 5, 1976)	0.02	Trace (0.003)	0.01
Lehman Caves, Nevada: (Sampled Jan. 6-8, 1976)	0.37	0.10	0.21
Wind Cave, South Dakota: (Inner reaches of Tour Route) (Sampled on Jan. 19, 1976, by MESA Field Office in Rapid City, SD. Only trace values were found in outer reaches of Tour Route)	0.19	0.05	0.12
Jewel Cave, South Dakota: Sampled by MESA Jan. 29, 1976 along Tour Route)	0.28	0.13	0.21
Crystal Cave, Sequoia National Park, California: (Sampled Jan. 21-22, 1976)	0.22	Trace (0.003)	0.07
Marble Cave, Sequoia National Park, Ca.: (Sampled Jan. 23, 1976)	0.01	0.01	0.01
Oregon Caves, Oregon: (Sampled Jan. 24-26, 1976)	0.35	0.02	0.16
Lava Tube (Valentine) Cave, Lava Beds Nat'l Monument, Ca.: (Sampled Jan. 27, 1976)	0.13	Trace (0.003)	0.07
Round Spring Cave, Ozark Nat'l. Scenic Riverways, Mo.: (Sampled Feb. 14-15, 1976)	0.60	Trace (0.003)	0.29
Mammoth Cave, Kentucky: (Sampled Mar. 26-30, 1976; all tour routes included here)			
1) MESA Measurements	1.00	0.30	0.65
2) NPS Measurements	0.88	0.24	0.49
Great Onyx Cave, Kentucky: (Sampled Mar. 29-30, 1976)	1.22	0.68	1.00
(Sampled Apr. 22, 1976)			
1) MESA Measurements	0.80	0.57	0.72
2) NPS Measurements	0.76	0.48	0.62
Floyd Collins' Crystal Cave, Kentucky: (Sampled Mar. 29-30, 1976)	1.49	0.83	1.12
(Sampled Apr. 22, 1976)			
1) MESA Measurements	1.45	0.79	0.95
2) NPS Measurements	1.29	0.70	0.87
White Cave, Kentucky: (Sampled Apr. 22, 1976)			
1) MESA Measurements	0.64	—	—
2) NPS Measurements	0.52	0.45	0.49

PART B: WARM WEATHER MEASUREMENTS

Cave	Working Level Measurements (WL) Maximum	Minimum	Weighted Avg.
Mammoth Cave, Kentucky: (Sampled Aug. 3-5, 1976 by NPS and MESA; all tour routes included here)			
1) MESA Measurements	1.41	0.23	0.76
2) NPS Measurements	1.04	0.26	0.65
White's Cave, Kentucky: (Sampled Aug. 3-4, 1976 by NPS and MESA)			
1) MESA Measurements	1.18	0.60	0.76
2) NPS Measurements	1.22	0.58	0.77

Cave	Working Level Measurements (WL) Maximum	Minimum	Weighted Avg.
New Discovery Cave, Kentucky: (Sampled Aug. 4-5, 1976 by NPS and MESA)			
1) MESA Measurements	1.19	0.87	0.99
2) NPS Measurements	1.10	0.97	1.04
Floyd Collins' Crystal Cave, Kentucky: (Sampled Aug. 3-5, 1976)			
1) MESA Measurements	1.48	0.87	1.22
2) NPS Measurements	1.54	0.54	0.75
Great Onyx Cave, Kentucky: (Sampled Aug. 3-4, 1976)			
1) NPS Measurements	0.89	0.75	0.82
2) MESA measurements	1.11	0.65	0.84
Wind Cave, South Dakota: (Sampled June 7-10, 1976; all tour routes included here)			
1) NPS Measurements	0.29	0.06	0.18
2) MESA Measurements	0.36	0.03	0.18
Jewel Cave, South Dakota: (Sampled June 8-9, 1976; all tour routes included here)			
1) NPS Measurements	0.27	0.07	0.24
2) MESA Measurements	0.66	0.10	0.32
Big Horn Cave, Montana/Wyoming: (Sampled by MESA June 29, 1976)	0.73	0.36	0.52
Features at Wupatki/Sunset Crater, Ariz.: (Sampled June 30-July 1, 1976)			
1) Blowholes	0.25	0.07	0.14
2) Earthcracks	0.55	0.05	0.32
3) Ice Cave	Trace	Trace	Trace
Selected Caves at Grand Canyon Nat'l. Park: (Sampled July 7-16, 1976)			
1) Stanton's Cave	3.28	1.08	2.05
2) Bat Cave	3.45	0.95	2.50
3) Sand Cave	0.27	0.21	0.23
Crystal Cave, Sequoia National Park, Ca.: (Sampled Aug. 8-9, 1976)	1.88	0.43	0.86
Lava Tube (Valentine) Cave, Lava Beds National Monument, California: (Sampled Aug. 10, 1976)	0.09	0.03	0.06
Oregon Cave, Oregon: (Sampled Aug. 11-12, 1976)	0.38	0.02	0.21
Timpanogos Cave, Utah: (Sampled Aug. 13-14, 1976)	0.08	Trace	0.03
Lehman Cave, Nevada (Sampled Aug. 15-16, 1976)	1.40	0.08	0.55
Carlsbad Caverns, New Mexico: (Sampled Aug. 24-26, 1976 by MESA and NPS)			
Toured Areas Open to Visitors:			
1) Main Corridor and Scenic Rooms			
NPS Measurements	0.33	0.24	0.30
MESA Measurements	0.38	0.24	0.30
2) Big Room			
NPS Measurements	0.36	0.28	0.33
MESA Measurements	0.41	0.31	0.38
3) Lunch/Pump Room			
NPS measurements	0.40	0.38	0.39
MESA Measurements	0.39	0.31	0.35
Non-toured Areas, Closed to Visitors: (Lower Cave, New Mexico Room, and Lefthand Tunnel)			
NPS Measurements	0.96	0.21	0.55
MESA Measurements	0.92	0.09	0.40
New Cave, New Mexico: (Sampled Aug. 25-26, 1976)			
1) NPS Measurements	0.24	0.21	0.23
2) MESA Measurements	0.28	0.17	0.24
Spider Cave, New Mexico:			
1) NPS Measurements	0.47	0.19	0.37
2) MESA Measurements	0.51	0.20	0.37

Figures 1 and 2 (drawn from Table 1 data) suggest seasonal variations based upon the initial data obtained in this investigation to date. From these results it is hypothesized that all caves having minimal man-made disturbances such as tunnels, elevator shafts, bore holes, sealed and closed gates, etc., which would alter the natural cave airflows, experience seasonal variations in airborne alpha radiation. (Also see data from one year's measurements at Carlsbad Caverns in the paper by Dr. Gary Ahlstrand and Mrs. Patty Fry). The radiation levels increase in summer but decrease in winter, based upon natural air movements through each cave system. However, the reasons for these seasonal fluctuations depend upon the general cave type of physical configuration and its control of the airflows.

Thus of particular importance to the exposure rates in natural caves are the natural ventilation patterns. These airflows are the only means by which the radiation is dissipated or concentrated. In mines, forced air ventilation is used to minimize the airborne alpha radiation in order to meet the health standards. In caves, although this type of radiation is usually much less, it is not possible to use artificial ventilation because of the adverse effects upon the microclimates of the caves. John McLean of the U.S.G.S. has shown this by his studies at Carlsbad Caverns.

Two general types of cave configurations have been identified for the purpose of relating natural cave airflows and resulting airborne alpha radiation levels. Figure 3 shows these. The measurement of radon daughter radiation levels serves as a useful means to describe airflow patterns, in addition to employing the methods of fluid mechanics.

The two general results of analyzing the data (see Figures 1 and 2 and the paper on Carlsbad) obtained to date comparing *upside-down* (USD) and *right-side up* (RSU) cave airflows and ventilation (only on the toured routes) are:

1. Measurement of the airborne alpha radiation in caves must be accompanied by airflow and meteorological measurements to describe the physical microclimate characteristics of each cave and to relate these to the outside meteorological patterns of the area in which the cave is located. The two—radiation and airflow—are inextricably linked and complementary. Indeed, radiation is a "tracer" for airflow and indicates its general tendencies.
2. Both general configurations of caves experience increased radiation concentrations in the summer, compared to the winter, in an overall sense, but for different reasons which have been hypothesized for the limited data. In upside-down caves, this summer

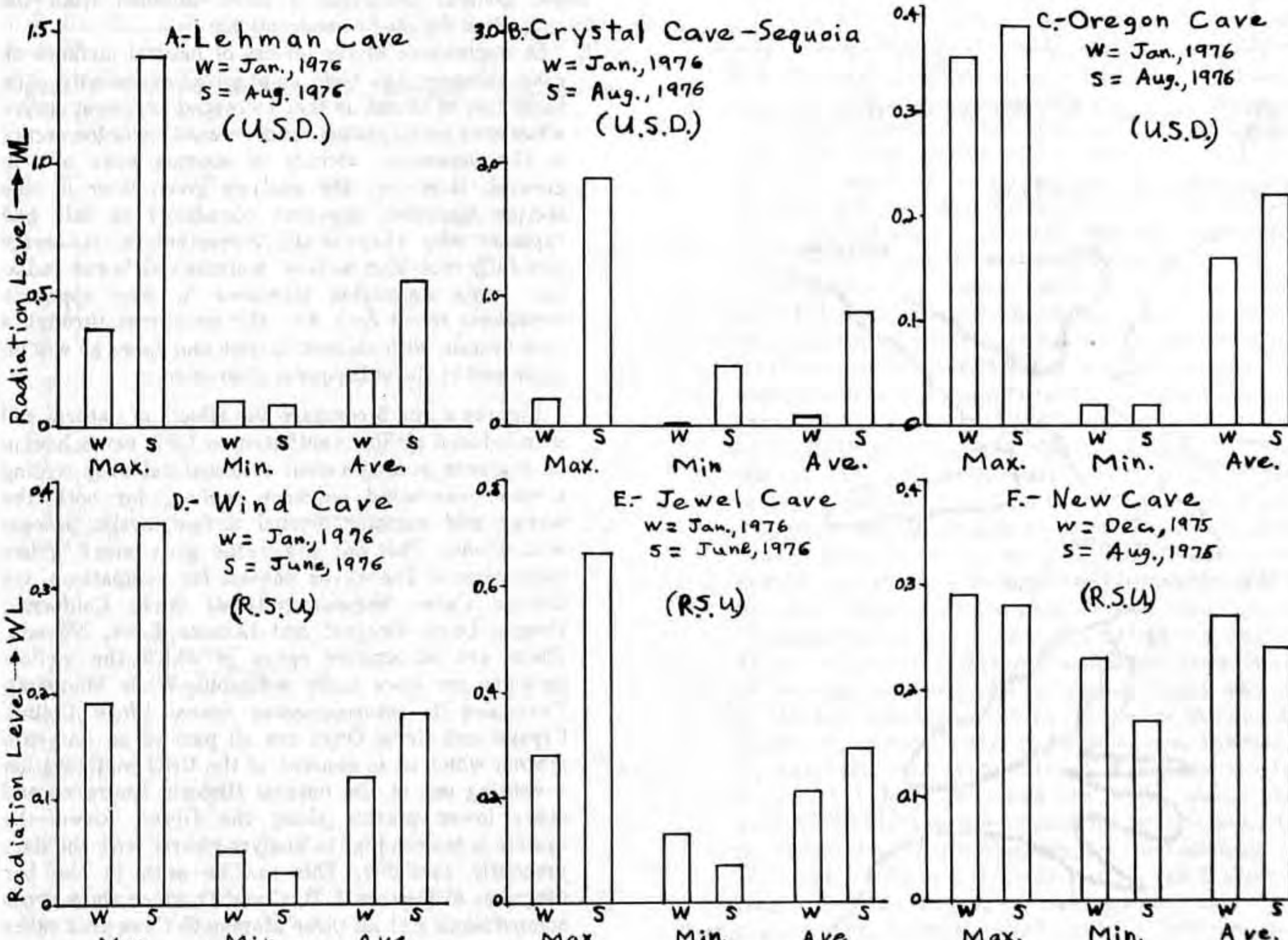


Figure 1. Extrema and Averages, by season, for NPS caves—Radiation.

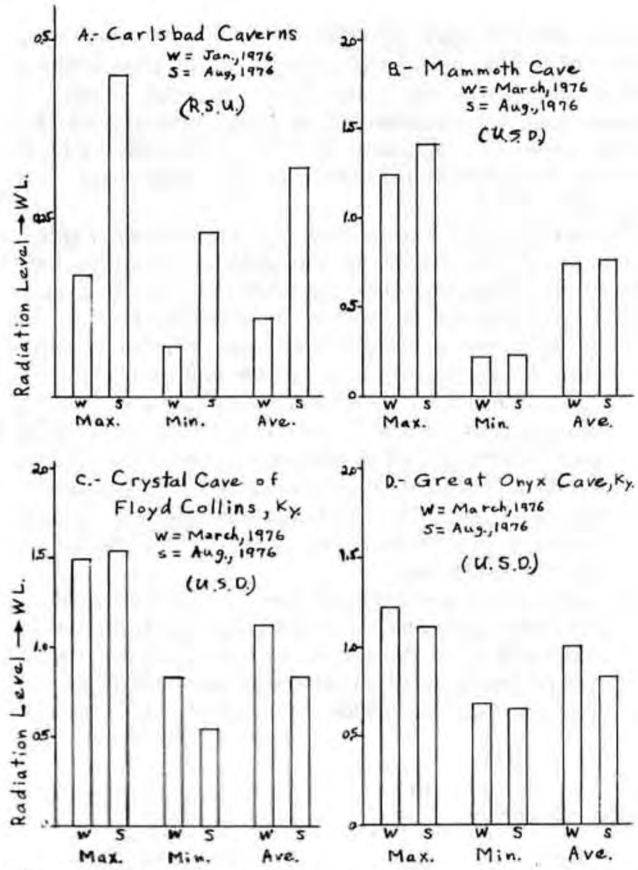
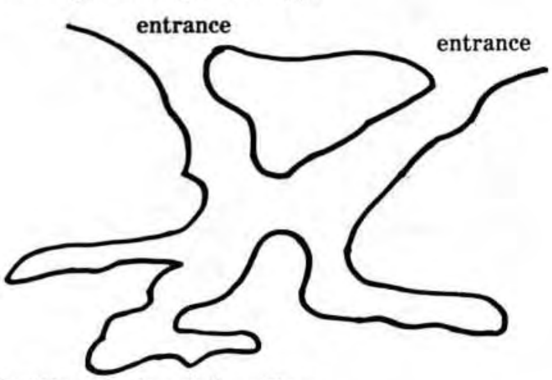


Figure 2. Radiation Extrema and averages, by season, in NPS caves.

A. "Right-side-up" Cave Type



B. "Up-side-down" Cave Type

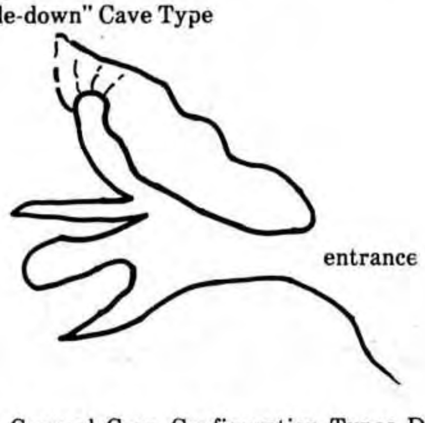


Figure 3. General Cave Configuration Types Determining Natural Airflows

increase is produced by air flowing out of such caves' lowest portal(s)—usually in a diurnal cyclic process. In right-side up caves the summer increase is due to the fact that the air does not flow. This is not a paradox, however—simply a result of the physics of each situation. In general, therefore, all caves of whichever configuration experience increases in airborne alpha radiation in the summer compared to the winter, as long as there has been little or no man-induced disturbance to the caves' airflow patterns.

Interesting diurnal as well as seasonal interactions of airflows and radon daughter levels have been observed to date in three USD type caves: Lehman, Oregon, and Crystal in Sequoia. Similar data for such USD caves as Mammoth and the several connected to it: Floyd Collins' Crystal, Great Onyx and New Discovery have yet to be obtained. Also, data for RSU caves such as Wind and Jewel, Carlsbad Caverns, and New Cave are not fully available as yet. Work on this is proceeding in order to test the hypothesized seasonal radiation/airflow behavior of USD *vs.* RSU caves. In addition, the initial data already taken at Mammoth and its connected caves and at Oregon Cave show the effects of human management actions.

The thoron daughter radiation levels in all NPS caves were found to be negligibly small as far as any health problem potential.

These general observations were obtained from the following more detailed considerations:

1. The importance of the effects of natural airflows on cave radiation has been emphasized repeatedly. The basic rule of thumb is that increased radiation occurs when cave air stagnates but decreased radiation occurs in the *immediate* vicinity of moving cave air, in general. However, the analysis given later in this section describes apparent paradoxes to this and explains why they occur. Nevertheless, it seems generally true that airflow decreases airborne radiation while stagnation increases it. Any apparent paradoxes result from *how* the air moves through a cave system with respect to time and space as will be explained in the subsequent discussion.

Figures 4 and 5 compare the effects of natural and man-induced airflow ventilation in USD caves having no entrance sealing *versus* seasonal entrance sealing *versus* year-round entrance sealing, for both the winter and summer diurnal airflow cyclic process situations. The bar diagrams give more gross comparisons. The caves chosen for comparison are Crystal Cave, Sequoia National Park, California; Oregon Cave, Oregon; and Lehman Cave, Nevada. These are all smaller caves in which the airflow patterns are more easily definable. While Mammoth Cave and its interconnected caves: Floyd Collins' Crystal and Great Onyx are all part of an immense system which is, in general, of the USD configuration —venting out at the natural Historic Engrance and other lower portals along the Green River—the system is too complex to analyze clearly with the data presently available. This can be seen in the bar diagrams of Figures 2, B, C and D which show gross comparisons. For all three Mammoth Cave area caves the extrema are about the same in winter and in summer, except the minima for Crystal where the summer value is much lower than the winter value.

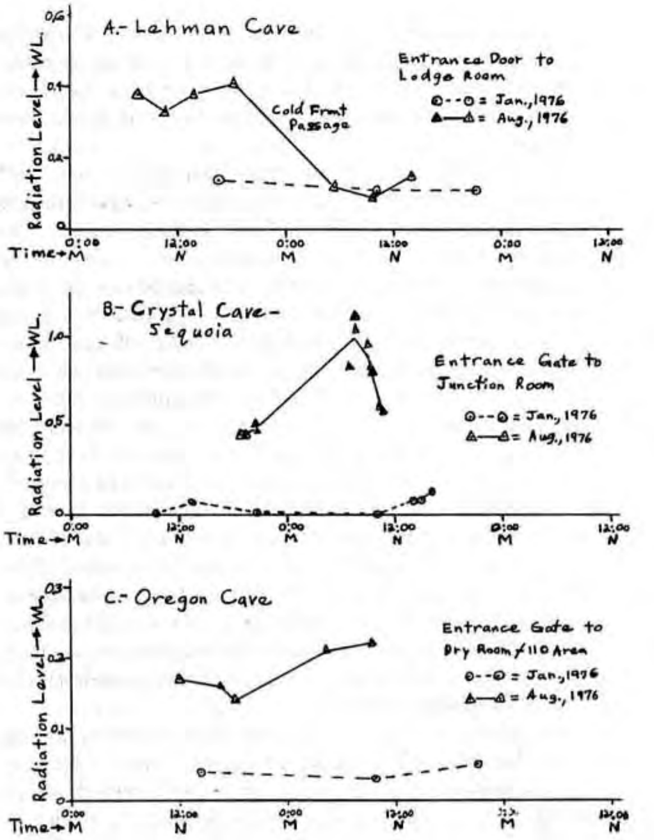


Figure 4. Seasonal and diurnal radiation variations in U.S.D.-NPS caves.

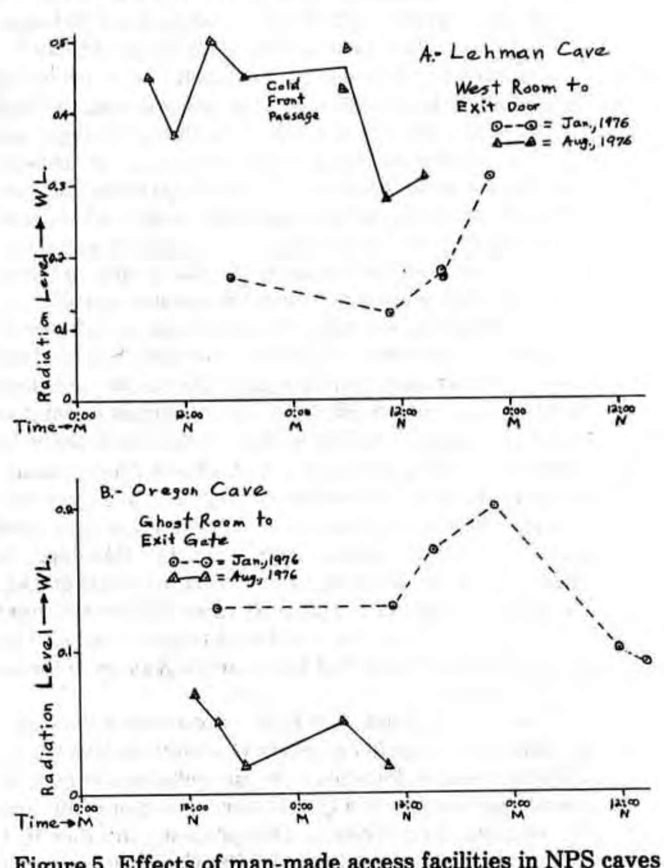


Figure 5. Effects of man-made access facilities in NPS caves on radiation with seasonal and diurnal variations.

However, although the averages for Mammoth are about the same, with the summer only slightly higher than the winter, the summer averages for both Floyd Collins' Crystal and Great Onyx are lower than the winter averages. All three of these vent out through their portals, though the entrances at at Crystal and Great Onyx are solid doors which provide considerable sealing effect. The Historic Entrance at Mammoth is sealed by a sheet metal covering attached to its gate from about late October to mid-April each year. This reduces the natural airflow regime and elevates the winter radiation levels.

2. The management procedure at Oregon Cave and Mammoth Cave (both USD) is to put up seals over the entrances and exit doors in mid-fall and remove these in mid-spring each year. This minimizes the cold airflow and resulting chill of visitors. As a result, the winter and summer radiation levels are about the same, even though the airflows are much greater in summer than in winter. These outward airflows mobilize radiation materials from much greater extents of the caves' systems in summer than in winter. However, the sealing doors decrease the inward flow in winter, when airflows mobilize radiation materials from lesser extents of the caves' systems. Thus, this sealing action permits radon daughters to approach equilibrium more closely and to elevate the radiation levels so that the summer values are approached. Because Floyd Collins' Crystal Cave and Great Onyx Cave are both connected by a vast (some 180 mile) cave system to Mammoth Cave and because both caves have solid steel doors which produce partial air seals in their entrances, their winter values actually exceed the summer values in an accentuated example of the "sealing" effect of door covering. The entire system drains air downslope to the natural ("Historic") entrance to Mammoth and to the Green River.

Crystal Cave in Sequoia has only one year-round unsealed portal but outside air can enter its upper reaches through fissures. It has a short tunnel in its inner reaches but this has not altered the general, natural airflow patterns appreciably. Oregon Cave has two entrance portals and one man-made exit tunnel portal, each of which was sealed during the winter months but not in summer. Lehman Cave has man-made tunnels at both its entrance and exit. These are closed by pairs of solid doors at each end of each tunnel. These are fairly airtight. This minimizes the disruption of the natural airflow patterns. The natural discovery entrance at Lehman is not sealed and various fissures and blowholes also still permit air fluxes. Thus, the original airflow and venting characteristics of Lehman Cave are probably not too greatly altered by the two man-made tunnels, because of the double doors. This is *not* the case at Oregon Cave, however; because the man-made tunnel was unsealed in warmer weather and forms the major portal for airflows to enter the cave system and to flow downhill inside the cave; thereby flushing out the radiation.

The bar diagrams in Figures 1, A, B and C show a large increase in summer radiation for both the maxima and average values at both Lehman and Crystal Caves, compared to their winter values. This is not true for Oregon Cave, which had the pronounced man-made tunnel induced airflow effect in summer. This effect was greatly precluded in winter by sealing all the cave's portals—the two natural entrances and the exit tunnel gate. By contrast, the double doors on most airflows year-round and cause it to act very much as an undisturbed cave, such as Crystal Cave in Sequoia is.

Though the air can move into each of these three caves, especially in the summer in a more extensive way than in winter, the existence of the exit tunnel at Oregon Cave promotes flushing out of the radiation materials in summer, but not in winter when it was sealed. Therefore, the average and maximum summer levels are slightly increased. While this increase is small, it still indicates the trend and tendency of all USD caves left in their basically natural state to show increased summer levels. However, the radiation levels rise dramatically in both Lehman and Crystal caves in summer because air continuing to move into the upper reaches of each tends to become ladened with radiation, which fluctuates in level as it is affected by the diurnal airflow cyclic process. The minima rise in Crystal but fall slightly in Lehman from winter to summer due to differences in the effectiveness of the overall airflows. Thus, the radiation levels rise in evening, at night and early morning during the summer but are flushed out and fall in late morning, during the day and sometimes into early evening. Figure 4 shows this as well. Figure 5 emphasizes the effect of sealing the portals at Oregon Cave by showing that the *winter* levels exceeded those of summer. This is the only instance of such a "reversal."

Nevertheless, the overall effect of the daily airflow cycle is to *increase* the summer radiation levels over those in winter in caves for which the basic natural flow patterns have not been altered by man. This was precluded at Oregon Cave due both to the existence of the man-made exit tunnel and the management decisions to seal it in winter but open it in summer. At Lehman Cave, the natural airflow processes (and probably the natural microclimate) of the cave are basically undisturbed by the two man-made tunnels which remain sealed at all times. The main advantage of the operation at Oregon Cave seems to be to suppress the radiation level in the summer below the values which it might attain. (This also enhances bat access.) However, this may be at the expense of the cave's natural integrity: its microclimate. All of this shows man-caused effects *versus* those which are natural. Comparison of Figures 1, A, B and C and 4, A, B and C shows this most clearly. In Figure 5 the summer values are actually below those of winter due to the strong and continuing air inflows at the exit gate.

3. In the winter time at such USD caves as Lehman and Crystal in Sequoia, and Oregon too, the airflow is much less. It occurs to some extent in the mid to late afternoons of warm, sunny days. This begins the overall cyclic process, but it is shifted in time in winter compared to summer (see Figures 4 and 5). In winter the outcast airflows and resulting *increases* in radiation do not occur until late afternoon and early evening. The rise in radiation does not last very long before the outside air cools below the cave air temperature and outside air then flows into the cave, diminishing the radiation in the areas closest to the portals through which the air is moving. The toured parts of the three caves discussed here lie in these areas of diminished winter radiation.

In summer, the airflow process at the three USD caves begins earlier in the day, and lasts much longer (see Figures 4 and 5). However, the overall pattern of cyclic airflow from stagnation, to increase, to stagnation again (or, instead of stagnation, perhaps very low airflows, either incast or outcast depending on the cave) causes the typical cycle of radiation: decrease into late morning or early afternoon to even early evening, with an increase from night to early or even mid-morning. The differences; as shown by comparing Figure 4 A for Lehman Cave, with Figure 4 B for Crystal Cave in Sequoia, and with Figure 4 C for Oregon Cave; are due to the unique characteristics of each, but the basic fall-rise-fall rhythm of the airflow induced radiation level fluctuations can still be seen. This persists even after the cold front passage at Lehman altered the radiation levels. This front changed the outside weather from hot summer to crisp spring, though sunshine persisted throughout both the two August days, 1976.

All very good—but how come the summer radiation levels in these USD caves are higher than in winter, just as occurs in RSU caves, such as Carlsbad, Wind and Jewel? In USD caves it appears that the radiation levels increase in summer because of the strong airflow, but in RSU caves it appears that the radiation levels also increase in summer, but because the air tends to stagnate (except for weather front passages which may induce some airflows). How can this be?

The seeming paradox is explained by considering *how* the air tends to flow in each general cave configuration type: USD *versus* RSU. In the USD type, the airflow process is *cyclic and unsteady*, in general (except as perturbated by weather systems inducing pressure changes and thus, pressure produced airflows superimposed on the cave's general gravity airflows). However, in winter these cyclic flows are of short duration and occur only near the cave's portal(s). In winter, although air may sink into the caves upslope, it takes it a long time; *i.e.*, perhaps several days of cyclic actions, which may be interrupted by cloudy weather; to travel to the portal(s). Thus, the airflows mobilize small total amounts of Rn in winter and move these to the toured areas where the measurements are made. Therefore, even if in radioactive equilibrium, per unit volume, the *concentration* (*i.e.*, radiation per unit volume of air in pCi/l) *levels* are less. However, in summer, air moves from the extremities more quickly bringing greater *total* quantities of radiation in shorter time periods to the toured areas. Hence, the concentrations measured there are higher in summer than in winter.

On the other hand, the RSU cave types have more *sustained and steadier airflows* in winter because then the colder more dense outside air sinks into the cave, displacing comparatively warmer, less dense air and flushing out the radiation. This process continues in a long-term fashion (as shown by the Carlsbad paper by Ahlstrand and Fry) so that the winter radiation levels are lower than in summer. Indeed, the airflow in RSU caves can be greater at night than in the daytime since the outside air temperature is lower at night. In summer, the reverse of this process occurs, and the cave air, being comparatively colder and denser than the outside air, tends to stagnate. Hence, the radiation levels can build up and become higher than in winter (see Figures 1, D, E and F and 2A for example). Of course, as in USD caves, the effects of passing weather fronts can perturbate a RSU cave and produce airflows in summer which overcome the stagnation to some extent. In winter, these can augment the gravity flows and depress the radiation levels further. Indeed, it can be speculated that the fluctuations on long-term plots might be the superposition of pressure produced airflow/radiation level oscillations on the long-term gravity airflow/stagnation situation.

Therefore, the basic radiation/airflow difference for the two cave configuration types, USD *versus* RSU, is due to how the air moves with respect to time and over space. Both cave types experience increased summer radiation levels, but for different physical reasons. The only exception is a cave, such as Oregon Cave, which is affected by man-made portals and/or management procedures. Figure 5 emphasizes the effect of sealing in winter because then the radiation near the exit is less than in summer (despite any air leakage which may occur through the winter seal). Comparing Figures 5 A and B, the winter increase in the latter is due to the sealing effect whereas the winter decrease in the former is due to outcast air leakage in winter.

Therefore, in general, airflows tend to reduce radiation levels in localized areas and short times in all caves, but long-term seasonal effects are produced by cave configuration. Conversely, localized stagnation of air in all caves leads to localized, short-term radiation level increases, but long-term seasonal effects again result from cave configuration. Paradoxically, increases occur in summer in all caves: because the air flows in the USD type and because it does not flow in the RSU type. It is all a matter of configuration and season. Further work on this, especially making radioactive equilibrium and age of air measurements as well as radiation observations seasonally and over time at different places in the caves is needed for more complete confirmation of these ideas.

4. The bar diagrams for all four RSU caves show the RSU cave radiation level seasonal fluctuations. This has already been described above. The bar diagrams, Figures 1 D and 1 E, show that although the summer average and maxima exceed those for winter, the summer minima are less than the winter minima in Wind and Jewel Caves. This suggests that the pressure produced airflows in certain parts of each cave produce the lower summer minima because they are greater than in winter. The situation at New Cave, Figure 2 F, is not understood—as to why all its winter values exceeded those of summer. Although a RSU cave, perhaps it has some special, as yet undetermined, airflow situation. Nevertheless, the W and S values are about the same. Perhaps air pressure effects caused these results, which more complete data analysis can clarify. Whether there is any diurnal cycling remains to be shown by future work. Perhaps data plots such as Figures 4 and 5 will result. If so, this would suggest that pressure induced airflows in RSU caves can produce radiation level fluctuations similar to the temperature induced gravity flows of USD caves. Wind Cave and Jewel Cave have RSU configurations and outward venting at their portals which is produced primarily by pressure effects of passing large-scale storm frontal systems in the outside atmosphere. Secondary effects of venting stem from seasonal outside air temperature changes and resulting air movements into the cave, as at Carlsbad Caverns. These frontal systems cause strong outcast airflows through the portals of both these caves, especially Wind Cave (hence its very appropriate name). This is how it was discovered. Long-term radiation data will be useful in establishing seasonal trends. These data, along with meteorological measurements, will be made in future work starting in mid-December 1976. The detailed effects of passing frontal systems can then be quantified, hopefully. The seasonal variations at Wind and Jewel Caves show that summer maxima and average levels exceed the winter values in these caves, but that the summer minima are less than the winter minima for each cave. All this is reasonable because the RSU configuration produces summer stagnation situations and the resulting buildup of radiation materials which are not vented out as often as during the winter. Thus, the higher maxima and overall averages. However, the frontal system pressure fluctuations tend to be stronger in the summer, so that the minima are lower than in winter in some parts of these caves due to more efficient flushing when pressure airflows *do* occur in the summer. Carlsbad Caverns, also a RSU cave, is subject to the passage of frontal systems. However, much of the variation in its radiation levels is produced seasonally by outside to inside air temperature differences. In late fall, winter and early spring the outside air temperatures are less than the cave air's year-round average of 56°F. The cooler, more dense outside air sinks into the cave through its portals and fissures and displaces the warmer cave air. This leads to venting and a reduction of the radiation level. In warmer seasons, especially in summer, the outside air is warmer and less dense than the cave's air. Therefore, no density induced displacement occurs and instead the cave's air tends to stagnate. The radiation levels tend to rise. Only the effects of weather frontal systems passing with resultant air pressure pulsing will cause venting during the warmer seasons.

5. The airflow from both Mammoth Cave and Carlsbad Caverns had at one time been used to air condition surface buildings. This practice has been terminated to preclude adverse effects on the caves' microclimates and to eliminate airborne alpha radiation in these buildings. Carlsbad behaves in the expected RSU manner with summer increases in radiation. The situation at New Cave is not clear. Although it is RSU, its entrance is not sealed. The data here are limited as yet. All of this (see Figures 2, A, B and C) shows the effects which man's interference and/or management activities has on caves—using the airborne radiation/airflow observations as a yardstick. This sealing activity also affects bat access.

6. The general airflow pattern shows outcast flows through the natural Historic Entrance of Mammoth Cave and the entrances of other nearby caves, (Crystal, Great Onyx, etc.) of any size during the day when the cooler cave air is denser than the warmer outside air. The main flow is out the Mammoth Cave entrance. This gravity flow indicates that the overall Mammoth system *is* an USD cave of immense proportions, sloping down elevation gradient to the several portals in the park. Its known physical configuration supports this. This outward venting is very strong during the warmer days of summer, but is lessened during the passage of cold fronts.

   The flow patterns must be defined in much more explicit detail in order to describe the complex situation. This will be done using meteorological equipment. The levels increase somewhat in summer in some areas but decrease in others, as compared with winter values, due to airflow. Nevertheless, the overall tendency seems to be an increase in winter and a decrease in summer in Crystal and Great Onyx Caves which are less well vented in winter, but little change in the overall levels at Mammoth Cave due to sealing.

   The permanent personnel at Mammoth Cave have been rotated as to work area assignments to reduce cumulative exposures. Most spent the summer working above ground while seasonal personnel conducted tours or worked at various stations underground on the self-guided tour routes.

7. Wind and Jewel Caves (both RSU) are of the "down-into" type, as their physical configurations show. The wind movements are attributed by NPS staff at each cave more to the passage of weather frontal systems with the accompanying outside atmospheric pressure fluctuations than to the configuration of the caves. Thus, the flows are more pressure gradient induced than being solely gravity flows. Meteorological equipment will be used to check the inside and outside conditions in these caves in order to quantify the airflow patterns and behavior.

   Although the data of early June 1976 probably are not representative of true summer conditions, they do show a general increase over the winter values of January 1976. Airflows are due to the combined interactions of outside pressure effects and the overall RSU configuration of both caves. The flows out from the portal of Wind Cave are especially strong; hence its name. These may tend to suppress the radiation levels at both caves in the summer, especially in Wind Cave (see Table 1), though the increase of summer over winter values still occurred. Therefore, neither could be of the USD type. See Figure 1 for seasonal changes.

8. The outcast airflows of Crystal Cave in Sequoia (USD) increase during the day and decrease at late night and very early morning in summer. The radiation is flushed out by mid-day and the levels fall and remain low until late at night when the outside air cools and the outcast airflow diminishes. This same diurnal cycling process was observed to some extent in the winter on warm, sunny afternoons, but is very pronounced during the summer. It is interrupted only by the passage of cold fronts, but is reestablished in a day or two of subsequent clear weather. This is the same as also observed at Mammoth Cave, where it is on a much larger and more complex scale.

9. At Oregon Cave (USD), because the entrance and exit portals were sealed in winter to preclude the entry of cold airflows, the airborne radiation levels in parts of this cave tended to rise. Airflows do develop in winter to some extent on warmer sunny late mornings and afternoons. However, in summer the sealing covers were removed from all the portals so that the airflows increase. This flushes out the radiation in a diurnal cycling process similar to that of Crystal Cave in Sequoia. Therefore, the management decision on sealing or not sealing the portals greatly affected the radiation levels. It can only be speculated as to how high the radiation levels might become in the summer if the portals remained sealed. However, if the seals remained on in summer, the levels might exceed 0.30 WL considerably in some parts of the cave's toured regions, based on the winter and summer (early morning with no airflow) data. Keeping the seals on would also tend to reduce evaporation in the cave, which no doubt affects its microclimate. Studies at Carlsbad Caverns have shown that man-induced airflows will have these effects. At Oregon Cave, the man-made exit tunnel seems to enhance the airflows through the entire cave considerably, especially during the summer when it was unsealed. On the other hand, unsealing does not seem to produce airflows from a greater extent of cave, as happens at Sequoia's Crystal Cave. Thus, the levels at Oregon would not rise much in summer, indicating a smaller cave system.

10. Lehman Cave (USD) has greater diurnal cyclic venting and radiation level fluctuations in the summer than in the winter. The man-made entrance and exit tunnels are sealed by double doors (one at each end), so that these are fairly airtight. Also, several blowholes and the natural "discovery" entrance permit air to flux in and out of the cave system. Therefore, it behaves similarly to Crystal Cave in Sequoia with radiation level buildups during the night in summer and a flushing out decrease during the day. The winter seems to be the reverse of this in general, though the overall radiation levels are less in winter than in summer. (See Figure 1 A.) Meteorological equipment is being obtained to evaluate these processes for Lehman Cave. Cold front passages alter the diurnal cycling of the summer by affecting the airflows. Therefore, part of the airflows is probably an interaction of pressure effects and seiching with the gravity flow.

11. Little radiation has ever been found at Timpanogos Cave, though its summer values (not plotted) are somewhat higher than in winter. Its configuration is neither RSU nor USD, but is more "straight through"; being located on a mountainside, it parallels a deep creek ravine, but has little elevation change throughout its length. Air moves through it readily, flushing out any radiation. Nor has any appreciable radiation been found in volcanic areas (as the lava tube caves at Lava Beds in California, or the ice cave in the lava flow at Sunset Crater in Arizona), though thermal areas such as Hot Springs in Arkansas (data not shown here) have high radon daughter levels in *enclosed* cisterns. This dissipated quickly in the open air. (Yellowstone's

thermal formations have yet to be observed for airborne radiation.)

12. The thoron daughter levels traces to very low in all NPS caves investigated. Hence, this source of alpha radiation is no problem to health.

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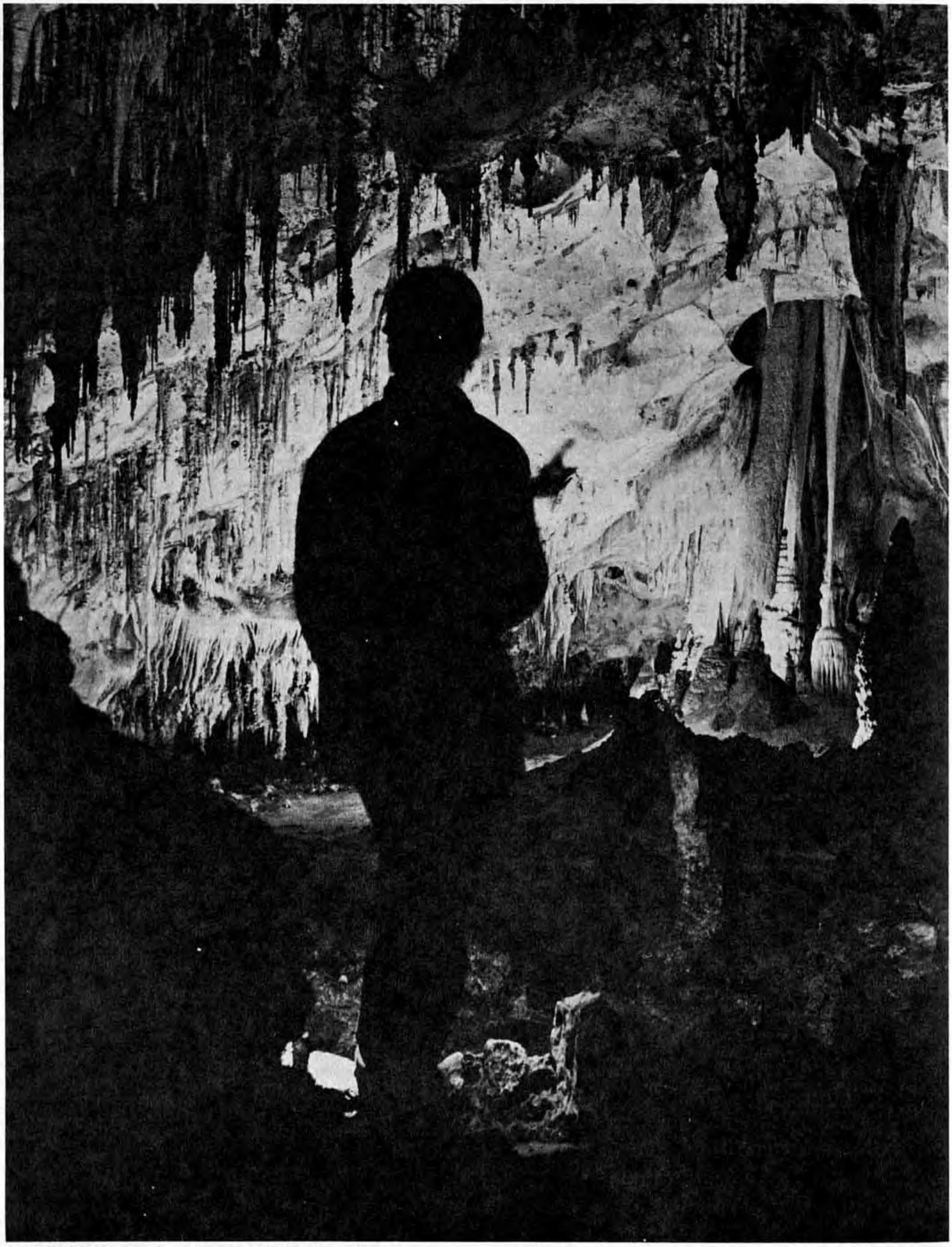

Carlsbad Caverns. *Photo by Don Martin.*

Alpha Radiation Associated Studies at Carlsbad Caverns

Gary M. Ahlstrand *

ABSTRACT

The presence of radon and its radioactive decay products in Carlsbad Caverns was first publicly reported at the National Cave Management Symposium held last year in Albuquerque, New Mexico. How awareness of the problem evolved and steps that have been taken to characterize the nature of the problem are presented in this paper.

Assistance and advice were sought from various sources. Instruments and monitoring equipment were borrowed from the Mining Enforcement and Safety Administration (MESA), the Bureau of Mines, and the Environmental Protection Agency. An extensive radiation survey of the cave was conducted with personnel from MESA's Denver Technical Support Center.

In addition to a routine monitoring program, radon and radon daughter levels are measured periodically in non-developed portions of the cave. A Geiger-Mueller counter and a portable ultra-violet lamp have been employed in a search for possible sources of radiation. The effect of additional condensation nuclei on radon daughter levels in the cave was the subject of another study. Pulmonary cytology examinations have been conducted on long-term underground employees.

Currently, records of radon concentrations in the cave are being compared with radon daughter levels, cave carbon dioxide concentrations, barometric pressure, and temperature differentials in an attempt to better understand both short and long term fluctuations in alpha levels.

A 1968 article by Richard L. Breisch reviewed the occurrence of natural radiation in underground cavities. Much of Breisch's discussion focused on the presence of radon and its decay products in caves. Today the paper serves as the classic paper of the time on cave radiation. At the time of its appearance, however, it apparently gave little cause for concern.

The Breisch paper did not go entirely unnoticed. Their curiosity aroused by what they had read, Jo Bob Trout and David Watkins, under the supervision of Marvin H. Wilkening, set about measuring radon 222 concentrations in Carlsbad Caverns and caves in the area during 1973 through 1975 (Trout, 1975; Wilkening and Watkins, 1975).

Radon 222 is a radioactive noble gas and is an intermediate in the natural decay of uranium 238 to lead 206. Being an inert gas, radon itself presents no great problem to individuals in cave environments. But as the gas decays, radioactive descendent products called radon daughters are formed and include isotopes of polonium, lead, and bismuth. When inhaled, some of the daughter products are retained for various lengths of time in the lungs and can irradiate epithelium of the respiratory tract.

Wilkening and Watkins report on their work at Carlsbad Caverns was received at the Carlsbad Caverns National Park Headquarters office on 12 June 1975. A copy of the report was sent that day to the National Park Service (NPS) Regional Office in Santa Fe. The findings, based on four different sampling times during a two year period, indicated that NPS personnel spending much of their tour of duty underground might be approaching the exposure limit set for workers in uranium mines (29 CFR 1910.96) if the radon daughters were in transient equilibrium with radon.

A follow-up memorandum sent to the Regional Office on 2 July 1975 again expressed concern stemming from results reported by Wilkening and Watkins. A meeting with the principal author of the report took place in Albuquerque on 30 July 1975. From the meeting it was determined that radon daughter concentrations in the cave should definitely be measured. However, the means for accomplishing this task were not immediately known.

On return to Carlsbad from the Albuquerque meeting, I launched a telephone search for information and aid pertaining to measurement of radon daughter levels. During the second day of the search the problem was explained to Tom Castor and Frank Csepregi, mine inspectors from the Albuquerque Field Office of the Mining Enforcement and Safety Administration (MESA), and they volunteered to check the cave for radon daughters.

While sampling at Carlsbad Caverns on the morning of 5 August, both MESA inspectors expressed several times, almost apologetically, that they did not believe their instruments to be sensitive enough for measuring the low levels of alpha emitters they expected to be present. When the count button was pushed with the first sample in place in the field alpha counter, numbered lights raced on and off indicating an activity of more than 150 counts per minute. Neither inspector appeared to be ready to accept this count.

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Connecting cables of the instruments were inspected for electrical shorts and loose connections and then the scaler was checked with an alpha source standard in the counting chamber. Total counts from the standard indicated that the instrument was operating within acceptable limits of accuracy. With the first sample in place once more, the count button was again pushed. About five seconds into the count, one of the inspectors advised that any cigarette smoking employees that worked in the cave should be urged to drop the smoking habit immediately.

Based on the findings of the MESA inspectors, a decision was made to establish a radon daughter monitoring program. This decision was made largely as a moral obligation to cavern employees, since no standards or regulations applying directly to this situation were in existence. Radiation standards written for miners (29 CFR 1910.96) were used as guidelines in establishing the cave monitoring program. Instruments and supplies were acquired on loan from various sources during the remainder of August 1975. Routine monitoring commenced in September 1975 at Carlsbad Caverns and New Cave along with maintenance of employee exposure records. Meetings were held with employees for the purpose of explaining why the monitoring program was being instituted.

This was the status of the investigation when it was reported publicly for the first time at the 1975 National Cave Management Symposium (Van Cleave, 1976).

With the monitoring program in operation, attention turned to certain basic problems such as identifying the source(s) of radon, determining radon daughter to radon ratios, and tracing ventilation patterns within the cave. MESA's Denver Technical Support Center (DTSC) was asked to conduct a radiation survey at Carlsbad Caverns. Robert Rock, Chief of the DTSC Radiation Group, responded to this request by sending Robert Beckman, Don Rapp, and Lyle Rathbun to the cave to conduct the survey during the first week in November, 1975. Radon daughter levels were measured according to the Kusnetz method (Holaday, 1974). Thoron daughter concentrations were determined using a method described by Rock (1975). Gamma radiation in representative portions of the cave were measured with a sensitive X/gamma survey meter. Air samples were collected in Lucas flasks and measured for radon levels using a special low-level alpha-scintillation counter (Lucas, 1957). Radon concentrations were also determined according to the two-filter method (Beckman, 1975) and condensation nuclei concentrations were measured concurrently. Unattached radon daughters (free ions) were sampled using a 60-mesh wire screen filter (Holaday, 1974). Individual levels of polonium 218, lead 214, and bismuth 214 were determined according to the Tsivoglou method as described by Thomas (1972). Water samples from various locations within the cave were analyzed for radium and radon following methods described by Misaqi (1975). Solid samples from the cave were analyzed by the Denver Mining Research Center (DMRC), U. S. Bureau of Mines, by gamma ray spectroscopy for thorium, uranium, and potassium. Finally, several air samples from the cave were analyzed by gas chromatography for carbon dioxide, carbon monoxide, oxygen, and methane concentrations. When this survey was completed, the Radiation Group left much of their equipment for use by NPS personnel in acquiring additional data.

The radiation survey showed that gamma radiation, and concentrations of thoron daughters, free ions, and condensation nuclei were all relatively low. The ratio of radon daughters to radon was much lower than had been anticipated. Some of the water samples contained high concentrations of radium 226 and radon 222, but because of the small quantitites of water in the cave these sources were considered as minor contributors to the over-all concentration of radon in cave air. All solid samples demonstrated some radioactivity, but the levels were extremely low. Analysis of the air samples showed neither methane nor carbon monoxide to be present, oxygen concentration in all air samples exceeded 20 percent, and carbon dioxide averaged about 700 parts per million.

At the suggestion of the MESA Radiation Group, arrangements were made for a limited number of employees to participate in a pulmonary cytology examination. Sputum samples from 15 participants that had been employed in the cave for between 4 and 24 years were sent to the laboratories of Saccomanno, Saunders, and Klein at St. Mary's Hospital in Grand Junction, Colorado, for cytological examination of pulmonary cells contained in the cough specimens. Participants included both smokers and nonsmokers. Eighty percent of the participants were found to have some degree of metaplastic pulmonary cells present in their samples. No conclusions concerning the reason(s) for the apparently high incidence of squamous cell metaplasia could be stated on the basis of the initial study due to the sample size, sampling methods, and the absence of a control group. The study did suggest the need for a more thorough folow-up study.

Upon receipt of the MESA radiation survey report in December, 1975 (Beckman, *et al.*,) the Environmental Protection Agency (EPA) and the Occupational Safety and Health Administration (OSHA), U. S. Department of Labor were advised of the problem and asked for recommendations. The EPA replied that, in their opinion, the radiation levels involved do not represent a significant health hazard to visitors. A notice to this effect appeared in the 3 June 1976 Federal Register (Strelow, 1976).

An OSHA representative from the Regional Administrative Office in Dallas visited Carlsbad Caverns on 2 February 1976 to observe procedures used in the monitoring program and to become more familiar with the problem. In addition to measures already instituted at the time of his visit, the OSHA representative suggested that the National Institute for Occupational Safety and Health (NIOSH), Department of Health, Education and Welfare be requested to conduct a health hazard survey. In June 1976 an expanded pulmonary cytology study was initiated at Carlsbad Caverns by NIOSH personnel. A complete summary of this study is not yet available, but initial indications are that atypical cells are common. Comparisons with results from participants at other NPS administered caves and with a control group are still to be made.

During May 1976 a continuous radon monitor was placed in the Pump Room area of Carlsbad Caverns by personnel from the DMRC. Other monitoring devices have been or are being tested at the cave. NPS personnel added a recording barograph and an infrared carbon dioxide analyzer to the monitoring instruments in the Pump Room. A beta-gamma instant working level monitor was supplied by the DMRC and installed by DTSC personnel in the Pump Room, utilizing an NPS portable scaler. In addition, the NPS is cooperating with the EPA in testing some of their radiation detection devices in the Big Room and Pump Room areas of Carlsbad Caverns.

Personnel from the Radiation Group of MESA's DTSC returned in August for a second radiation survey. As expected for this time of year, measured radon and thoron daughter concentrations were higher than those found during the first survey (made in November, 1975). The unattached daughter percentages were also higher than those measured during the first survey. The MESA personnel ran tests in the Pump Room on a personal alpha radiation dosimeter being developed in their Denver laboratories.

Much of the cave has been examined with a portable ultra-violet lamp for possible concentrated sources of radiation. Nothing significant has thus far been detected.

Evidence to date suggests that the source of radon is probably from minute quantities of radium present in limestone formations, sandstone, clay, and other materials in the cave. The highest levels of radon daughters have been found in nondeveloped, seldom-visited sections of the cave. The New Mexico Room, a rather isolated section of the cave, has radon daughter concentrations characteristically higher than those found in most other areas of the cave. The highest levels detected are consistently from a certain segment of Lower Cave in Carlsbad Caverns. Although some sections of the cave may contain more radioactive material than others, the variations in radon daughter levels from one section to another are believed to be caused primarily by differential air exchange rates.

Radon daughter levels for regularly monitored sections of the cave show seasonal fluctuations. These levels follow the same general curve formed by a plot of minimum daily temperatures. Practically all sections of the cave lie below the known entrance. Air in any section of the cave is at a relatively constant temperature throughout the year. Ventilation of the cave slows during the summer months because the cave acts as a sink for the cool, more dense air within it. Radon daughter concentrations increase during the summer months as the decreased rates of air exchange allow radon daughter concentrations to approach transient equilibrium with radon. Transient equilibrium between radon and its daughters can be established in about three hours. Maximum rates of exchange between cave and outside air occur during the winter months and results in minimum radon daughter concentrations in the cave during this time of the year.

Radon and resulting radon daughter concentrations often show marked daily variations. These fluctuations correspond with pressure systems moving into or out of the area. A lowering of radon concentrations accompanies high pressure systems. Apparently, the higher atmospheric pressure slows the emanation of radon from the surface layers of radium containing materials. A low pressure system produces the opposite effect and results in higher radon concentrations within the cave.

Most of the effort expended thus far has been directed at the compilation of cumulative exposures for each individual employed in the cave. The highest 12-month cumulative exposure recorded for any employee at Carlsbad Caverns was well below what initial models predicted it might be, and was less than 70 percent of the maximum annual exposure allowed uranium miners.

The monitoring program at Carlsbad Caverns must continue for at least another year. The same moral obligation that was responsible for initiating the monitoring program now requires that attention be focused on determining if cave radiation constitutes a health hazard for employees. Current standards for alpha radiation exposure are directed toward the uranium industry. These standards are based in part on epidemiological studies of uranium miners where exposures were estimated or there were other complicating factors such as diesel fumes and dust mixed with the radon daughters. In addition, a majority of those included in the studies were cigarette smokers. Increasing evidence suggests that cigarette smoking may be the determining factor in deciding whether long-term exposure to radon daughters in caves constitutes a health hazard to the individual. (Saccomano, *et al.*, 1974; Martel, 1975). More attention should be directed to determining actual absorbed doses of alpha radiation and especially if these differ significantly between smokers and nonsmokers. Hopefully, information from the pulmonary cytology studies now in progress will give direction to future efforts aimed at a better understanding of alpha radiation effects.

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Comments on Cave Radiation

Tom Aley *

A substantial amount of attention was given to the cave radiation question at the Second National Cave Management Symposium and in the resulting papers. I am personally disturbed by the crisis atmosphere which surrounds this issue, and feel compelled to make some personal observations.

First, let's consider what we know. Research evidence shows a relationship between total radiation exposure for uranium miners and an increased probability of lung cancer in these workers. Complicating factors in the epidemiological studies on the miners (as Ahlstrand notes in his paper) were diesel fumes and dust in the mines.

The second thing we know is that some caves can have radon daughter concentrations within the general range encountered in ventilated mines. In some cases radiation levels approach or exceed the levels requiring some sort of reporting or other action on the part of mine operators.

One of the things we do not know is whether or not there is any relationship between natural radiation levels in caves and any detrimental human health impacts. Ahlstrand comments on this in his paper. At present, there is no demonstrated evidence of a problem.

National Park Service (NPS) and Mining Enforcement Safety Administration (MESA) personnel have too often considered caves as basically analogous to uranium mines, and people who visit or work in caves as analogous to miners. Neither the NPS nor MESA has developed any data whatever to support this analogy. Are we to believe that since both caves and mines are underground, they must be the same?

Research work by Jacobi (1971) indicates that particulate matter in the air significantly affects the depositional probability of radon daughters within various respiratory regions of the human body. Perhaps particulate matter is related to the much higher lung cancer occurrences among miners who smoke as compared with miners who do not. The dust and fumes in mines are hardly comparable to the typically much cleaner air conditions found in caves.

The standards considered for caves in Yarborough's paper are essentially identical to those applied to the mining industry; this is illogical when one considers the differences between caves and mines. The radiation standards in existence for mines are based upon a maximum lifetime exposure of 120 working level months and an assumption that miners may work underground for eight hours a day, five days a week, for 30 years. That may be the way miners work; it is not at all representative of the way people work in caves.

Mines generally are (or at least can be) ventilated. To ventilate a cave may well be to damage or destroy its natural integrity and some of its most beautiful features; there is no natural integrity to destroy in a uranium mine. Furthermore, even if we were willing to sacrifice natural integrity and other cave features, ventilating a large cave would be a physically and economically impossible task.

The mining radiation standards are based on the fact that mines are (or should be) ventilated. In some respects, the standards are used to assess the effectiveness of mine ventilation. Archer (1976) states: "There is no evidence that an increased dose rate enhances the carcinogenicity of alpha radiation, so there is no medical or biological justification for setting an excursion limit. However, excursions substantially above 0.3 W.L. reflect improper control of radon daughters, and is therefore a legitimate object of administrative control." Archer's comments about "administrative control" may be fine for the mining industry, where ventilation exists or is possible; "administrative control" is hardly realistic for the cave situation.

Those of us who visit or manage caves should be aware that alpha radiation may pose a potential health risk. It seems wise to strongly encourage people to not smoke in caves. In those caves (such as the commercial caves) where a few people spend a great number of hours, radiation monitoring on at least a reconnaissance basis would be prudent.

Cave radiation regulations and health standards such as discussed in Yarborough's paper are, at a minimum, premature. In my opinion they are too heavily based upon unsupported assumptions and inferences. That hardly seems to be the way to establish regulations and standards which could have very damaging environmental and economic consequences.

In my opinion, we are not dealing with a situation where there is reasonable evidence that standards and regulations are urgently needed to protect human health. I doubt that there is anyone in the United States who has encountered, from cave work, a lifetime radiation exposure of 120 working level months (it will be remembered that this was the maximum allowable lifetime exposure used in the uranium mining standards). There is no justification for rushing into standards, regulations, enforcement, and ventilation schemes. Instead, prudence dictates a comprehensive and scientifically complete investigation of the entire issue and possible courses of action, if action is needed. Courses of action must be considered with respect to possible public health benefits plus environmental and economic costs.

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Gating As A Means of Protecting Cave Dwelling Bats

Merlin D. Tuttle *

INTRODUCTION

As a result of a growing awareness of the endangered status of most populations of cave bats (see Mohr, 1952, 1953, 1972; Jones, 1971), private and public land owners increasingly are turning to cave gating as a primary method for protection of local roosting sites. Despite the fact that the intent behind such action is highly commendable, many gates are ill-conceived and have resulted in destruction of the bat populations. From 1969 through 1976 I have had several opportunities to visit five southeastern caves which were gated in 1969, or earlier, to protect bats. This paper presents my findings and provides suggestions for cave gating as a method for protecting endangered populations of cave bats.

RESULTS OF PAST GATING

In four of the five instances of gating that I have observed, bats abandoned their caves either immediately or within two years after gating. One abandoned cave was originally used as a hibernating site and three were occupied by maternity colonies. A hibernating population in the fifth cave suffered heavy mortality but continued to survive at a reduced size.

In 1969 the National Speleological Society purchased and gated Shelta Cave in Huntsville, Alabama, as a biological preserve (Fig. 1). The two cave entrances were gated with inadequate spacing (11¾ in. vertical, 3 in. horizontal) between bars, and the roughly 25,000 gray bats (*Myotis grisescens*) that used the cave for a maternity site completely abandoned this cave within two years. They apparently attempted to rear fewer than 100 young in the first summer after the cave was gated, then failed to return at all in subsequent years.

Georgetown Cave is on public land administered by the National Park Service and is also located in Alabama. This cave once contained a maternity colony of roughly 150,000 gray bats, but by 1969 frequent visitation by spelunkers had caused a 90 to 95 percent decline in numbers. When alerted to the problem local authorities gated the cave but were not careful to provide adequate space for the bats to enter and exit. Roughly 80 percent of the cave entrance was covered

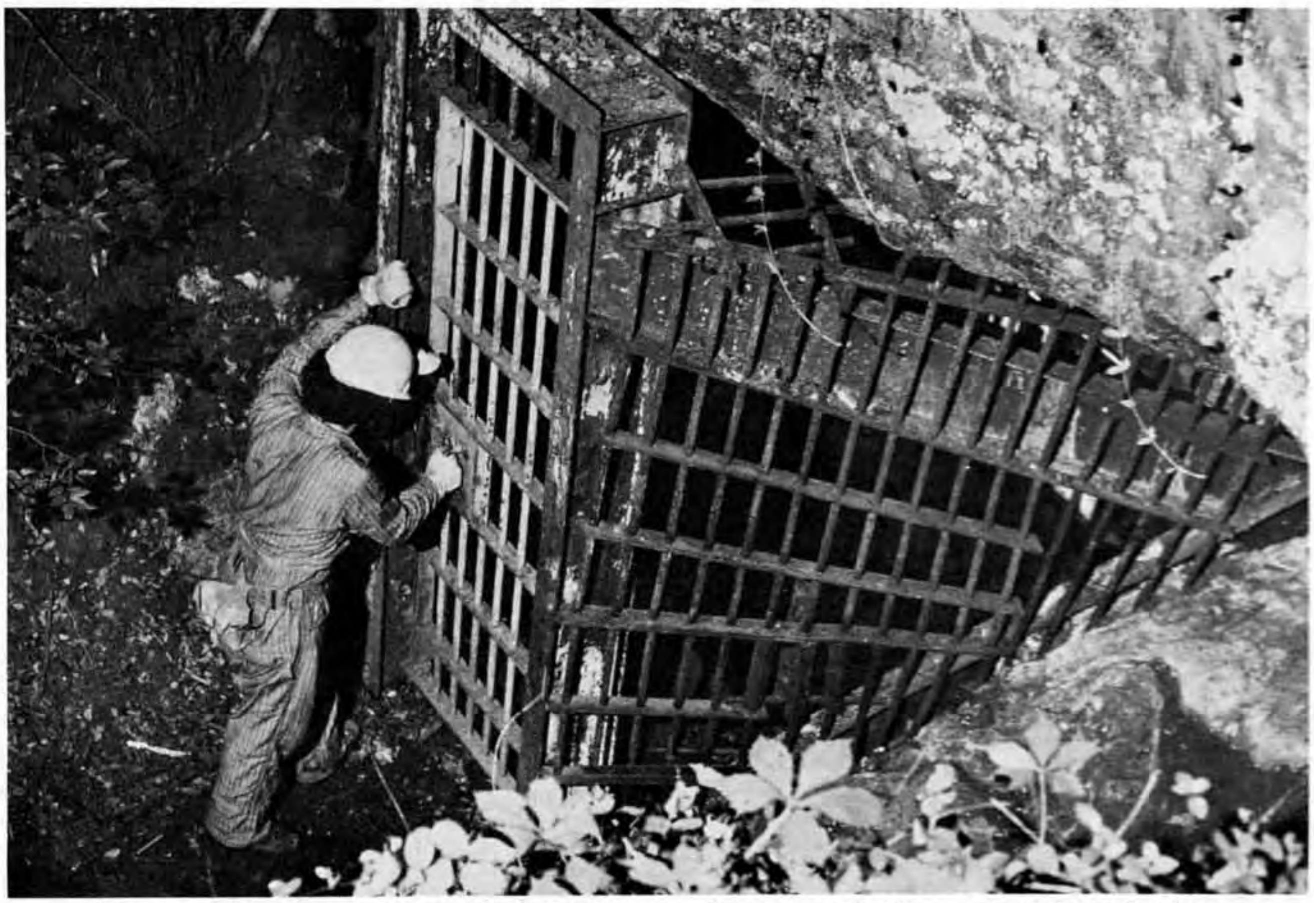

Figure 1—Shelta Cave gate: note the inadequate space between vertical bars and restrictive framing.

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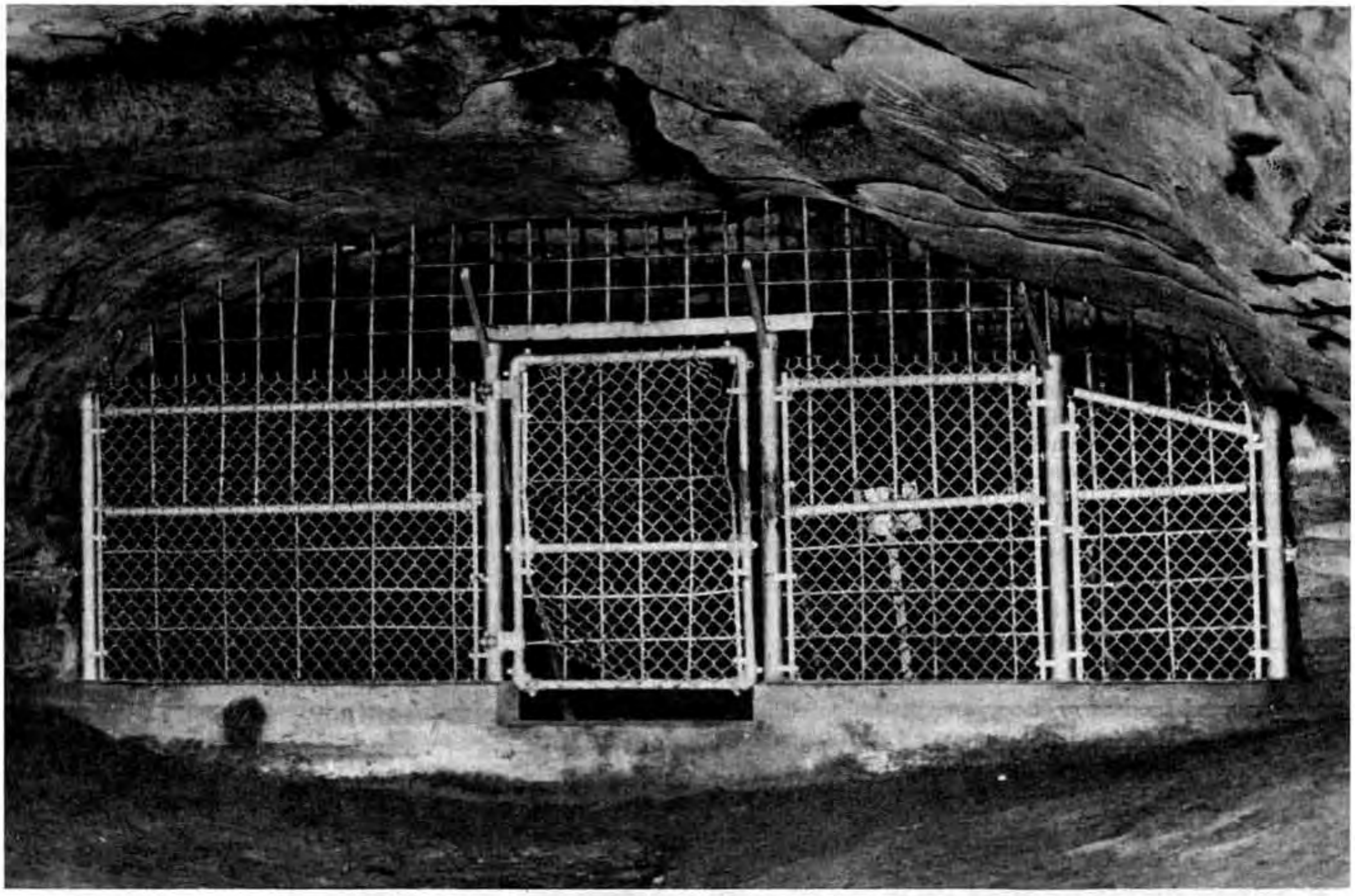

Figure 2—Georgetown Cave gate: vertical bars are too narrowly spaced, and fence covering further restricts bat movement. Concrete foundation projecting above floor level alters air flow.

with cyclone fencing and spaces of only 5¼ inches horizontally were left open in the upper 20 percent of the entrance (Fig. 2). The remaining 10,000 bats abandoned the cave immediately, apparently refusing to enter through the spaces provided.

In 1972, a third summer colony of 5000 gray bats was found to have abandoned their cave soon after a gate was installed. The gate was placed approximately 100 ft. inside in a narrow place in the entry passage and was about 4 ft. wide by 2 ft. high, with a 6 in. cement foundation. Spacing between bars averaged 6 in. high by 12 in. wide. Abundant tracks indicated that raccoons often visited this gate, presumably to catch bats.

The recent demise of bats living in Old Indian Cave, located in Florida Caverns State Park, is an excellent example of the kind of problems that can arise from gating a hibernation cave. By 1969 the once large populations of gray bats and southeastern bats (*Myotis austroriparius*) that used this cave had dwindled to less than 2 percent of former numbers as a result of disturbance at their hibernating roosts. When alerted, park officials quickly closed the cave to the public. In order to do so, several small *breathing only* entrances were plugged, and the three main entrances were gated. Parts of each entrance were filled with concrete to form foundations and plug potential access around gate sides. The three original gates provided 11½ in. horizontal and 5½ in. vertical spaces between bars to permit bat entry (Fig. 3a). Later, the second entrance was further protected against break-in by the addition of concrete posts (Fig. 3b).

Finally, Old Indian Cave became so well protected that air flow in the second entrance was approximately 80 percent blocked, while that in entrances 1 and 3 was at least significantly restricted. Through 1970 up to 1500 gray and southeastern bats continued to occasionally visit Old Indian Cave in summer, especially when disturbed in other caves. They refused, however, to use this cave on a regular basis. By 1976 fewer than 50 *Myotis* appeared to be visiting the cave at any time, and only 25 southeastern bats and two gray bats attempted to hibernate there in the winter of 1975-76.

Abandonment of the cave as a wintering site can be attributed to the blocking of entrances and a subsequent rise in cave temperature (see later section). The two gray bats that attempted to hibernate in Old Indian Cave in 1975/1976 were forced to roost within 2 ft. of the cave floor where temperatures were low enough to be within their range of tolerance. Such behavior is quite abnormal and exposed the bats to greatly increased danger of predation from raccoons which frequently visited the bat roosting areas. Predation at the gates (also see later) probably contributed to the continued decline in summer use.

At James Cave, in Kentucky, a gate was installed by the Park Mammoth Resort when the cave was commercialized sometime prior to 1968. The primary purpose of this gate was simple protection of the commercial cave. The entrance grating and gate are similar to the one used at Shelta Cave (Fig. 2). Gray bats are extremely loyal to their hibernating caves (Tuttle, 1976) and, in this case, refused to abandon their cave even when it was difficult for them to pass through the gate. The resort manager, Mr. Patrick Moran,

Figure 3—Gates at Old Indian Cave, Florida

a. Main gate: note cement-filled areas at sides and poorly located sign which restricts air flow. Small entrance size makes increase in predation particularly severe.

b. Second entrance: original gate (like the one shown above including concrete blocking) already restricted bat and air movement. Concrete posts, added later, almost totally closed the entrance. Uninformative signs such as these probably do little to engage the cooperation of cavers.

told me that large numbers of bat wings were removed almost daily from in front of the gate during fall and spring arrival and departure of the bats. I personally observed bat wings in front of the gate on several visits between 1968 and 1971. These clearly were left by predators that caught the bats as they attempted to pass through the gate.

FACTORS DETERMINING SUCCESS OR FAILURE OF GATES

Obviously, improperly constructed gates can be extremely damaging to populations of cave bats. In some instances poor gates have caused greater damage to bat colonies than vandals or disturbance would have caused. Gating projects should not be attempted unless the completed gate can be constructed in such a manner as to ensure that it will not restrict the free movement of either bats or air.

Air flow and cave temperature—Most hibernating bats require exceptionally cold caves which do not freeze, while summer colonies must find unusually warm caves (Dwyer, 1971; Tuttle, 1975, 1976). Since temperatures of most caves roughly approximate mean annual above-ground temperatures, some caves at very high latitudes may be too cold to permit use at any time of year while those at relatively low latitudes are too warm for use as winter hibernating sites but ideal for summer maternity colonies (Dwyer, 1971). Caves that differ markedly in temperature from the outside mean annual temperature must do so as a result of circulation of outside air into the cave (briefly, cold air settling in in the winter or out in the summer). Consequently, the direction and intensity of positive or negative effects brought about by a gate's restriction of air flow will differ markedly with latitude and with the use made of the cave by its bats.

If the mean annual temperature of a region falls within the range tolerable for bat hibernation, restriction of air flow in or out of hibernating caves should be of minimal importance. Such conditions, however, exist in the United States only in the northernmost areas, if at all. As mean annual temperature increases, restriction of air flow in or out of hibernation caves becomes increasingly problematic. Especially in caves located south of about 37° north latitude, even slight restriction may cause a rise in temperature that is intolerable for hibernating bats. Summer maternity colonies face the opposite problem, requiring the highest cave temperatures available. They also may be adversely affected by restriction of cave air flow, particularly in the northernmost caves used.

Predation at cave entrances—Many birds, mammals, and reptiles prey opportunistically on bats (Gillette and Kimbrough, 1970), and large bat colonies are known to attract a variety of these predators to cave entrances (Constantine, 1948). Predation is sometimes a serious source of mortality for colonial cave bats even when gates are not present. Rice (1957) believed that predation was "the most important mortality factor among populations of *Myotis austroriparius* in Florida", and I have observed evidence of extensive predation at entrances of caves occupied by *Myotis grisescens* as far north as central Kentucky.

Restrictive gates often cause bats to slow down and circle in front before entering. This increases vulnerability to predators that wait for emerging and returning bats. I have observed both raccoons and feral house cats catching slowly circling bats in mid-air in front of gated entrances. I also have observed single gray rat snakes catching four or more bats in a few minutes while hanging from the bars of a gate. Pack rats are known to be potential predators of bats (Cockrum, 1952), and I have twice seen individuals waiting on the cross bars of gates where bats emerged. Screech owls frequently are heard and seen near cave entrances where bats emerge, and I have observed successful attacks on bats.

Although the problem of predation at cave entrances may be serious at either winter or summer caves, it is especially problematic at summer sites. Here emergence and return occurs daily over a period of several weeks or months annually, permitting predators to develop behavior appropriate to a particular situation. Also, young bats that are just learning to fly may frequently alight on gate bars, becoming especially easy prey. Even when they do not land, they often circle repeatedly while flying very slowly.

RECOMMENDATIONS FOR PROTECTING BAT CAVES

Gating—Hunt and Stitt (1975) have prepared a valuable guide to cave gating which may be purchased from the publishers of these Proceedings. Those contemplating gating as a means of protecting caves should carefully consider their discussion of general considerations of gating.

A major problem involves gate location. As pointed out by Hunt and Stitt, "it is simplest to build an effective gate in a relatively tight passage, since it is not only easier to fill in around the gate, but the restricted space affords little room for the gate-breaker to work in." However, it is very important to note that gates placed in tight places will cause maximum damage in terms of restricting movement of both bats and air. Gates at bat caves always should be built in the largest possible places in the cave entrance or in an inner passage where the diameter is large. Locations well within the cave are advantageous in reducing predation but are difficult to patrol. Several of Hunt and Stitt's (1975) gate designs should be avoided whenever possible and never installed at caves used by bats. These include wall gates, drum-type gates, interior steel plate gates, and water gates. Chain gates and open grid door wall gates also would seriously threaten bat use of caves in most places. Open grid wall and door gates have not been tested adequately but have proven unsuitable in several cases where cave entrances less than five feet in diameter have been involved. Hunt and Stitt's bat cave gate is the best general design yet developed, but even it may be unsuitable in some instances (especially at maternity caves).

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

Since it is impossible to construct a vandal-proof gate, "the most effective gate, both from a protection and a cost standpoint, may be the strong, well-designed and well-constructed gate, which is deliberately left with a weak link so that forcing entry to the cave does not destroy the entire gate" (Hunt and Stitt, 1975). The "weak link" used most often is a chain or lock that is more easily cut or broken than is the gate (or fence). An explanatory sign (inside the gate but out of the way of bats and air flow) should detail reasons for protecting the cave, penalties for trespassing, and the address of the person, organization, or agencies who control access. When endangered species are involved the penalties for violations are potentially serious (Federal Register, 1975).

Fencing—Chain link or cyclone fences built around but not directly in front of or over cave entrances provide a good means of protecting bat caves, and may be the only satisfactory means of protection where predation or restriction of air flow are potentially problematic. When constructed well back from the cave entrance, fencing does not hinder exit or entry of bats. Other advantages are that fences are relatively inexpensive, easy to install, easy to patrol, and easy to repair when vandalized. Easily read signs can be placed inside as suggested above, explaining reasons for protecting the cave and potential penalties for trespassing.

Disadvantages include the fact that fences are often conspicuous, thereby attracting attention, that they may not be aesthetically pleasing, and that they often must be patrolled more frequently than gates. Although fences may be more easily violated than gates, this is at least partially balanced by their greater ease of repair. The incorporation of "a weak link" into the fence can also minimize repair costs.

Hunt and Stitt (1975) have pointed out that several strands of barbed wire should be attached "at the top of the fence, overhanging on each side and supported by angle-iron projecting from the top of each support post." They further suggest that "a concrete footing along the bottom of the fence will help prevent persons wriggling under," but note that the bottom of the wire fence should not be embedded in the concrete, as that would make repair more difficult.

Considerations for fencing versus gating—Fencing may prove to be the only alternative for protecting bats in many caves with small (less than 5 ft. diameter) or vertical entrances, or in southern caves where predators such as gray rat snakes may present special problems. Another risk, sometimes necessitating use of a fence, exists in areas of heavy public use, where people may throw fireworks into bat caves or kill emerging bats with switches if they are not prevented from approaching a cave entrance too closely. Aside from the potential disadvantages of weakness and marring of the surrounding landscape, fences appear, in many cases, to be best suited for protection of bat caves: when constructed well away from cave entrances they have no known effect on air flow or bat movement.

Unfortunately, since few past gates have been designed adequately to meet the needs of bats, we have very little knowledge regarding the extent to which they may be useful, and there is a possibility of overreacting against them due to some of the disastrous results thus far observed. Obviously fences are not esthetically pleasing and, in areas which cannot be patrolled frequently, they may not prove adequate to stop determined vandals. For these reasons alone, there is much incentive to use gates whenever possible. Even using rather undesirable gate designs, Yalden and Morris (1975) have reported at least limited success in protecting British bat hibernation caves. Certainly there is reason to believe that carefully designed gates may prove adequate for protection of many hibernating bat populations, especially in northern areas. For reasons already discussed, gates are least likely to meet the needs of bats when used at caves occupied by summer maternity colonies. If gates are used at such sites they should be restricted to caves with entrances at least five feet or more in height and preferably of even greater width.

Although examples presented in this paper are limited to gray and southeastern bats, the problems and solutions discussed are not unique to these species. Protection of cave-dwelling bats is a complex problem which needs much additional study, and it is vital that any gating or fencing be followed up by careful observation of the impact on the bats being protected. Only through such measures will we be able to evaluate our success in protecting populations of endangered bats and further improve our methods.

NOTE ADDED IN PROOF

Since I submitted this paper, Hall (7th Annual North American Symposium on Bat Research, 1976) has reported evidence of predation on a maternity colony of the Virginia big-eared bat (*Plecotus townsendii*) at a gate in West Virginia, and Bill Sconce (personal communication) has reported predation on Indiana bats (*Myotis sodalis*) at Wyanotte Cave, in Indiana. Apparently Indiana bats often refuse to fly through the gate at this wintering cave and are caught by predators as they land to crawl through. Both gates reportedly provide spaces of at least 12 in. between vertical bars.

A Tennessee cave, not discussed previously because it was not gated, nonetheless serves as an excellent example of the detrimental impact of partial air flow blockage in the entrance of a hibernating cave. In 1969 this cave contained 133 Indiana bats and 117 gray bats. In 1970, following strict owner protection from disturbance, there were 183 Indiana bats and 490 gray bats. Sometime between 1970 and 1973 the owner blocked approximately 30 percent of the cave entrance in order to protect his water pipes there from freezing. This resulted in a rise in cave temperature of roughly 2°F (possibly more but not detected due to timing of visits). Even though the cave remained protected from disturbance during the period from 1970 to 1974, in 1974 there were only 60 Indiana bats (a 67 percent reduction; and 65 gray bats (an 87 percent reduction). Other species also declined noticeably but were not carefully censused. The 1969 January air temperature of approximately 52°F in the area of heaviest use was already near the upper limit normally tolerated by hibernating bats in that region, so even a slight shift upward would have been expected to be detrimental to this cave's hibernating bat population, as was observed.

These further observations are submitted in order to verify that problems involving blockage of air flow and gate-associated predation are not unique to gray or southeastern bats and they they are widespread.

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Report on Workshop IV: Management of Commercial and High Value Caves

Barbara Munson *

Three broad subjects—Cave gating and bats, Guide training, and Radiation hazards—were discussed during Workshop IV on The Management of Commercial and High Value Caves. Papers relating to these subjects had been presented prior to the Workshop.

Those participants particularly interested in cave gating held a separate round-table discussion to review the environmental and engineering aspects of their individual situations. This specialized discussion has not been included in this Workshop Report. The NSS Conservation Chairman announced the NSS Handbook on Gating was being revised and that information presented during the Symposium would be included.

On the subject of Cave Guide Training, comments were heard from operators of privately owned commercial caves, managers of state and federally owned caves shown to the public, from cave guides, and from individuals who visit commercial caves during their vacations or as a hobby. The trend away from the inaccurate, sing-song, *stone fairy* type tour toward well-delivered, well-researched interpretive type cave tours was mentioned by a number of speakers. There seemed to be general agreement that although there are many workable methods of guide training, all guides should be supplied with ample accurate information about caves in general and about their particular cave. With this information, and with guidance from management, a guide can develop his own tour—a tour that he can adjust to the needs of each group he conducts through the cave, making each tour an enjoyable and interesting experience for every visitor. The need for a guide to develop a rapport with each of his groups was stressed several times.

Although no simple answer to guide boredom was suggested, such techniques as peer evaluation, periodic reevaluation by management, free-time exchange visits to other commercial caves, exploration of undeveloped sections of their cave or of caves in the area all help guides to take an interest in showing *our* cave to the public with pride and enthusiasm. Arranging for the guide to have a few minutes before each tour to relax and focus mentally was recommended to help the guide present a good tour.

The Workshop was reminded that cave guiding is a craft and that the craft of cave guiding predates all other cave sciences. The guide is the most important link between the cave manager and the people who come to see a cave.

Through such gatherings as the Cave Management Symposium members of the National Speleological Society, the National Caves Association, representatives from State and Federal agencies, independent researchers, and individuals with a special interest in caves can meet to discuss and exchange ideas about such aspects of overall cave management as guide training. Through this exchange of ideas comes an increased ability to present both commercial and *wild* caves to all visitors. Also through this exchange comes an increased understanding of some of the problems faced by all cave managers.

Turning their attention to Radiation hazards, Workshop IV panelists and participants discussed the impact of recent findings and pending regulations on cave management—questioning whether standards set for Uranium mines should be applied to caves. More needs to be known about radiation levels in caves and how these levels affect those who work in caves and those who visit caves. There is also a need to know how levels of radiation could be reduced and how such efforts would affect the cave environment. Additional meetings were scheduled during the Symposium to discuss cave radiation in greater detail.

In closing, Workshop participants were reminded of the Moderator's opening statement that what may work for one will not be the answer for another. The comments of panelists and audience indicated this statement could, indeed, be applied to the subjects of Cave Gating, Guide Training, and Radiation Hazards.

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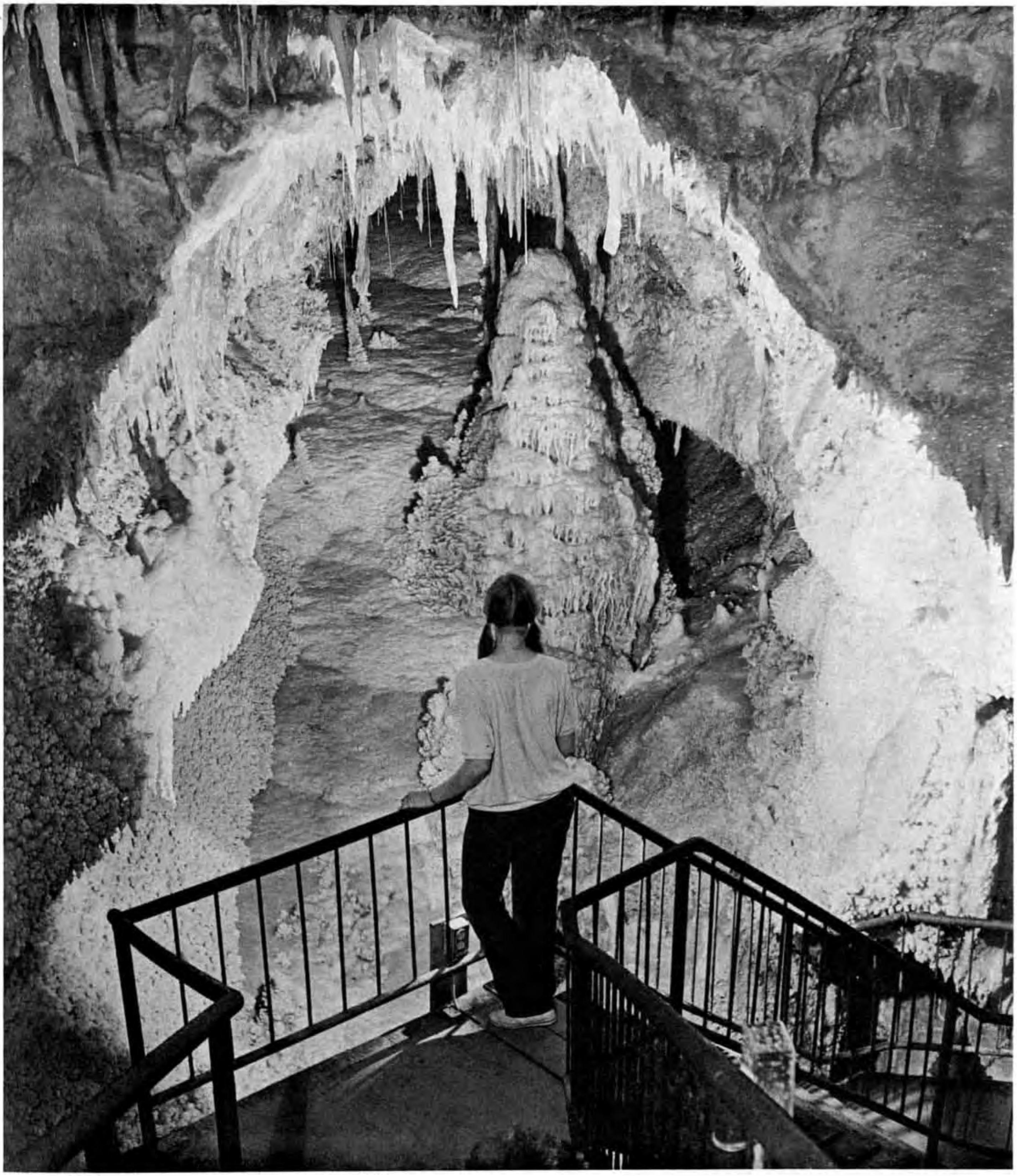
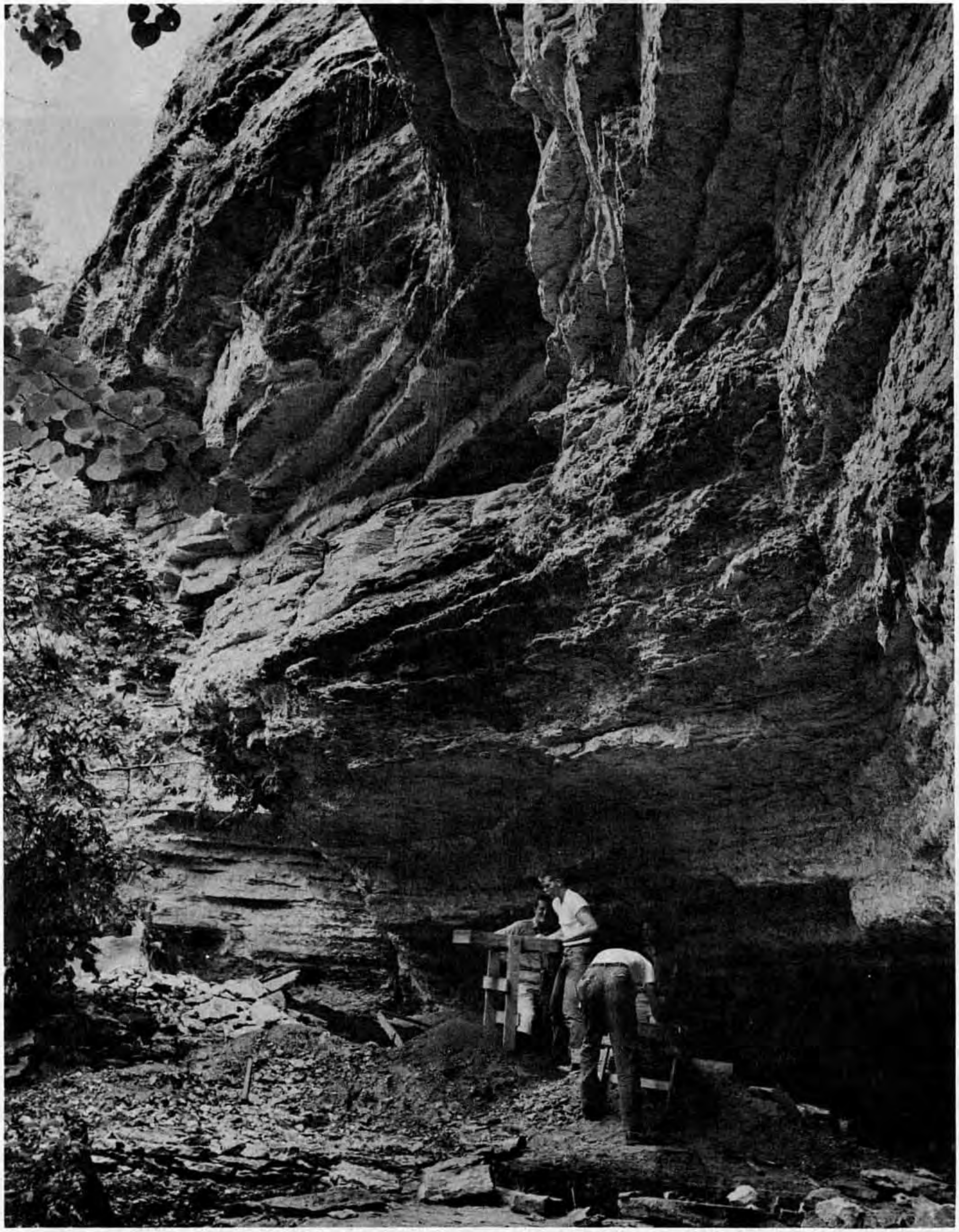
Other Papers





Archeological excavations at the Breckenridge rockshelter (3CR2), a prehistoric habitation site in the Arkansas Ozarks. *(Courtesy, University of Arkansas Museum.)*

Cave Resource Management: An Archeological Perspective

David G. Anderson *

ABSTRACT

The management of archeological resources bears many similarities to the problems of cave resource management. Both archeological and speleological resources, for example, may be considered fragile and essentially nonrenewable. Mechanisms developed by [and in some cases forced upon] archeologists in the management of their resource base can be of value in cave resource management. Useful mechanisms include the advantageous use of existing federal legislation, discretion in publication policy, the development of programs of public education and involvement, and the development of efficient communications arteries.

INTRODUCTION

In recent years archeologists have been increasingly charged with responsibility for both assessing and managing cultural resources. The problems and challenges that these responsibilities have brought the archeological profession are similar to those currently before the speleological community. Archeologists have been forced to develop coping mechanisms, many of which could be effectively adopted by speleologists. These mechanisms include the effective utilization of federal legislation to advance research and preservation interests, the development of quality-control procedures to ensure high standards of research, the development of programs of public education and involvement, and the establishment of reasonably efficient communication channels within the profession. It is argued that archeologists and speleologists can greatly assist each other's interests, both in the development of effective resource management policies, and in the area of general research.

THE NATURE OF ARCHEOLOGICAL AND SPELEOLOGICAL RESOURCES

Archeologists have long been linked to other members of the speleological community through overlapping research interests and the similar nature of their respective resource bases. The two communities share a long history of cooperation in research dating back to at least the early 19th century, when many cave geologists were simultaneously some of Europe's earliest scientific archeologists (Gruber, 1965). Caves and rockshelters are widely recognized as potentially rich sources of archeological data, since many served as places of shelter, habitation, burial, or storage for past populations. In the investigation of these remains archeologists are often assisted by specialists who may be active in other fields of speleological research, including geology, palynology, paleontology, botany, sedimentology, physics, chemistry, and a number of other disciplines (Bordes, 1972; Watson, *ed.* 1974).

In recent years both archeologists and speleologists have become strongly aware of the nature and limitations of their respective resource bases. Much of this recognition has developed from watching these bases dwindle around them. Urban sprawl, agriculture, and construction activity, and increasing public interest have combined to create problems of intentional and unintentional resource destruction on a monumental scale. While construction-related damage is a major problem, both archeological and speleological resources are also suffering increasingly greater destruction at the hands of ignorant or malicious members of the public. The depredations caused by pothunters or antiquities dealers, for example, are matched in destructiveness by the plunderings of the mineral or speleothem collectors (Hill, 1976; Schmidt, 1965).

Archeological resources are extremely sensitive to damage, much as are many speleological resources. This sensitivity stems from the nature of the archeological data base. Artifacts, as remains of past systems of human behavior, can be used to inform on these systems. The study of artifacts associated horizontally, for example, on an occupational surface or living floor, can lead to a reconstruction of the activities that took place in that area. An important assumption behind most archeological investigation, however, is that disturbance of the remains, whether accidental or otherwise, has been minimal. The disturbance or removal of archeological remains from their original context without record greatly reduces their interpretive potential and is, in effect, a piece of human history lost forever.

Archeological resources may, therefore, be regarded as nonrenewable cultural resources—once destroyed or even greatly disturbed, their information content is gone forever. Speleological resources may be thought of as largely nonrenewable geological, cultural, and biological resources. While geological and biological resources within a cave system may regenerate, given enough time, from the perspective of a human lifetime they may be viewed as nonrenewable. Cultural resources within caves, or entire

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species of cave-dwelling organisms, however, are literally irreplaceable—once destroyed or extinct, they are gone forever.

ADVANTAGEOUS USE OF FEDERAL LEGISLATION

A considerable body of federal legislation currently exists that directly pertains to both archeological and speleological resources. Properly utilized, this legislation can considerably advance general conservation and management goals. While much of this legislation refers specifically to archeological or cultural resources, these often occur in caves. Even if a fortuitous direct co-association is not apparent, the occurrence of cultural remains in the general vicinity of a cave may be sufficient to ensure a measure of protection or preservation (Grady, 1975).

Specific federal legislation of value to both speleologists and archeologists includes the Antiquities Act of 1906 (PL 59-209), the Historic Sites Act of 1935 (PL 74-292), the Wilderness Act of 1964 (PL 88-577), the Historic Preservation Act of 1966 (PL 89-665), the National Environmental Policy Act of 1969 (PL 91-190), and the Archeological and Historic Conservation Act of 1974 (PL 93-291). Additionally, Executive Order 11593, for the "Preservation and Enhancement of the Cultural Environment" lends added weight to many of these measures. This Executive Order specifically charges federal agencies with the preservation of cultural resources on their properties *and* on nonfederally owned lands that their projects affect. While an Executive Order is not directly comparable to a piece of federal legislation, it does carry practically the weight of law with federal agencies.

The Antiquities Act of 1906

Under the Antiquities Act of 1906 a fine of up to $500 and a jail sentence of up to 90 days may be levied against any person damaging or destroying antiquities on federally owned property. In addition to covering archeological resources, this law has also come to apply to paleontological remains (McGimsey 1972:111). Thus, sanctions against certain forms of cave vandalism may be derived from this legislation.

The Historic Sites Act of 1935

Under the Historic Sites Act of 1935 a register of sites of national significance was established, and provisions were set forth for the acquisition and preservation, by the federal government, of historic and archeological sites, buildings, objects, or property of national significance. In addition, the National Landmarks system was established. Under this law sites worthy of preservation may be recognized, and provisions are established for their possible transfer to federal ownership, management, preservation, and protection.

The Wilderness Act of 1964

Under the provisions of the Wilderness Act of 1964 large areas of federally owned land may be designated wilderness areas, ensuring that they will be left in a relatively unspoiled state, inaccessible to most forms of transportation. Such a designation affords considerable protection to natural and cultural resources, since the lack of ready access discourages wholesale movement of destructive equipment into, and plundered remains away from, the wilderness area. In arguing for the establishment of a wilderness area the presence of both archeological and speleological resources should be considered; the relative isolation protects both.

The Historic Preservation Act of 1966

The Historic Preservation Act of 1966 established a greatly expanded National Register of Historic Places, including provisions for the inclusion of sites significant to state, local, regional, or national history, architecture, archeology, or culture. Should any federally-funded project endanger a site on the National Register, alternative policies must be considered during a formal review process. The Advisory Council on Historic Preservation reviews the situation, and makes recommendations for the resolution of the construction impact. While the Advisory Council's recommendations are merely advisory, without the authority of law, they have considerable weight, particularly in light of Executive Order 11593.

Guidelines for the nomination of sites to the National Register, and a detailed description of the formal review procedure for endangered sites, are to be found in the *Federal Register* for 25 January 1974 (Garvey, 1974). Additionally, information on procedures for the nomination of sites to the National Register may be obtained from almost any archeologist, or from the State Historic Preservation Officer for each state.

It almost goes without saying that a great many cave sites within the United States warrent inclusion on the National Register. Caves with prehistoric remains, historical inscriptions, saltpetre mining equipment, or even old moonshining stills may be eligible. The criteria for inclusion are broad enough to encompass almost anything that can be rationally and realistically defended. In addition to providing a degree of protection from federally-funded destruction, this same legislation provides for a program of matching funds for the preservation, for the public benefit, of sites on the National Register. This program of matching funds is especially important to note, since it effectively doubles the funding state, local, or even private interests can use to preserve National Register properties.

The National Environmental Policy Act of 1969

Under the National Environmental Policy Act of 1969 any federal agency contemplating a project that may significantly affect the environment must prepare, prior to initiating construction, an Environmental Impact Statement that gives the impact of the project on the environment, alternatives to this impact, irreversible effects, short-term versus long-term effects, and recommendations for the mitigation of these effects. This legislation could be one of the most significant sources of funding for speleological research and assessment, if it was given the attention it warrented. Archeologists are literally swamped with NEPA-related work, largely because effective lobbying and the weight of Executive Order 11593 have combined to ensure that archeological and other cultural resource assessments are a part of an EIS.

NEPA applies to *both* natural and cultural resources, however, and there is no reason why the resources found in caves should be excluded from NEPA-related environmental assessments. This fact has recently been noted by members of the speleological community (Stitt, 1974; Mohr, 1976). What is needed, to ensure greater compliance, is an increased willingness to detect and challenge EIS's where the project impact on speleological resources is glossed over or ignored. Guidelines delimiting what must legally be contained in an Environmental Impact Statement are to be found in the *Federal Register* for 1 August 1973 (Train, 1973). These same guidelines also indicate basic appeal or review mechanisms that, if used effectively, could greatly augment speleological research.

The Archeological and Historic Conservation Act of 1974

Under the provisions of this act federal agencies initiating construction projects that endanger archeological resources are authorized to expend project monies to provide for the effective mitigation of the damage. The increased level of funding the act provides gives archeologists a research potential undreamed of only a few years ago. Interdisciplinary archeological research projects are already burgeoning, bringing increased contact with specialists in other disciplines. The intersection of archeological and speleological resources makes increased interdisciplinary action in this area a virtual certainty.

This brief review of federal legislation should suggest that members of several disciplines will almost certainly find it advantageous to collectively promote research and conservation goals. Archeologists are prepared to join forces with other groups towards the advancement of conservation measures (Lipe, 1974), and they have an effective battery of legislative support to enlist in this activity. While not discussed here, it should also be noted that many states have laws protecting archeological resources on state and, in some cases, even on private lands (McGimsey, 1972). These laws may provide additional sources of protection, through negative sanctions, of speleological features.

THE ROLE OF RESEARCH IN RESOURCE ASSESSMENT

If one fact is established by the National Cave Management Symposium, it is that the management of speleological resources is going to receive increasing attention in the years ahead. Management responsibilities are entailed in NEPA and other federal legislation and guidelines, and a number of federal agencies such as the National Park Service and the Bureau of Land Management are developing management policies and objectives concerning cave properties (Tousley, 1976; Loose, 1976; Lewis, 1976). Effective management will necessarily involve resource assessment, and it is here that speleological researchers can play a major role. Before turning to the responsibilities before researchers, however, it would be well to review some positive gains deriving from resource assessment.

Essential to cave management is the concept of resource

Exposing a human burial found in the mouth of an Ozark rockshelter, for photography and measurement prior to removal. Careful recovery of archeological remains greatly increases their value in interpreting past human behavior. (*PHOTO COURTESY OF University of Arkansas Museum*).

assessment. What *are* significant cave sites and resources? While a scientist might declare that caves are significant to the extent to which they provide information relevant to particular research problems, this is hardly a satisfactory answer. Commercial and governmental owners do not manage caves solely for the benefit of scientists, but also for the general public. What should a resource assessment accomplish, and what are responsibilities associated with resource assessment?

From a managerial perspective, the primary value of assessment is as an aid to planning. Inventory or locational data is useful for both visitor-access control and for land modification planning. The U.S. Forest Service, for example, recently contracted with the Arkansas Archeological Survey to determine high and low site probability areas within sections of the Ouachita National Forest (Raab *et al.* nd). Knowledge of where archeological sites are located, or are likely to be located, is of both immediate and long term value in the planning of access roads, logging operations, and other land-modification projects. The example could easily apply to cave, in addition to archeological, sites.

Adequate resource assessment is necessary to ensure a realistic perspective. Many archeological sites, for example, have initially appeared to be insignificant, yet with further examination have proven tremendously important. The same is undoubtedly true for cave systems. It would be unwise to write a cave off as insignificant unless that status had been demonstrated by investigation. Opinions or preconceived notions as to what constitutes a significant cave should not prevent checking these opinions with a little serious investigation.

RESOURCE ASSESSMENT: THE NEED FOR QUALITY CONTROL

The assessment of speleological resources entails major responsibilities for both management *and* the community charged with undertaking the assessment. Perhaps the greatest responsibility is that of quality-control: ensuring that investigation effectively meets the needs of the contracting agency, and simultaneously does justice to the resources themselves.

Speleological resources are often fragile or nonrenewable, and it is apparent that many kinds of speleological investigation or research damage these resources to a greater or lesser degree. Investigations that are likely to damage speleological remains should be undertaken *only* if no possible preservation alternatives exist. If research must be undertaken that damages cave resources, it should be conducted, if at all possible, in caves slated for destruction and not in caves being protected or preserved.

In conducting resource assessments or contract-related research, speleologists should routinely prepare specific research designs linking project goals with methods for their resolution. This will help ensure that the contracting agency's demands are met. If an investigator cannot clearly explain how he is going to conduct his research, or why, it is probably because he does not know. If an investigator does not know what he is doing, and why, at the beginning of the research, the end product may be equally confused or misdirected. By laying out the general course of research at the onset, all concerned parties should be able to see whether or not their requirements, be they management, professional-scientific, or otherwise, are met.

Research designs or proposals should also endeavor to control for, or make explicit, possible sources of bias. Furthermore, as noted at this conference last year (Poulson, 1976:51), research proposals should be routinely subject to peer review. That is, prior to project approval or funding relevant specialists should be contacted and given the opportunity to evaluate the research design for its logical, scientific, and/or conservation merits. The policy of peer review should eliminate poorly designed research that could, if followed, result in the senseless destruction of resources.

Quality control measures do not end with the contract award, however. Finished reports should also be subject to both agency and peer review. Reports that do not measure up to peer standards, or that fail to follow through on the original research design (barring unavoidable or unforeseen circumstances), should be rejected, or sent back for rewriting. Investigators who consistently prepare inadequate reports as judged by both peer and agency standards, should be excluded from future funding. While such procedures may seem harsh, they are becoming commonplace in contract archeology; furthermore, since public money is being spent, the public is entitled to the best possible return on its investment.

A final comment on resource assessment concerns the need to control for possible sources of bias. This should, as noted, be routinely considered in project research designs. An emphasis on large, unique, or beautiful cave resources is certainly justified—as long as the more mundane remains are not completely overlooked. It is probable that *any* cave, regardless of size or beauty, can provide data useful to research questions in a variety of fields. Many cavers, for example, do not snub certain caves because they lack formations, deep pits, or spacious passages. Adequate assessment must be taken to mean concern for *all* cave resources, not arbitrarily delimited portions of them (c.f. Klinger, 1976). In preservation measures, efforts should be made to include a representative sample of all the available resources, and not merely those we presently happen to think significant.

RESOURCE PROTECTION: PROTECTING THE PUBLIC FROM ITSELF

A major area of concern for both archeologists and speleologists is the problem of site protection. Both caves and archeological sites are increasingly subject to intentional and unintentional destruction. The damage caused by construction activity, mining, or deforestation is massive enough, but caves and archeological sites are also subject to destruction through the actions of the uninformed, unconcerned, or malicious members of the public. A major part of cave management, therefore, inevitably concerns protecting the resources from irresponsible public use. Proper actions can, however, ensure that cave resources will remain available for public benefit and appreciation in the future.

Three approaches are suggested by which the speleological management, research, and avocational communities can interact with the general public to help protect the cave resource base. These areas are: (1) the use of discretion in reporting site locational data, (2) the development of programs of public education and involvement, and (3) the development of efficient information-exchange mechanisms within the speleological community to facilitate interaction with the public, and to deal with management problems. Each of these areas will be discussed in turn, using parallels from archeological experience.

CAVE LOCATIONS: PUBLISH AND PERISH?

Recently the National Speleological Society has been beset with an internal controversy concerning the publication of cave site locations (Medville, 1974; Rhodes, 1974, Watson, 1976; Davis, 1976). The argument centers on the possible use of such information by various elements of the public. At present, accurate information on the effect of publication on cave resources is not available, which is unfortunate considering the extent of the controversy. Parallels from archeological experiences in these matters may prove instructive, especially when one considers that the character of archeological and speleological resources are similar: sensitive and nonrenewable.

Archeologists have learned the hard way that revealing exact site locations in publications designed for the general public is a serious mistake. In many parts of the country such a practice virtually ensures subsequent vandalism. Important early man sites in the southeastern United States, like Brand (Goodyear, 1974) or Hardaway (Coe, 1964), were ripped apart when public attention was drawn to them. No formal publication policy exists within the archeological community, but most professionals with any sense at all are discrete in announcing unprotected finds. This does not mean that technical reports or reports to managerial agencies should not include cave or archeological site location data. On the contrary, both management and research requires openness. But it does suggest that considerable caution and discretion should be followed in more popular accounts.

Inventory data on resource location can be discretely maintained without hampering either research or management ends. Every state in the country has one or more archeological site files, each containing detailed locational and descriptive information. This information is usually routinely made available to qualified researchers or management personnel on a "need-to-know" basis. Archeological research does not seem to be suffering unduly from this policy. The NSS cave files are a parallel "data bank" that can and should be used to further responsible cave research and/or management.

Human burial and associated basketry, *in situ*, exposed in excavations at the Putnam shelter (3WA4), Washington County, Arkansas. (*Photo courtesy of University of Arkansas Museum*).

PROGRAMS OF PUBLIC EDUCATION AND INVOLVEMENT

Effective public education is probably the single best way to ensure acceptance of sound management policies. One of the best links that management can have with the general public is through avocational groups. Currently some 25,000 people within the United States are members of archeological societies (Hester A. Davis, personal communication); much of the recent federal legislation enumerated previously is due in part to their lobbying action. The four to five thousand serious avocational cavers in the United States (based on NSS membership) can be an equally effective force for advancing management/conservation goals.

Avocational cavers can greatly assist management through programs of direct involvement: cave research or rescue can often be undertaken by such groups. NSS cave maps, for example, are frequently found accompanying reports of archeological remains found in caves (e.g. Walthall & DeJarnette, 1974). Avocational members can report incidents of vandalism, and in some cases can help repair damage (Rhodes, 1976). Formal site monitoring programs are currently underway in both Arkansas (Schambach, 1975) and British Columbia (Russell, 1975), employing avocational archeological society members. Additionally, such members are invaluable in emergency situations. Archeologists in Arkansas often hear about major mound sites that are going to be totally destroyed "next week" or "next month" by land leveling operations (Morse, 1973). Often the help of a few avocational archeologists has meant that something of value can be saved from destruction.

Whenever possible, then, avocational groups should be incorporated into research and management programs. Equally important is the much larger segment of the general public consisting of those who are or would be interested in cave resources, but are generally uninformed about them. Just about everyone visiting a commercial cave, or those who enjoy reading about caves and cave exploration, would qualify under this rubric. These people need to be reached, if for no other reason than to achieve a broad base of sympathetic support for sound management programs.

The general public needs to be aware of the concept of *nonrenewable resources* as it applies to caves, speleothems, and endangered species (Aley, 1976). The value of cave resources as an important part of the natural heritage needs to be stressed. To achieve these ends the speleological community (management, research, and avocational) will have to put forth a considerable effort. The management of caves, particularly those open to the public, will have to increasingly adopt an educational, as opposed to entertainment, role (Smith, 1976). Instead of merely showing "neat things," the fragility and essential nonrenewability of the resource should be emphasized. A gutted section of a cave can be a particularly forceful object lesson, as most NSS cavers can testify.

If at all possible tourist/visitor oriented caves should have both popular and technical publications available, and should encourage interested people to contact or join responsible avocational groups. While this conflicts with the recent NSS policy of discouragement, it is probable that anyone willing to pay dues or read the literature is, in most cases, going to be an ally rather than an enemy. Caving is becoming

Small rockshelter-overhang, prior to excavation, in the Arkansas Ozarks. Even relatively small shelters such as this can yield rich and important archeological remains. (*Photo courtesy, University of Arkansas Museum*).

increasingly popular, and it is through conversion, and not castigation, that a responsible conservation ethic will spread.

Both professional and avocational members of the speleological community also have a responsibility to promote public appreciation for cave resources. Avocational groups, through weight of numbers, media connections, or lobbying action, can make themselves and their purpose known. If the education of the public can be said to begin at home, than avocational groups should see to it that their memberships have a healthy conservation/management ethic. Furthermore, both avocational and professional speleologists should be capable, and willing, to inform others about the value of cave resources. Most archeologists have to give a five minute lecture on "what is archeology and why it is important" on the average of about once a week; ideally they win a convert, more often than not. By discussing the basic reasons for pursuing one's profession or avocation, it is possible to strongly reinforce personal feelings about it.

EFFECTIVE INFORMATION EXCHANGE: THE ASCA EXAMPLE

To interact effectively with the general public in the promotion of management goals, the speleological community needs to develop efficient internal communication mechanisms. Perhaps the single greatest reason is that such mechanisms, if successful, can stimulate tremendous amounts of activity. Effective communication channels can serve, therefore, as sort of *consciousness raising* devices. Through effective information exchange the speleological community should also be able to present a reasonably unified and consistent viewpoint, an essential requirement to achieving widespread credibility. If cavers in one part of the country stress the need to close off all caves to the general public, while cavers in another part of the country stress something else—such as permitting unlimited access—then unlimited confusion can arise (unless, of course, both groups can back up their positions in relation to area-specific circumstances).

Currently the NSS publication program is the single major voice linking together all the sections of the speleological community. Unfortunately, the goals of this organization are disparate, and not solely limited to management problems. The tentative formation of the Cave Management Section of the NSS at this conference does, however, reflect the growing awareness within the avocational community of the need for responsible cave resource management. If it can attract a broad membership base, the Cave Management Section can make a valuable contribution in the area of information exchange.

Two years ago, in 1974, a number of archeologists formed the American Society for Conservation Archeology (ASCA). Coincidentally, this society was formed at a national Cultural Resource Management meeting. Through its newsletter this organization has come to play a major role in making American archeologists aware of their responsibilities in the ever-expanding contract/conservation/management scene. The federal legislation previously mentioned, while providing tremendous research funding, has also generated equally impressive (and often aggravating) responsibilities.

Through its newsletter ASCA relays information on a wide range of topics throughout the archeological community. The information exchanged centers on problems that are similar or identical to those presently before the speleological management community. It is argued that a similar policy of information dissemination, by those interested in cave management, would do much to further management goals. Topics discussed in the ASCA newsletter from 1974 through 1976 are briefly enumerated below; substituting "speleologist" for "archeologist", and "speleological resources" for "archeological resources", the topics can be seen to be particularly relevant:

(1) Federal legislation specifically affecting (speleologists) and (speleological) resources. Includes new legislation and changes in old legislation.
(2) Impending legislation (beneficial and otherwise) affecting (speleological) resources. This permits the development of lobbying campaigns through subsequent contacts with avocational groups.
(3) Methods to ensure greater federal agency compliance with existing legal mandates.
(4) State laws, legal actions (test cases or suits), affecting (speleological) resources.
(5) Federal agency actions and guidelines concerning (speleological) resources.
(6) Relevant bibliographic information about conservation and management of (speleological) resources.
(7) Courses being taught in resource management about the country.
(8) (Speleologists) employed in federal agencies. Established liaisons with this group to further information exchange.
(9) Research and publication standards for contract/assessment reports.
(10) Professional standards (who is qualified to conduct resource assessments?)

In addition to these functions the newsletter maintains a number of other services, such as membership listings, advertising (for positions open or wanted), upcoming meetings or symposia of interest, and so on. The newsletter appears from 4-6 times a year, and has become the major source within the archeological community for current conservation/management information. As such it complements more formal publications that must, of necessity, appear less regularly. A similar publication, oriented toward cave management ends, would be of considerable value.

CONCLUSION

This paper illustrates a few of the parallels between archeological and cave resource management. The similar nature of the resource bases, and the common problems both groups must deal with, indicate that each community can learn a great deal from the other. The potential for cooperation is exemplified in the site of this conference—Blanchard Springs Caverns. Because responsible management decisions were made, archeological remains within the caverns have been preserved, and currently provide information of both scientific and public interest (Wolfman, 1974).

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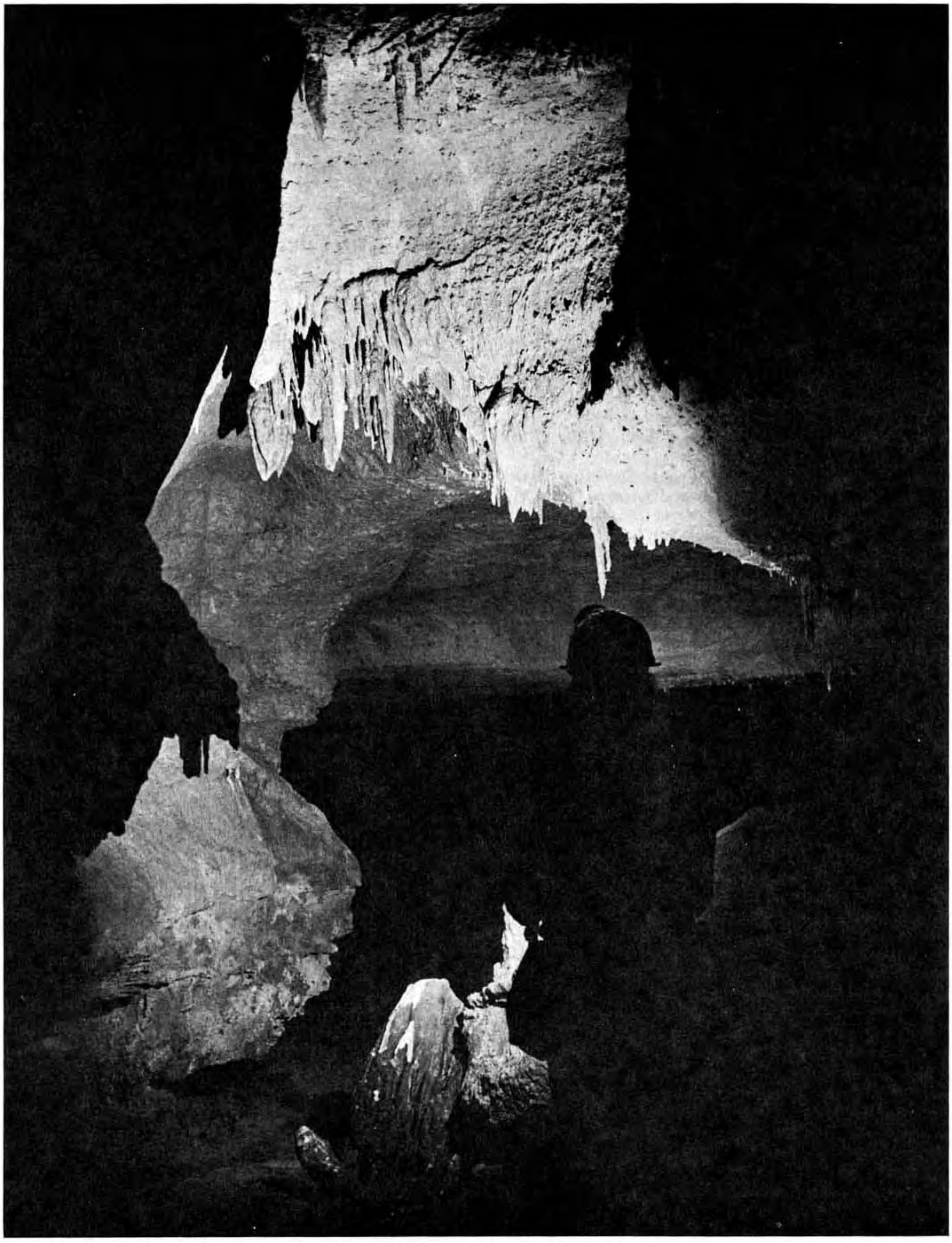

Tumbling Creek Cave, Ozark Underground Laboratory. *Photo by Bill Fitzgerald.*

The Ozark Underground Laboratory

Tom Aley
Director, Ozark Underground Laboratory

A field trip to the Ozark Underground Laboratory was held in conjunction with the Second National Cave Management Symposium. This paper briefly describes the Laboratory and its purposes for those who could not participate in the field trip.

The Laboratory, which includes Tumbling Creek Cave, is near Protem (about 25 miles east of Forsyth) in the southern Missouri Ozarks. There are approximately 2 miles of passages in Tumbling Creek Cave, and essentially all of these underlie the 126 acres owned by the Laboratory. An adjacent tract of 600 acres has been purchased by friends to help insure the protection of the recharge area for the cave stream.

Tumbling Creek Cave is a very diverse system; it has a sizeable underground stream, large passages, and areas well decorated with speleothems. One significant feature of the cave is the fauna, which includes about 100 species, including seven or eight new species and one new genus. The cave is a maternal colony site for the gray bat (*Myotis grisescens*) which has recently been added to the National Endangered Species List. The summer population of gray bats in the cave is about 150,000.

Ozark blind salamander (*Typhlotriton spelaeus*) in Tumbling Creek Cave.

Northwest Passage, Tumbling Creek Cave. *Photo by Robert Taylor.*

Approximately 2100 feet of trail has been built in the cave. The trail keeps all human travel in a narrow zone; areas off the trail are protected from trampling, which has major detrimental impacts in the muddy caves of the Ozarks.

Surface facilities at the Laboratory include a field house, bunkhouse and study room, and a residence which is under construction. The Laboratory is owned by Tom and Cathy Aley, and receives no grant support from any agency or group. The Laboratory receives its total support from charges made for use of facilities and services; the Laboratory operates full-time.

The term *laboratory* may create an image of a sterile room with test tubes and people in white lab coats. That is not at all what the Ozark Underground Laboratory is about. I am addicted to the idea that a laboratory is a place where scientists or technicians do their work. Our work deals with the karstlands, and particularly with caves and springs. Our laboratory is, thus, a piece of the land; it includes caves, springs, sinkholes, and other features with which we work.

The majority of our work involves trying to *improve* the way in which people live with, and relate to, karstlands. I define improvement as any action which decreases mans' adverse impacts on natural resources or improves the quality of life.

Many of the karstlands of the United States are areas of rural poverty. Humanly essential resources such as good soils, adequate and easily obtainable water, and easy and effective waste disposal are frequently scarce in karstlands. The scarcity of resources is tied to rural poverty.

When essential resources are scarce, we pay high societal costs for waste, damage, or poor use of these resources. The societal costs include economic, environmental, social and health costs, plus those costs which are borne by the land itself. Any activity which reduces waste, damage, or poor use of resources is a beneficial activity (to the extent that it does not cause offsetting damages).

One problem faced by people living in karstlands is a lack of a workable understanding of how underground conditions may affect what people do on the surface, and vice versa. For example, if you think that sinkholes and hydrologically similar features are adequate sites for waste disposal because you view the subsurface as an infinite filter, you or a neighbor may well end up drinking sewage or trash from your spring or well. The societal costs and costs borne by the land are obvious. If, on the other hand, you more accurately understand the relationship of the surface and subsurface, you can avoid many (and perhaps most) waste disposal blunders. The ultimate benefits are substantial.

Better public understanding of how the surface and the subsurface interact is essential to improvements in the way people live with, and relate to, karstlands. Improvements in the understanding of karstlands is the purpose of the educational field programs we conduct at the Laboratory.

About 70 colleges and high schools participate in our educational field trips; we have about 1000 visitors a year. Field trips spend about half a day on the surface (looking at ways the surface relates to the cave) and the other half a day in the cave (looking at ways the cave relates to the surface). The Laboratory has also been involved in documentary films on caves and groundwater pollution problems in karstlands.

In addition to educational programs, the Laboratory provides facilities and assistance for cave-related research conducted by outside researchers. Most of this work has been in cave biology, although one major hydrologic study has been conducted at the Laboratory.

The Laboratory does a substantial amount of consulting work and contract studies. The majority of this work deals with groundwater pollution and resource management problems in karst areas; much of this work is for state and federal agencies. Finally, the Laboratory is involved in interpretive training of cave guide staffs.

By owning a cave we have become involved in cave management. Our management is painfully simple; it is based on the conviction that any action which tends to maintain physical and biological integrity, stability, diversity and beauty is proper. Proper management must, to the extent of our knowledge and ability, take proper actions.

Surface tour at the Ozark Underground Laboratory. *Photo by Bill Fitzgerald.*

Field House, Ozark Underground Laboratory. *Photo by Bill Fitzgerald.*

Introduction to Management of Australian Caves and Karst Areas*

Elery Hamilton-Smith**

INTRODUCTION

First of all, let me stress that this is only an introductory review of the topic. Many hundreds of pages have been written on the special problems of managing cave and karst areas, yet we are only on the threshold of looking at the problems which are beginning to arise in parks and other cave areas throughout the world. So, I will focus upon introducing some of the key problems and reviewing the various attempts at some solution of these, merely as a starting point from which the practical issues of any one area might be tackled.

Secondly, let me try to clarify the nature of the field with which I am dealing. Caves are of various kinds, and found in a variety of rock types. Four kinds of cave are of particular importance in Australia:

1. *Weathering Caves*—shallow caves, perhaps more commonly and accurately known as 'rock-shelters,' are particularly common in arid areas, but are also found in granites throughout Australia, in the Hawkesbury sandstone of Central New South Wales, and in various other locations. From the management viewpoint, these caves are often significant because of the aboriginal paintings or floor deposits found within them. Victoria's best-known examples are the painted shelters of the Grampians and nearby ranges.
2. *Marine Caves*—the sea, acting upon softer layers of rock in coastal cliffs, will often erode out sizeable caves. Changes in the relative levels of land and sea may then leave some of these caves protected from further marine erosion and located high above present sea levels. Victorian examples are generally in limestone, and the relative significance of marine erosion vis-a-vis karstic processes may be difficult to determine. At present, none of these caves present management problems in Victoria, but some serve as seasonal shelters for bats, and these may well require management in the future as recreational pressure upon our shorelines increases.
3. *Volcanic Caves*—lava flows, particularly in basalt, give rise to several different kinds of caves. The Western Plains of Victoria are particularly rich in these caves, few of which are currently under adequate management, but many of which are deserving of adequate reservation and control. They provide important sites for bats and other cave fauna, for rare minerals, and some may yet prove of archeological importance.
4. *Karst Caves*—these originate in rocks which have a higher degree of solubility in natural waters than is usual. The most important rock of this kind in Australia is limestone, although examples also occur in dolomite, while in other countries major karst caves occur in both salt and gypsum. The term 'karst' refers not only to caves, but to the total terrain developed in these unusually soluble rocks, both on and below the surface.

Further discussion of these categories can be found in Jennings (1968, 1971). A much more detailed and comprehensive classification is given by Grimes (1975), while other papers in the same volume by Pavey, Bourke, Shannon, Toomer and Welch (all 1975) describe examples of some of the less familiar cave types in Australia.

Management of each of the first three kinds of cave generally only demands consideration of the cave itself and its very immediate environs. However, karst terrain often presents a very much wider problem, as adequate management of a cave system in karst often demands attention to the total hydrology of the karst unit itself, and sometimes of the watershed which feeds water onto the karst. Thus, although one might be able to develop a perfectly adequate management programme for many rock shelters or lava caves with little consideration to the surrounding countryside, adequate management of a karst area essentially demands consideration of the karst as a whole. Hence the title of this paper. Examples of the practical issues involved will be dealt with in more detail below.

Finally in this introduction, let me note that I am generally assuming the context of management within national parks or similar reservations. I will comment upon the significance of adjoining lands in some instances, but I am not dealing with the complex issues of managing karst areas which are under private ownership. As with all other parks, management poses two basic problems:

1. Maintenance of the environmental quality of the resource, and
2. Management of the people utilizing the resource.

Again, because I am discussing caves and karst areas within the park setting, I do not propose to deal at length with utilization conflicts engendered by quarrying, waste disposal, road construction or similar activities which pose major problems outside of the park situation. Basically within the park, utilization will centre upon research, recreation and tourism.

MAINTENANCE OF ENVIRONMENTAL QUALITY

Obviously, many of the problems of environmental quality found in any park system will also apply to caves and karst areas. I intend only to deal with a few of those which are of particular importance to these areas.

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The Hydrological System

As outlined above, the most common type of caves are those in karst terrain. These are formed by water action, and the decoration deposited within many caves which comprises one of the significant features (particularly in the traditional tourist cave) result from percolation of mineral-laden waters. Virtually any cave in karst and a number of others, are in a continuing interactive process with water in one way or another. The present quality of the cave environment arises from this process, and any change in the process can result in a change to the cave, sometimes with disastrous effects.

Let me commence with a non-karst example. Mt. Widderin Cave, near Skipton in Victoria, is a large lava cave. We know from both the extent of guano deposits and from contemporary records that this cave was inhabited by many thousands of bats until at least the 1860's. Today the bats have departed, and the ceiling of the cave is constantly wet—to the extent that it would not be a suitable environment for bats. The reason for this change is not known with any certainty, but it is a reasonable hypothesis that clearing of the forest from above the cave has greatly increased the rate of water percolation into the cave.

Switching to a famous karst cave, the Carlsbad Caverns of the Southern United States faced a problem (and still do to some extent) of the drying out of the cave, with consequent deterioration of decoration. This was due in part to construction of both buildings and paved car-parks on the surface of the ground above the caves, which served to seal off the caves from their normal water supply. The problem was further compounded by installation of a passenger lift without adequate air-lock systems, so that the lift acted as a gigantic air exchanger.

Aley (1976) documents a similar, if less spectacular, problem at Blanchard Springs Caverns in Arkansas, U.S.A.

Returning to the Australian scene, I must admit that I cannot cite an example of clear failure in management of the water regime in any of our cave parks. However, let me also say that this is no reason for satisfaction, because the only reason I am unable to do so is the complete absence of environmental monitoring of our developed caves. The vast expanse of paved car parks at Jenolan, New South Wales, certainly raise very real questions. Closer to home, I breathe a sigh of relief that the forest cover above the Princess Margaret Rose Cave (Glenelg River National Park, Victoria) has survived that era when people thought it was aesthetically desirable to remove our native bush.

However, we have not been so fortunate with the closely related problem of water pollution. A lack of understanding of the nature of water movements in karst has led, for instance, to pollution of Moon Cave, Buchan, Victoria from the camping ground sewerage. Waste disposal does present particular problems in karst, and Australia's outstanding problem of this kind is the wholesale pollution of the underground waters of South-Eastern South Australia (South Aust. E. & W. S. Dept. 1971, Aslin 1972, Waterhouse 1976). Irresponsible waste dumping, often directly into caves, has been a major contributor to the problem, although various other inputs of waste matter occur and are obviously more difficult to control. Recently some 300,000 litres of waste milk were poured into a cave in Western Victoria (White 1976). Although a single event, and the company concerned has been warned against any repetition of the act, it is indicative of the general ignorance of karst water problems.

Siltation

A further related problem is the extent to which streams can and often do carry sediments into caves. Williams et al (1975) have described the extent to which the famous glow-worm display at Waitomo in New Zealand is now seriously threatened by increasing sedimentation within the cave. This is due to a combination of factors, including major road works within the watershed area without adequate erosion control provisions, dumping of rocks (again from road works) in the cave stream, and the misguided erection of an artificial barrier in the streamway to raise the water level.

Although major problems have not yet arisen in this respect in Australia, sedimentation has provoked concern in at least three areas. At Yarrangobilly, New South Wales, re-routing of the Snowy Mountains Highway with the inevitable increase in erosion during road works certainly threatened a number of caves (Dunkley 1970, Middleton 1970). Although a complete evaluation has not been undertaken, it appears that damage was minimal, at least in part because of the precautions exercised by the construction authority. Dunkley et al.(1975) have also expressed concern at the potential impact upon the Jenolan Caves, New South Wales area by forestry activities around the headwaters of the Jenolan River, while Richards and Ollier (1975) have discussed the matter in their report upon the Ida Bay Caves in Southern Tasmania, where a potential threat similar to that at Jenolan exists.

Micro-climatic Balance

Each cave develops a distinctive micro-climate of its own. In general, this is characterized by high humidity and relatively uniform temperature, although caves utilized as maternity sites by bats exhibit an annual cycle with peaks of unusually high humidity and temperature coinciding with the maternity season (Harris, 1970). Maintenance of natural climatic conditions is important for various reasons, the major ones being preservation of the appropriate conditions for the natural fauna of the cave and retention of the attractive appearance of cave decoration.

The very traffic of large numbers of tourists through a developed cave will inevitably have some impact upon this climate, and the result can be easily seen in the dulling of cave decoration. Experience at Jenolan, New South Wales, when several caves were closed for an extended period for construction purposes, indicated that the quality of decoration rapidly improved when natural conditions were restored. This clearly raises questions about the carrying capacity of some caves—a point to which I will return below.

Much more concern must be expressed at any major change such as can be caused by the opening of an artificial entrance. Again, we have not adequate monitoring to know the full effect upon some of our caves. At Jenolan, New South Wales, the Binoomea Cut—an artificial entry to the Orient and Temple of Baal Caves—has been fitted with airtight doors to minimize possible impact upon cave climate. A similar door has been fitted to the artificial entrance to the South Glory Hole at Yarrangobilly New South Wales, although this was not done for several years after construction of the entrance (Middleton 1976).

Dust Control

Two kinds of dust problems arise in caves. The first is exampled by Cutta-Cutta Cave, near Katherine, Northern Territory, where the cave is subject to considerable fluctuations in micro-climate between wet and dry seasons. The silt floor dries out during the dry season, and dust is raised by the passage of visitors. A variety of treatments including the use of calcium chloride, cement and lime, have been suggested to overcome this problem, and experiments are currently in progress to determine the most suitable and effective techniques of control (Hamilton-Smith et al.1974).

A much more intractable problem is presented by the dust and lint which rises from tourist clothing. This settles upon decoration, and again, leads to dulling of what would naturally be lustrous surfaces. No effective method of prevention has yet been devised (despite some suggestions about nudist cave tours!) and the only demonstrated technique for treatment of the problem is steam-cleaning. This is an extremely arduous task, and has only been fully developed at Jenolan, New South Wales, by Ron Newbould (1964, 1976). Despite some fears, careful observation by Newbould and his associates indicates that no damage resulted from steam cleaning, and even the apparently delicate cave fauna survived the exercise. Newbould's work is a major innovation, but one wonders how many other cave rangers will show the energy and dedication necessary to repeat his work, either at Jenolan or elsewhere!

Growth of Algae and Plants

Installation of lighting in caves has led in many situations to a disfiguring growth of bright green algae and other plants. This growth is easy to remove by either steam cleaning or application of sodium hypochlorite solution (Williams et al. 1975, Lemon 1976). However, neither of these techniques can be applied, for instance, at Naracoorte, South Australia, where the discoloration affects surfaces coated with 'moonmilk'—a soft paste comprised of micro-crystals of calcite. Experiments have been conducted with using ultra-violet filters on lights, but the results are inconclusive to date (Lemon 1976). Much more careful placement of lights would have been adequate prevention in many cases, but this is not always practicable.

At the famous Lascaux Cave of France, a generalized growth of algae, coupled with the introduction of bacteria to the cave, constituted a much greater problem, as it threatened the very existence of the famous cave paintings at this site. It proved possible to remove the growth by applying formaldehyde without any resultant damage to the paintings, but prevention of recurrence has not yet been possible and the cave is now closed to the public (Lefevre and Leporte 1969).

Protection of Cave Fauna

Some special issues also arise in respect to cave fauna. Although most cave fauna is inconspicuous, it is an extremely important component of the total cave environment, particularly as a research resource. The one readily observed element of the Australian cave fauna is the bat, and, regrettably, most Western peoples have a deeply ingrained aversion to the bat. We now know at least some of the basic environmental requirements of cave-dwelling bats in Southern Australia (Hamilton-Smith 1970) and can develop management plans accordingly. Thus, at Naracoorte, South Australia, the Bat Cave is closed to all but genuine researchers, but the evening exit flight from the cave is used as an opportunity for interpretation to the visiting public. A similar programme has been proposed for Bat Cleft, at Mt. Etna near Rockhampton, Queensland, (Hamilton-Smith and Champion 1976) but this cave is subject to conflict concerning its future. Research is currently in progress upon the Ghost Bat, one of our more interesting tropical species, which will in turn lead to the possibility of adequate management plans for this species also.

The situation in respect to invertebrates in our caves is not so clear. We do know that they can readily be destroyed by changes in micro-climate or in food supply, changes in balance between species, pollution (e.g. by tobacco), or by over-collecting. However, planning for adequate management will demand detailed studies of each individual situation. Interestingly, only Tasmania has declared species of cave invertebrates as protected species (Skinner 1976). It is to be regretted that this is legislatively not possible in most states at the present time.

Floor Deposits

One of the most neglected components of Australian caves are their floors. Few visitors appreciate the importance of minimizing tracks through caves, nor do those responsible for the development of tourist caves appreciate the need to disturb the minimum floor area. Cave floors often contain layered sediments of great value to research (see for instance, Frank 1974). Perhaps even more importantly, cave floors often contain invaluable deposits of fossil material or aboriginal relics. Some of the most important finds of both fossils and of dateable aboriginal relics in this country have come from caves—we do not know how many have been lost by thoughtless damage.

MANAGEMENT OF PEOPLE

The second major theme of this article deals with the problem of managing visitor traffic in caves and karst areas. Here we are involved with a wide spectrum of visitors—the research scientist, the investigating speleologist, the recreational caver, the show-cave tourist and probably a small number of unmentionables. Obviously, the issues involved are diverse and complex. Time only permits me to touch upon a small number of the issues involved, but, I hope, to indicate the directions towards which we must direct future effort.

Different Visitors have Different Needs

The research scientist is concerned with easy access to those aspects of the cave or karst system which he wishes to study. Obviously, this may cause some problems to the manager of a tourist area, but I would argue that wherever possible, the research scientist should be provided for, as his work provides a basis for better interpretation services.

This view, of course, implies that the scientist feels a responsibility to make his results available in a form which will assist the park ranger in his task of interpretation, but I am sure that the majority of researchers are perfectly willing to assist in this way.

Somewhere between the professional scientist carrying out a specific research project and the recreational visitor, we find the speleologist, who is almost certainly an amateur, but who is genuinely concerned with the exploration, mapping, recording and general study of caves. Again, I would argue that the speleologist is an invaluable asset to park management. Many examples could be cited of the way in which Australian speleologists have contributed to the discovery and development of some remarkable new tourist caves, to solving technical problems confronting cave managers, to assisting in the improvement of interpretation programmes or the development of better display of cave features and even in carrying out practical tasks which might otherwise have remained undone. Victoria Cave, Naracoorte, provides an outstanding example of cooperative action between the managing authority, researchers and speleologists. Speleological investigation led to the discovery of an almost unparalleled fossil deposit in this cave, and the joint efforts of all concerned has not only facilitated the continuing investigation and research programme within the cave, but has made the cave into a unique tourist feature, where the visitor is able to see the on-going research programme and view some of the specimens found, all of which is accompanied by an excellent programme of interpretation (S. Aust. Dept. of Environment and Conservation, 1976).

However, the boundary between the speleologist who discovers new caves or maps old ones, and the so-called sporting caver, who visits caves primarily for his own enjoyment, is a rather vague one and this poses problems to cave management. There is no simple answer, but I believe the direction in which some solution lies is in development of an adequate classification of caves, with related control upon entry point that the purely recreational caver has a right to use natural resources for his own recreation. Overzealous exclusion of the recreational caver from caves merely because they are on a reserve or park may well be counter-productive, serving to increase visitor pressure upon other caves which by historical accident are not subject to park control, but may well be more important than some caves within parks. I would suggest this has happened in New South Wales where recreational caving has been excluded from caves on reserves. The consequent visitor pressure upon the Wee Jasper Caves has been extremely heavy resulting in serious damage to this very important group of caves (Hamilton-Smith 1976).

The tourist is concerned with gaining a pleasurable and interesting experience, and in general, with doing so in a safe and comfortable manner. After a long period in which Australian cave tourism focussed almost entirely upon caves with pretty decoration, and upon commentary from tour guides which ranged from the slightly humorous, through trite indication of such fantasies as the stalactite which looks like the three little pigs or some other nonsense, to the downright ridiculous or even offensive, we are at last entering into a period where educational interpretation is developing, and where we are experimenting with a range of options in tourism styles. Thus, we now have a self-guided cave at Yarrangobilly, New South Wales, (Middleton, 1976), caves at Chillagoe, Queensland, where individuals carry their own light and walk relatively freely about the immense caverns open to them, wilderness tours to Exit Cave in Southern Tasmania (R. Skinner, pers. comm.), the scientific tours at Victoria Cave, Naracoorte, South Australia, and a historical museum associated with the Jenolan Caves, New South Wales.

Zoning and Cave Classification

The concept of zoning as a basic tool in park management is by now widely accepted and beginning to be practised. I do not intend to discuss this further, except to note that the idea of cave classification should be integrated with zoning in a thoughtful way—the actual classification applied to a cave may be determined in part by the zoning controls over its location.

I believe cave classification is vital if we are to ever get to grips with adequate management of our cave resources. Firstly, let me emphasize that caves are a nonrenewable resource, and secondly, Australia is generally deficient in caves (see Jennings, 1975). Visitor pressure is increasing rapidly, and poses a very real threat to our caves, although we have not reached the disastrous situation of the United Kingdom (Wilmut 1972, Britton, 1976). Unless we develop adequate management patterns, we will inevitably destroy our own resources.

Now, let me make some suggestions about the kinds of categories which might be developed, and the way in which each of these might be used:

(1) *Completely closed caves:* a very few caves might be of no known value and represent extreme safety hazards; these might well be completely sealed for reasons of public safety. However, I know of no example in Victoria.

(2) *Reference caves*: There would be very considerable value in setting aside a few caves, each typical of the area in which they occur, as 'unspoilt' examples. These would essentially be caves in which little human disturbance had occurred. They would have to be gated in a way which precluded unauthorized entry yet did not interfere with the natural cave environment. Entry would only be permitted for research purposes, and in general, this research would be only approved if it were utilizing the cave as a baseline for monitoring studies.

(3) *Limited Access caves:* Some of these would be particularly hazardous caves, which would be gated for public safety, but which would be available to experienced speleologists on their own liability. The majority would be caves which particularly important features, either aesthetic or scientific significance. It concerns me that at least in Victoria, the responsibility for endeavoring to enforce limited access has rested with speleologists rather than management authorities. Thus, two caves at Buchan have been gated and otherwise restricted by speleologists because of their aesthetic quality (Matthews, 1972; White, 1973) while the archeological site in Cloggs Cave has been gated by the physical efforts of speleologists.

The erection of protective grids over some of the rock shelters in the Grampians to protect aboriginal art is another example of similar action, whilst the refusal to devulge the location of many more such rock shelters is in itself a means of limiting access. However, again, this is largely the responsibility of amateur archeologists rather than managers. The extent of permitted access to caves in this category would, of course, be related to the reason for the classification being conferred in the first place.

(4) *Speleological Access:* A considerable number of caves should remain open to continuing speleological investigation, although management authorities might well demand evidence of competent and responsible practice before issuing entry permits to such caves.

(5) *Tourist Access*: A self-explanatory category. However, some caves might be placed in this category as reserved for future development, or caves might be taken out of active use at intervals for 'resting' and regeneration of their decorative quality.

(6) *Open Access*: Some caves of interest, but with no special features and with minimal safety hazards should be declared as available to all and sundry, including youth and recreational groups wanting to experiment with recreational caving, training programmes for novice speleologists, self-guided tourists of the more adventurous kind and so on. A reasonable supply of open access caves will be vital if we are to conserve the remainder.

I now hasten to emphasize that these notions on classifications are my own. They owe something to discussion with other speleologists and with several park managers but they are not necessarily agreed to by others. However, I do hope that within the next few years we will see some real progress towards a general acceptance of classification and some equally real progress towards classification-based management.

Access vis-a-vis Protection

At first sight one might say that no access means complete protection, while heavy and continuous access means no protection. In fact, this is pure nonsense. A well-managed tourist cave with relatively heavy traffic is often far better protected than many unmanaged caves. Carrying capacity of a cave is not merely a function of the natural characteristics of the cave, but also of the management programme being exercised.

At the simplist level, one sees this operating in caves used only by speleologists. Where caving practice permits random tracks all over a cave and careless muddying of decoration or breaking up of floor deposits, a relatively few visitors can do untold damage. On the other hand, where local practice has led to marking a single track used by all visitors and care is taken to cause the minimum of alteration to the natural conditions of the cave, quite heavy traffic can be tolerated.

Regrettably, track construction in many of our present tourist caves leaves a great deal to be desired. Little sensitivity to either the aesthetic possibilities of track construction or to minimizing the impact upon the structure of the cave has been shown. Jeita Cave, in Lebanon, with its free form concrete pathway resting upon pillars and appearing to be suspended in mid-air shows something of the possibilities. Along with this, the extent to which self-guiding allows each visitor to move through the cave at his or her own pace, each enjoying the experience in their own way, provides an immense contrast to the crowding (and hence restricted viewing) imposed upon the typical guided party in our own caves.

So, classification of caves and corresponding access to enter the cave is one element; the second basic element is thoughtful planning and management of movement patterns within each cave.

This brings me to the question of physical development within caves. The Australian tradition has been to enclose anything of beauty with wire netting guards and to festoon it with inappropriate light fittings and yards of cable to supply power. The result detracts from the natural beauty of the cave and gives the visitor an inevitable feeling of constraint.

Wherever possible, lighting and other artificial introductions to the environment should be concealed or if it is not possible to conceal them they should at least harmonize with the environment. Lighting should be properly designed to show features to their best advantage. Moreover, it can provide an effective tool in control of movement, protection of the cave environment and safety of the visitor (Robinson, 1976; Hamilton-Smith et al 1974).

Interpretation

As with other park interpretation, a variety of methods and media should be used. Visitors should be able to have some preliminary information which will sharpen their observation; their on-site observation should be assisted; and they should be able to then assess their observation in the light of further information. It is basically a matter of operating the famous dictum of "tell them what you are going to tell them; tell it to them; tell them what you have just told them."

One of the specific things which is often neglected is helping visitors to visualize the shape and location of the cave which they are seeing. Maps and models can assist in this but a novel approach has been adopted at the Cutta Cutta Cave at Katherine, Northern Territory, where the position of the cave is actually marked on the surface in conjunction with a surface features nature trail (Hamilton-Smith et al. 1974).

At the same time there is always the possibility of overdoing the educational emphasis of interpretation to the detriment of the aesthetic experience. Jeita Cave in Lebanon has operated under a conscious policy of focusing entirely upon the aesthetic experience with little or no other interpretation. The aesthetic impact of a visit to this cave is a truly remarkable one. If economic viability is any guide to success of a management programme, then there is no question that Jeita Cave is one of the most successful show caves of the world. Similarly, people who have visited a wide range of such caves throughout the world generally agree that Jeita Cave and a few others which have focussed upon the aesthetic experience rather than educational interpretation are the highlights of their own visits.

Public Safety

There are some simple points which need to be made in relation to caves developed for tourism. It should be self-evident that all steps and pathways are easy to negotiate with an absolute minimum of risk or hazard. In actual fact this is often neglected and the anxiety engendered by negotiating pathways becomes a negative factor in public enjoyment. At the same time, the natural environment is often damaged to avoid the visitor having to bend down or pass through narrow constrictions. I would argue that narrow constrictions are not in themselves a negative feature and can add to the excitement of the visit, but I see no justification for adding to the excitement by badly designed steps or slippery pathways.

One simple precaution is that track lights should be on an independent circuit with appropriate fail-safe provision. They should not be turned out at any point in the course of the cave inspection so that exit from the cave in the event of an accident or sickness is facilitated.

Speleological organizations throughout Australia have worked to develop their own capacity for search and rescue and in most states this is integrated with official police provisions. Park managers should be aware of these arrangements in order to minimize any delay or confusion if search and rescue operations are ever required. In some cases arrangements have been made for a basic stock of the specialist equipment required for cave rescue to be stored at park centres. This seems to be a highly desirable practical arrangement. It indicates a further area of fruitful cooperation between park management and speleologists. Apart from anything else, the discovery and mapping programmes carried out by speleologists provide the documentation which is an essential requirement of search and rescue planning.

Vandalism

It concerns me that so much of our park management seems to assume that vandalism is best prevented by restrictions being placed upon visitors. These restrictions often have authoritarian tones and succeed in conveying a feeling of mistrust.

I would argue this approach as all too often counter-productive. One thing we do know about vandalism is that although some of it is due to thoughtlessness, a great deal is an expression of a sense of futility carried out by people lacking in well developed self esteem. This being so, it seems to be far more important that we endeavor to treat the visitor with dignity and respect, conveying a feeling of real trust and confidence. The experience of self-guided cave tourism has been somewhat surprising, in that it has generally led to a reduction of vandalism rather than an increase. I believe this is a demonstration of the principle which I am arguing. At the same time, one notes the evidence that the collective conscience of large groups of people is more effective than the individual response, and so self-guiding works best where there is a steady flow of visitors, rather than a dispersed trickle of individuals (Van Cleave 1976).

CONCLUSION

Two final points can be made. There is a rapidly growing literature which is serving to document experience in cave management. There is no excuse for cave managers not consulting this literature as an aid to their own planning. Although not exhaustive, I have tried to provide this paper with at least a starting bibliography.

Secondly, there is an urgent need in Australia for research on the specific issues of cave management (as opposed to research about caves themselves). We know all too little about visitor patterns and more adequate planning will only be possible in the light of more knowledge (O'Rourke, 1976).

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Directory of Symposium Attendees Willing To Assist Others With Cave-Related Problems

Editor's Note: During the course of the symposium several people suggested that a list be compiled of people with expertise in various facets of caves and cave management. Accordingly, a series of lists were placed in the lobby outside the main meeting room. Symposium attendees were encouraged to place their names in categories where they felt they had expertise. The resulting lists were compiled by James Quinlan, National Park Service, Mammoth Cave, Kentucky.

SPECIALTY	*CODE LETTER*
ANTHROPOLOGY	A
BIOLOGY	B
CAVE EXPLORATION AND MAPPING	E
CAVE LIGHTING	L
CAVE MANAGEMENT	X
CAVE PHOTOGRAPHY	M
GENERAL CAVE INTERPRETATION	C
GEOLOGY	G
HYDROLOGY	H
PLANNING	P
PREPARATION OF ENVIRONMENTAI IMPACT STATEMENTS	I
RADON PROBLEMS	R
SPELEOCINEMATOGRAPHY	S

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